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Vector-Based Metrics for Assessing Technology Maturity

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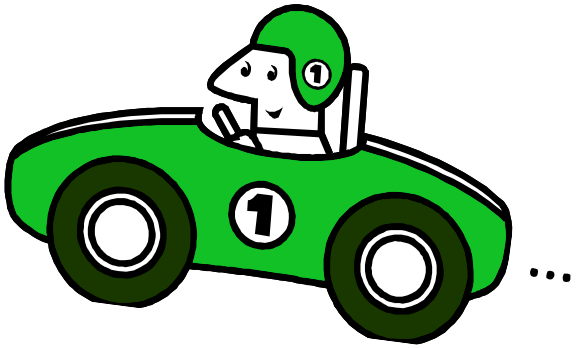
Presentation Outline

- Background and Motivation
- Scalar Metrics for Technology Maturity
- Introduction to Vector-Based Metrics
- Systems Engineering Example
- Technology Maturation Example
- Conclusion and Recommendations

Quiz Question

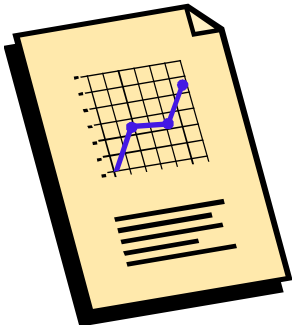
- A car is traveling at 50 mph, and a truck is travelling at 60 mph.

- When and where will they meet?



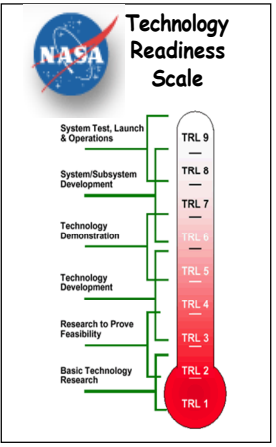
Quiz Question #2

- A Next-Generation Microprocessor is currently being prototyped (TRL=4, MRL=3).



- When will the new microprocessor hit the market (TRL=9, MRL=9)?

Scalar Technology Metrics



Technology Readiness Levels (TRL)

RETURN ON INVESTMENT (ROI)

Manufacturing Readiness Levels (MRL)

TIME-TO-MARKET (TTM)

System Readiness Levels (SRL)

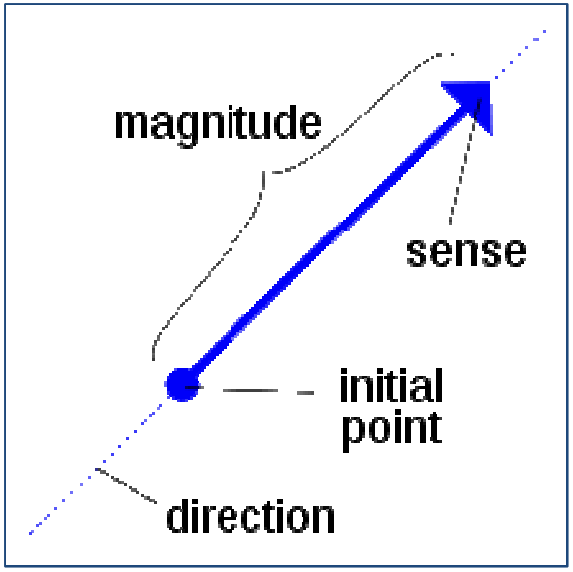
Intellectual Property (papers, patents)

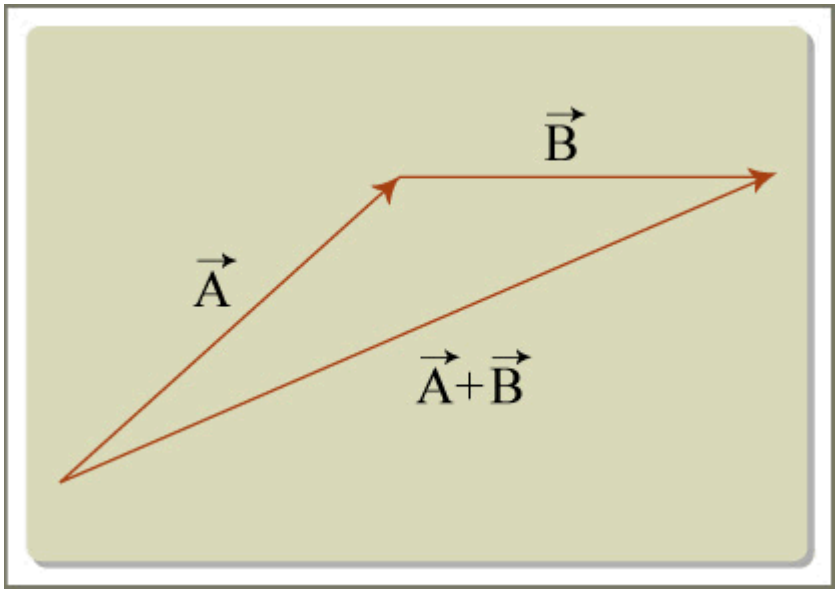
***For more technology metrics, see for example E. Geisler, 1999**

- Scalar Metrics play an important role in technology management, acquisition, systems engineering
- But: they measure only the magnitude of the current state
- And: they usually do not have a mathematical basis for performing system engineering calculations

Vector-Based Metrics

- Measure the Magnitude ***AND*** Direction
- Enables Vector Mathematics between Metrics





* after Marsden et.al., ***Vector Calculus***, 2003

Vector-based Technology Metrics

Some proposed vector metrics

- Technology Maturation Rate (TMR):

$$\overrightarrow{TMR}(t) = \frac{d}{dt} TRL(t)$$

TRL = Technology Readiness Levels

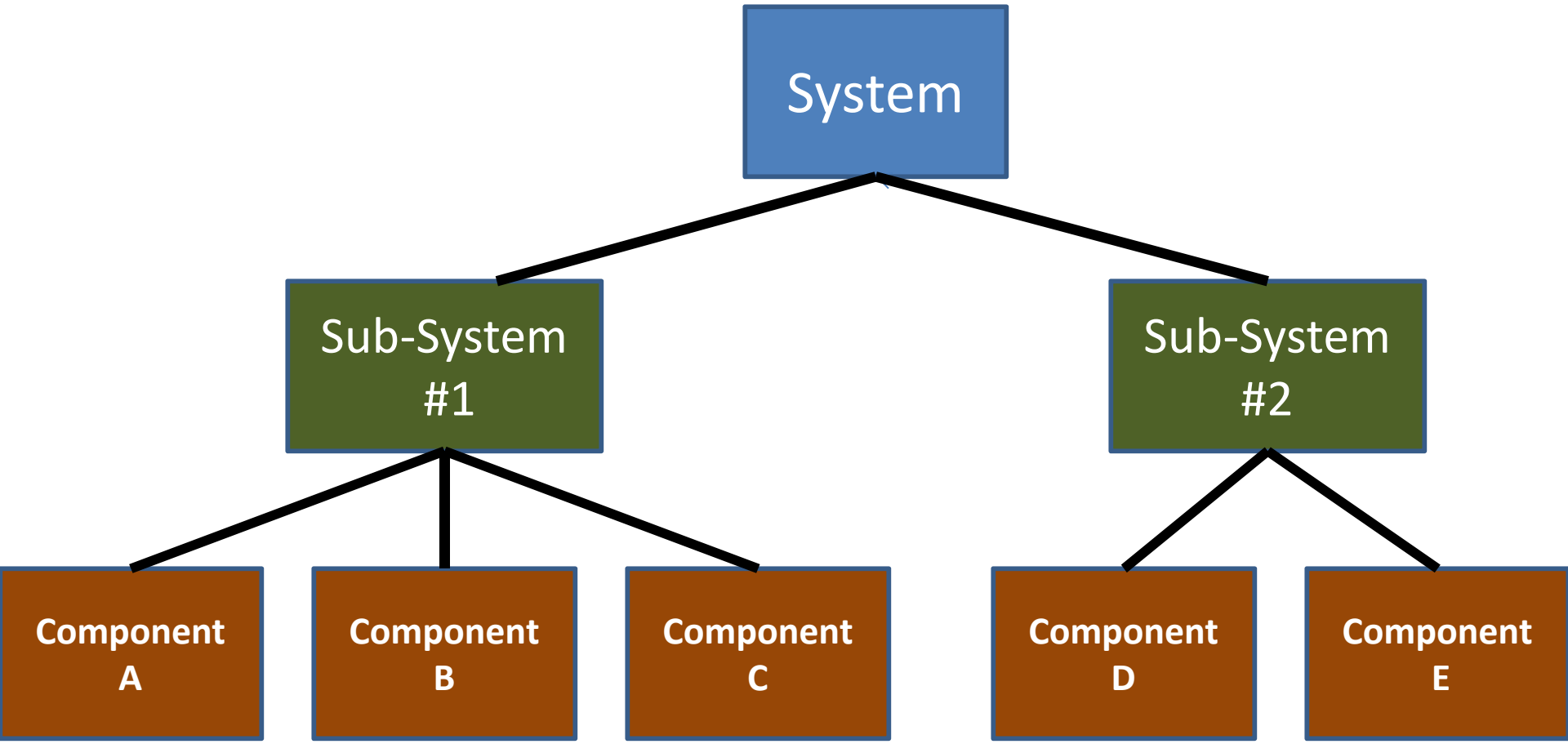
- Technology Profit Margin (TPM):

$$\overrightarrow{TPM}(t) = MV(t) - I(t)$$

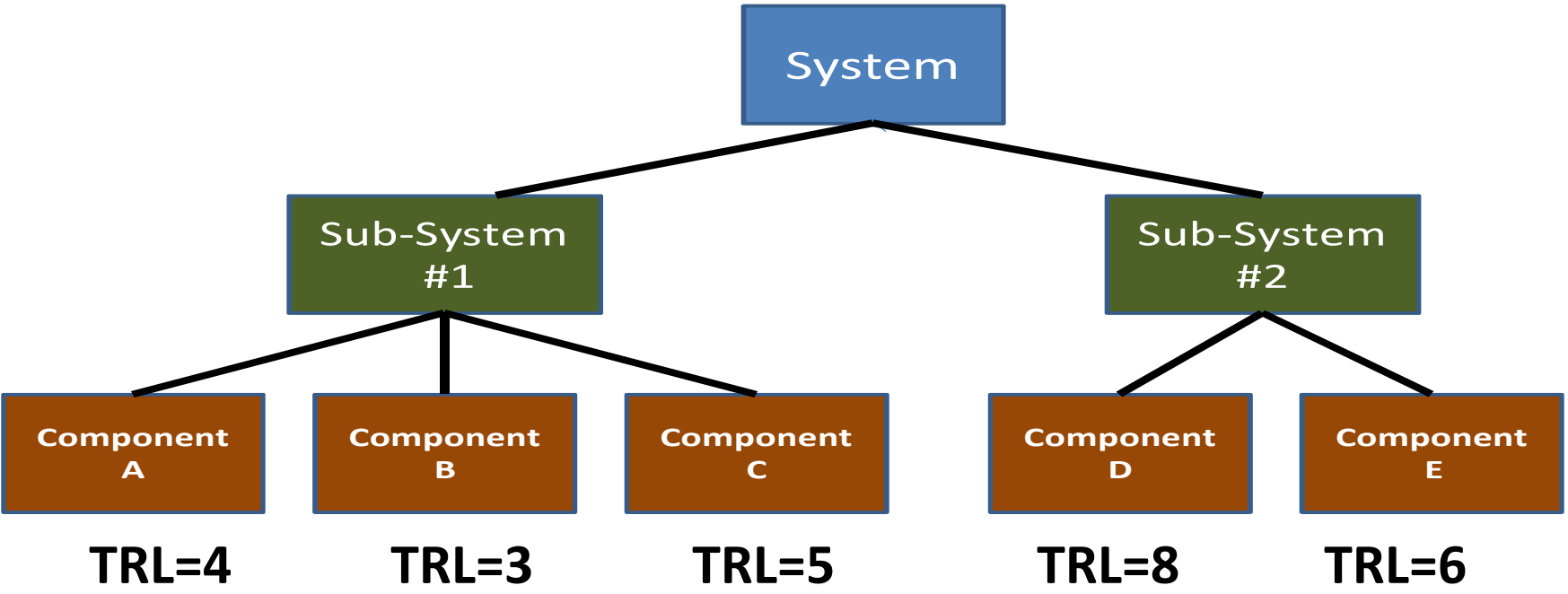
MV = Market Value of the technology

I = Investment in the technology

Systems Engineering Example



Systems Aggregation of TRL's

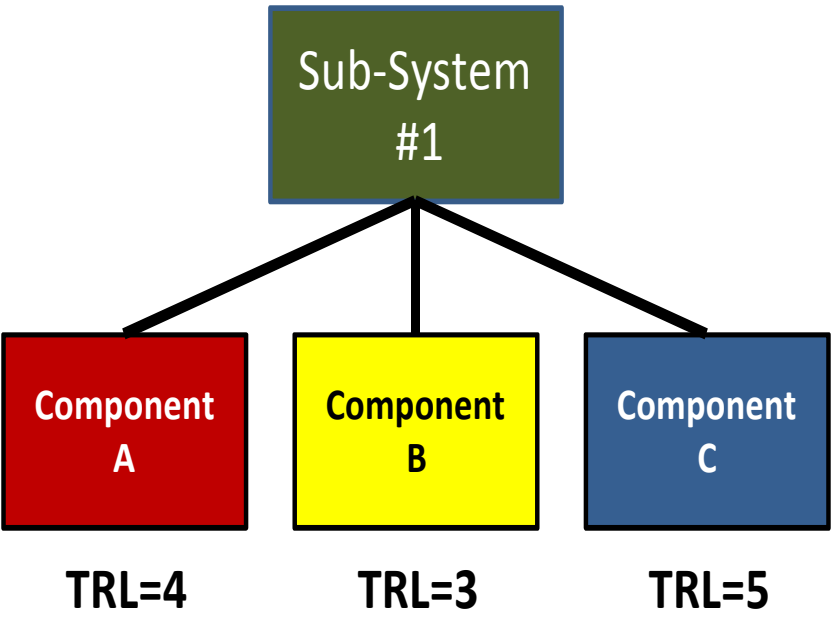


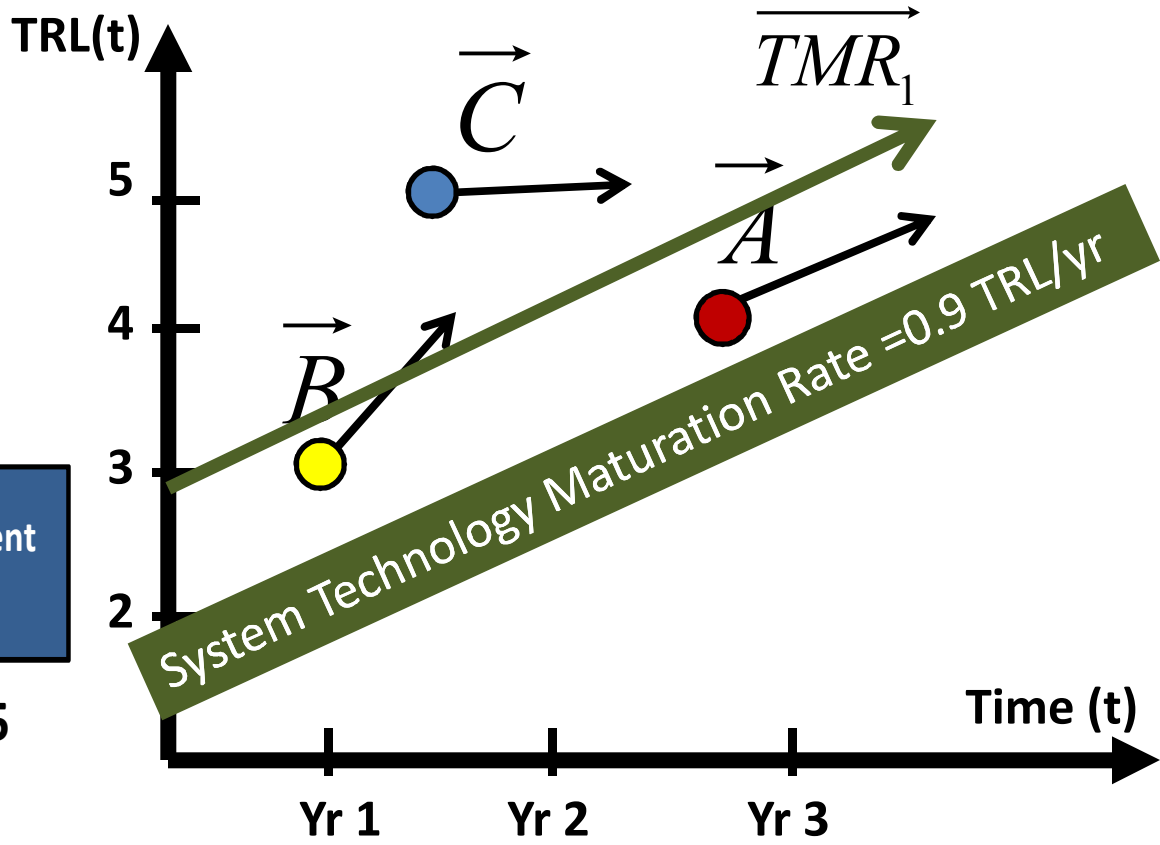
- **TRL of Sub-Sys #1 = min (TRL4, TRL3, TRL5) = TRL3**
- **TRL of Sub-Sys #2 = min (TRL8, TRL6) = TRL6**

TRL of the System = min (TRL3, TRL6) = TRL3

TRL's alone do not give full insight into system-level maturity

Vector Analysis of Systems



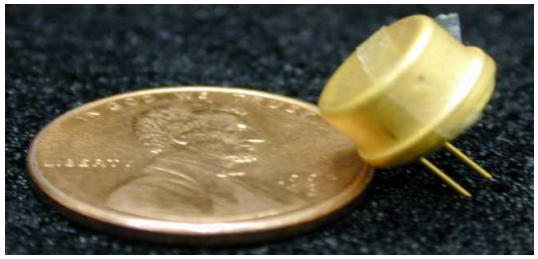


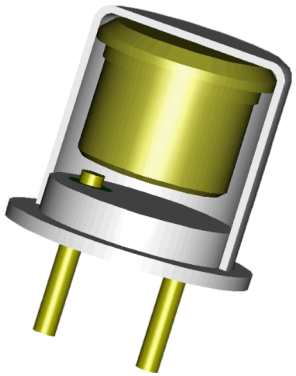
$$\overrightarrow{TMR_1}(t) = \vec{A}(t) + \vec{B}(t) + \vec{C}(t)$$

Technology Maturation Study

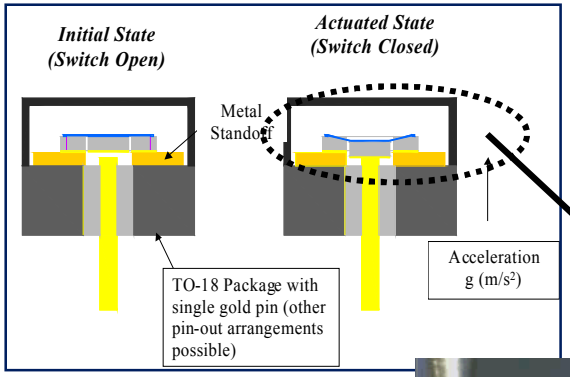
- Monitor an actual product development effort over the course of 18 months
  - Measure technology metrics throughout, and make informed decisions using technology vector analysis

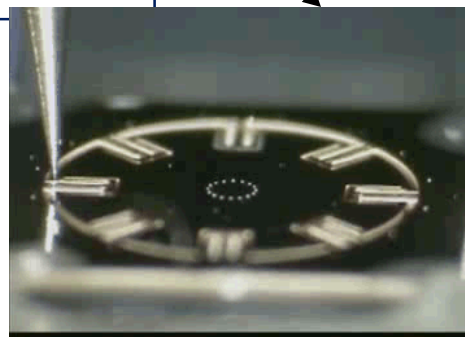
COTS Acceleration Switch





MEMS Acceleration Switch





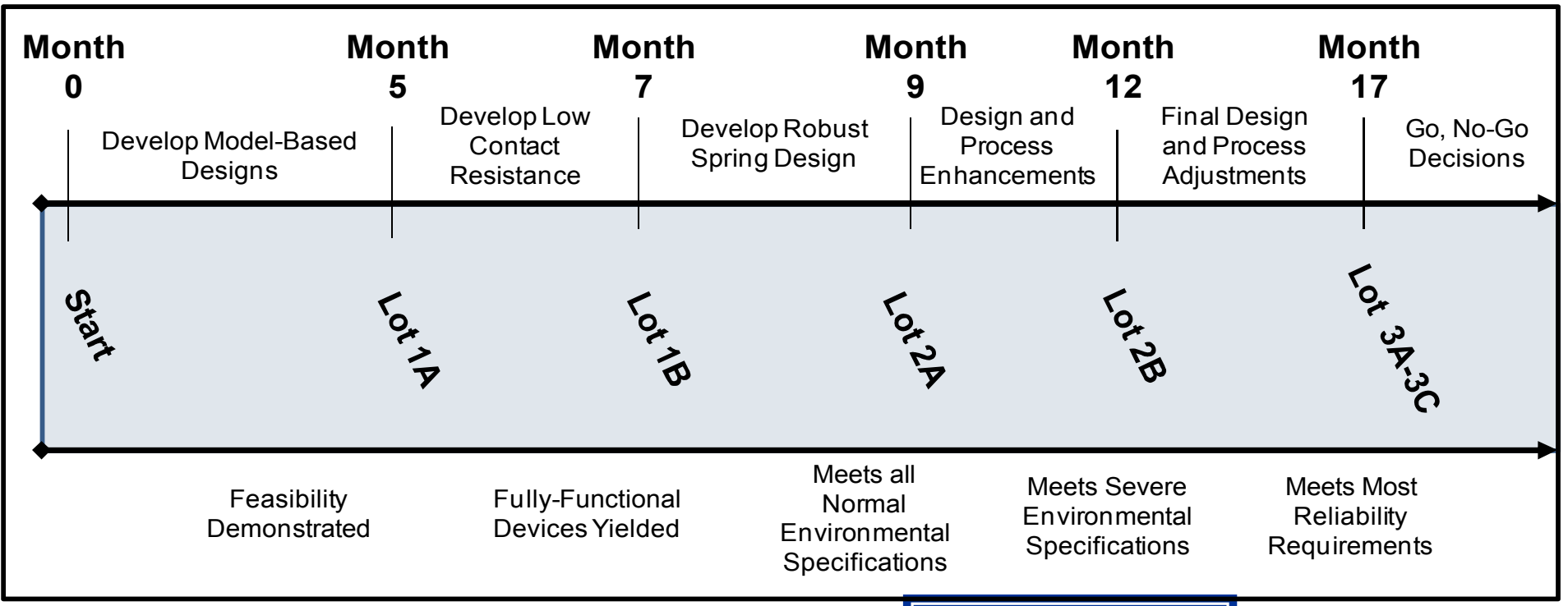
Acknowledgement:
Polosky and Garcia, 2006

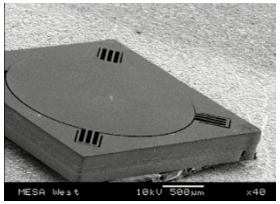
Experimental Observables

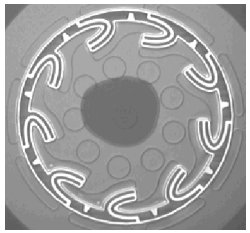
- Traditional project management metrics
  - Cost, schedule, and technical requirements
- Quantitative technology metrics
  - Technology Readiness Metrics (TRL, MRL, TMR, etc.)
  - Product development cycle time (months)
  - Prototype production yield (%)

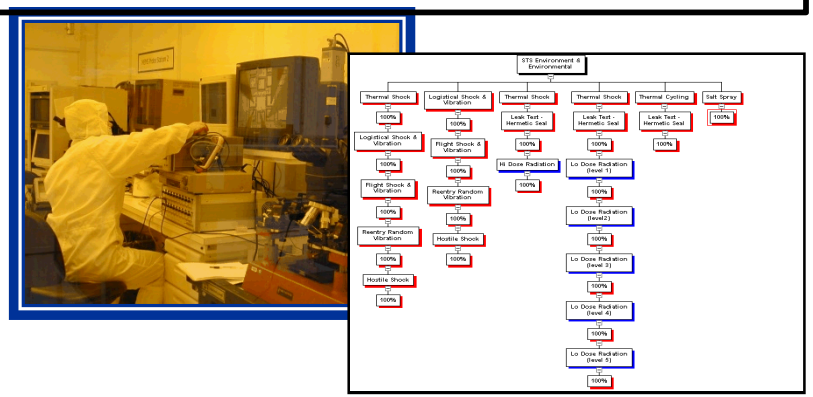
Experimental Results:

MEMS Technology Development Progression





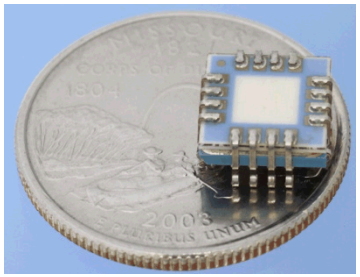


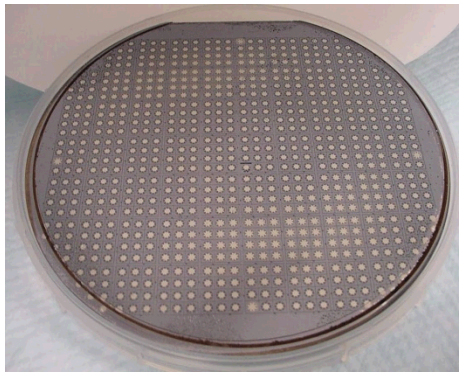


NDIA
National Defense Industrial Association

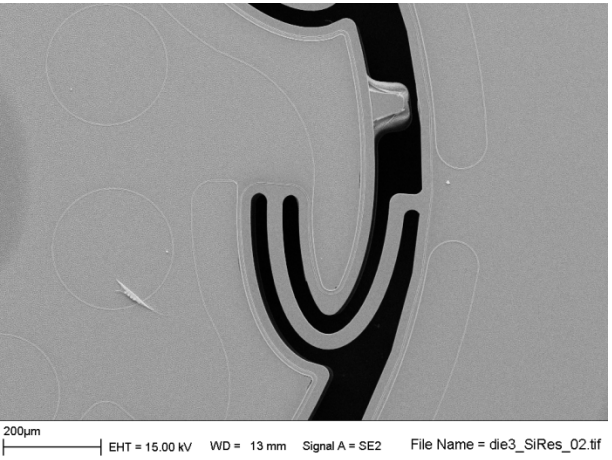
Experimental Results:

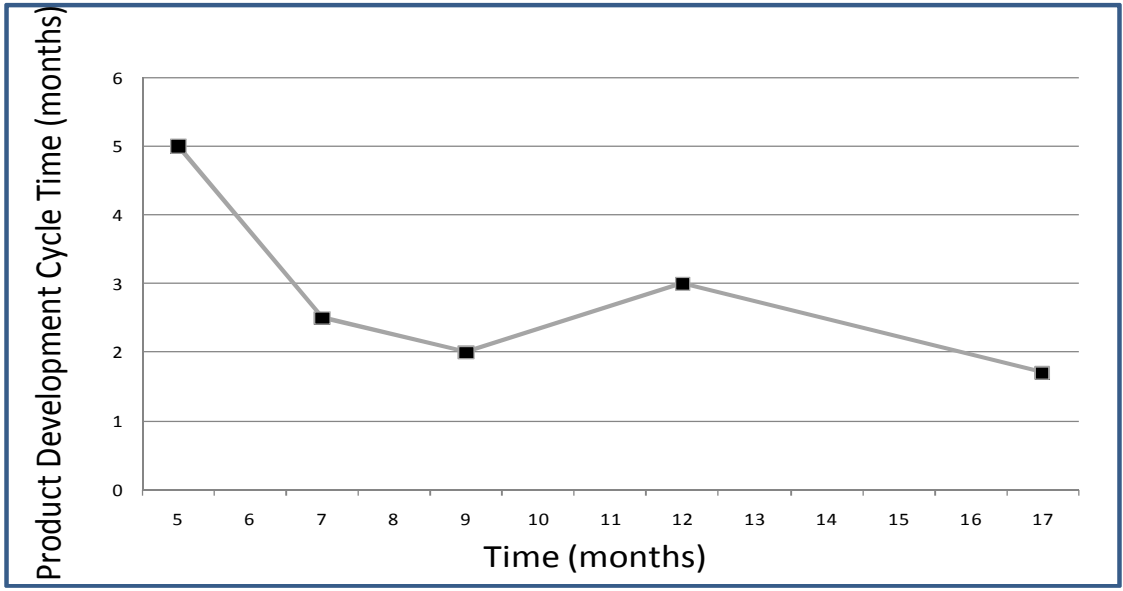
MEMS Development and Production Metrics

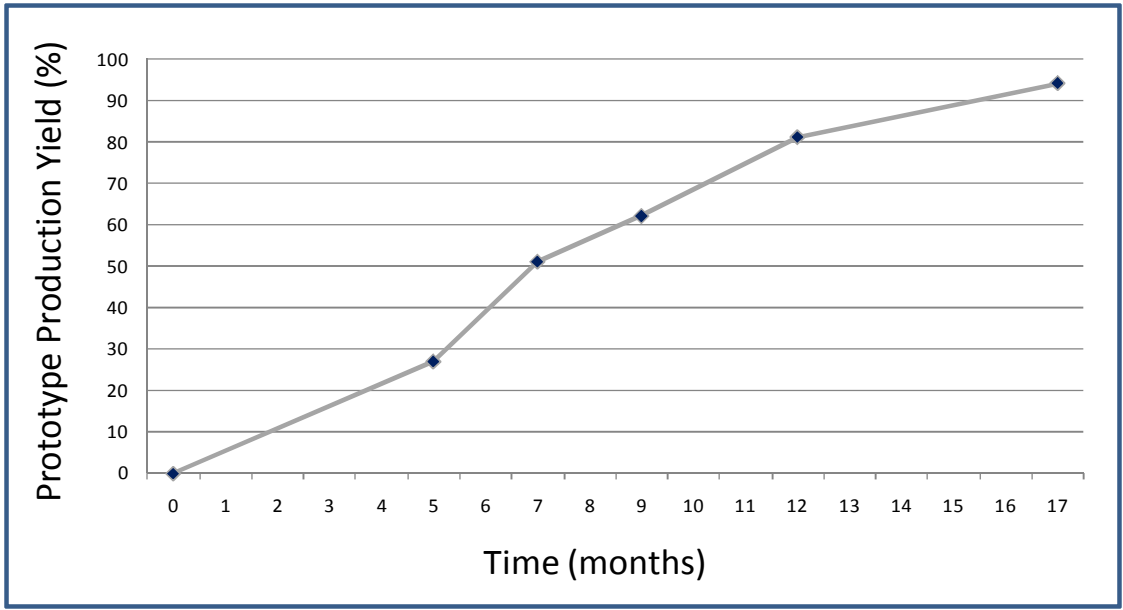




MEMS reached TRL=7 after 18 months

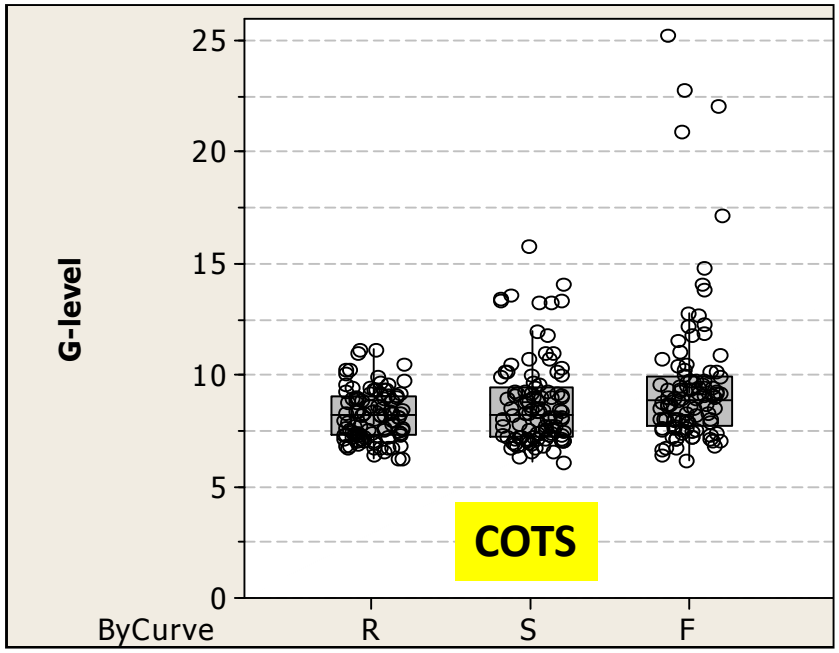






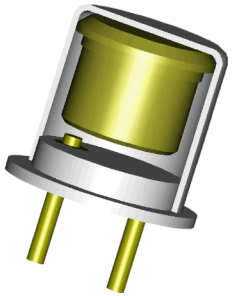
COTS Challenges

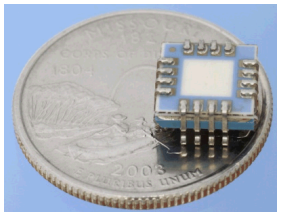
- Acceleration Sensitivity deviates from manufacturer's spec

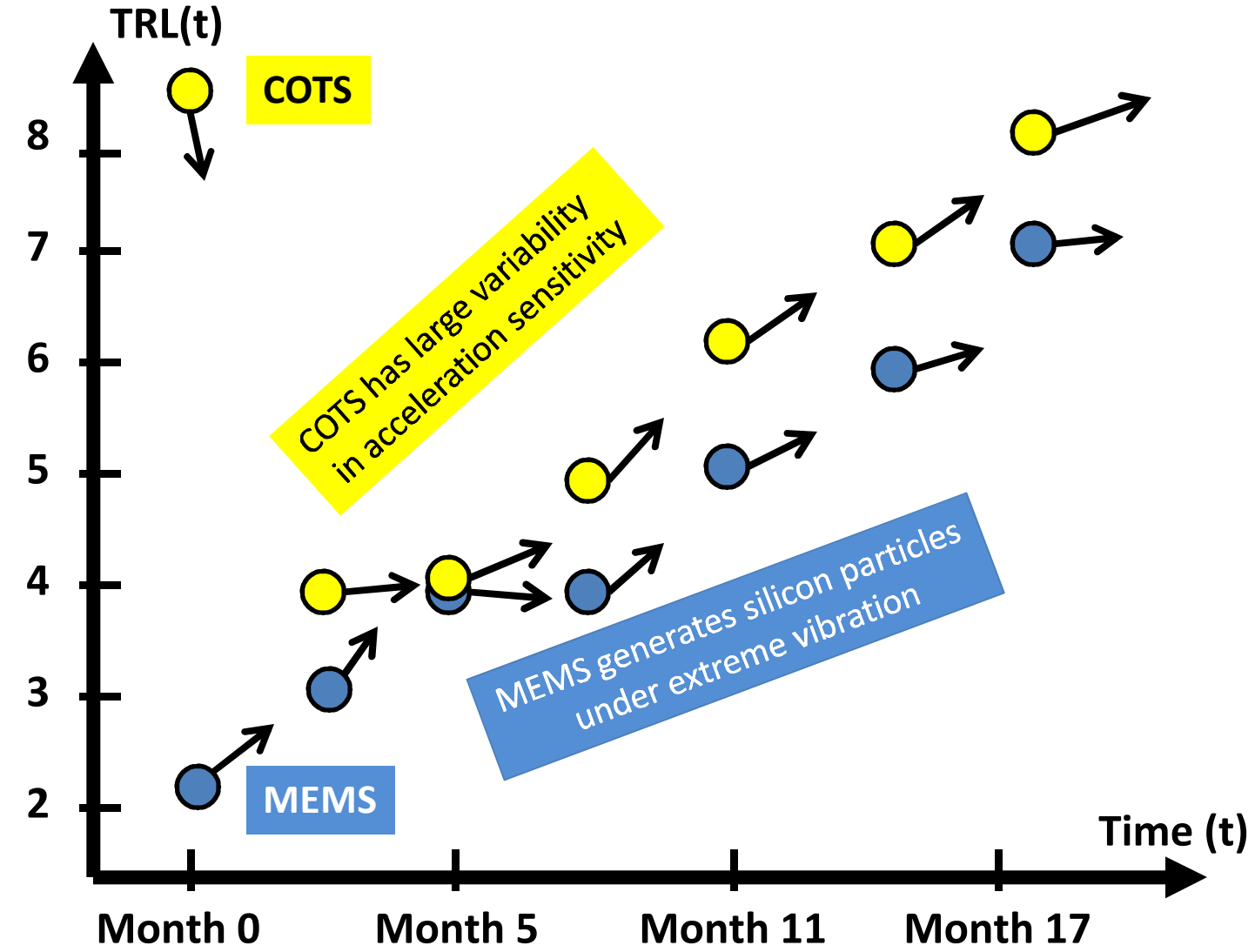


- Part Failed due to Metal Shard

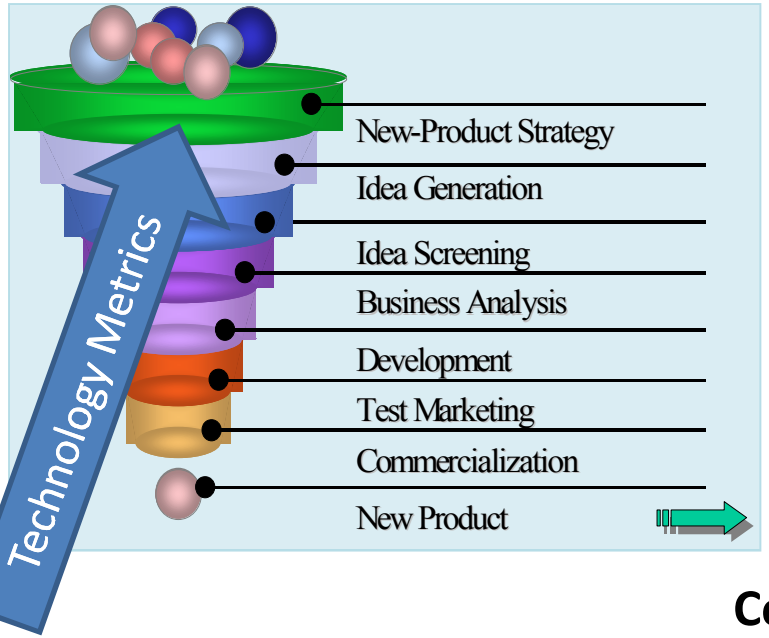
Technology Maturation Vector Analysis

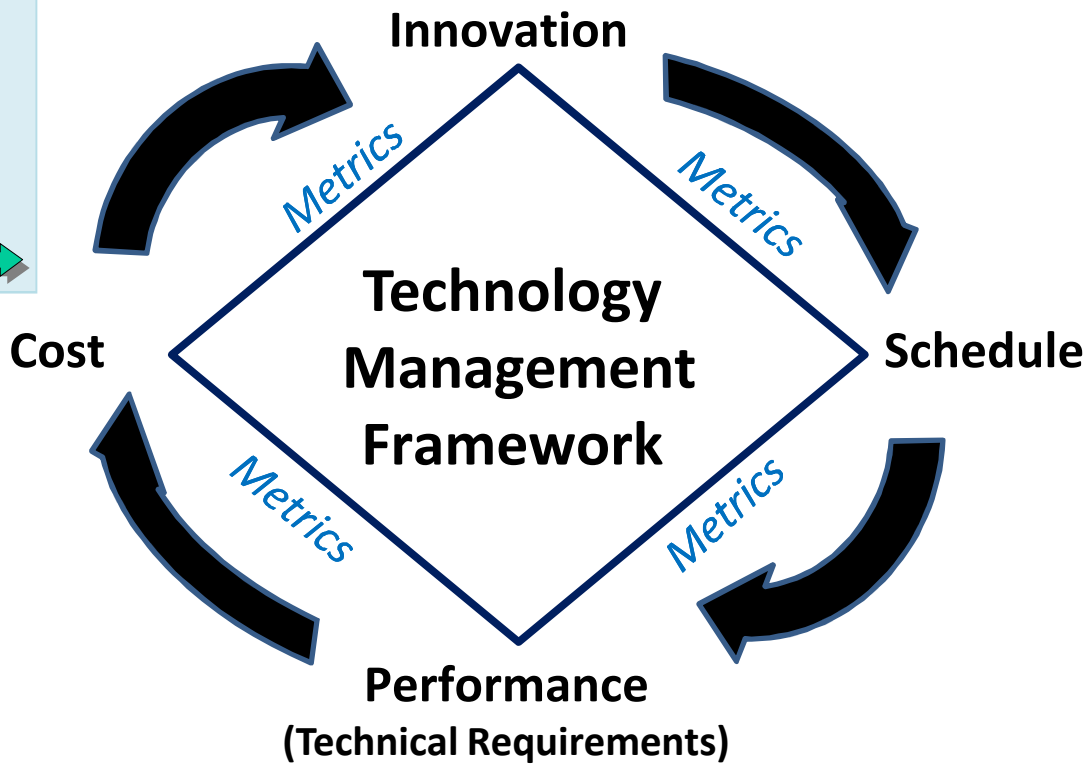






Vector-based Metrics Complement Traditional Technology Management Tools





Summary

- **Vector-based metrics can provide additional technology management insight:**
  - Enable the assessment of both magnitude and direction
  - Provide a mathematical framework for system analytics

- **Recommend that Maturation Rates (vector quantity) be used to complement the TRL and MRL scales**

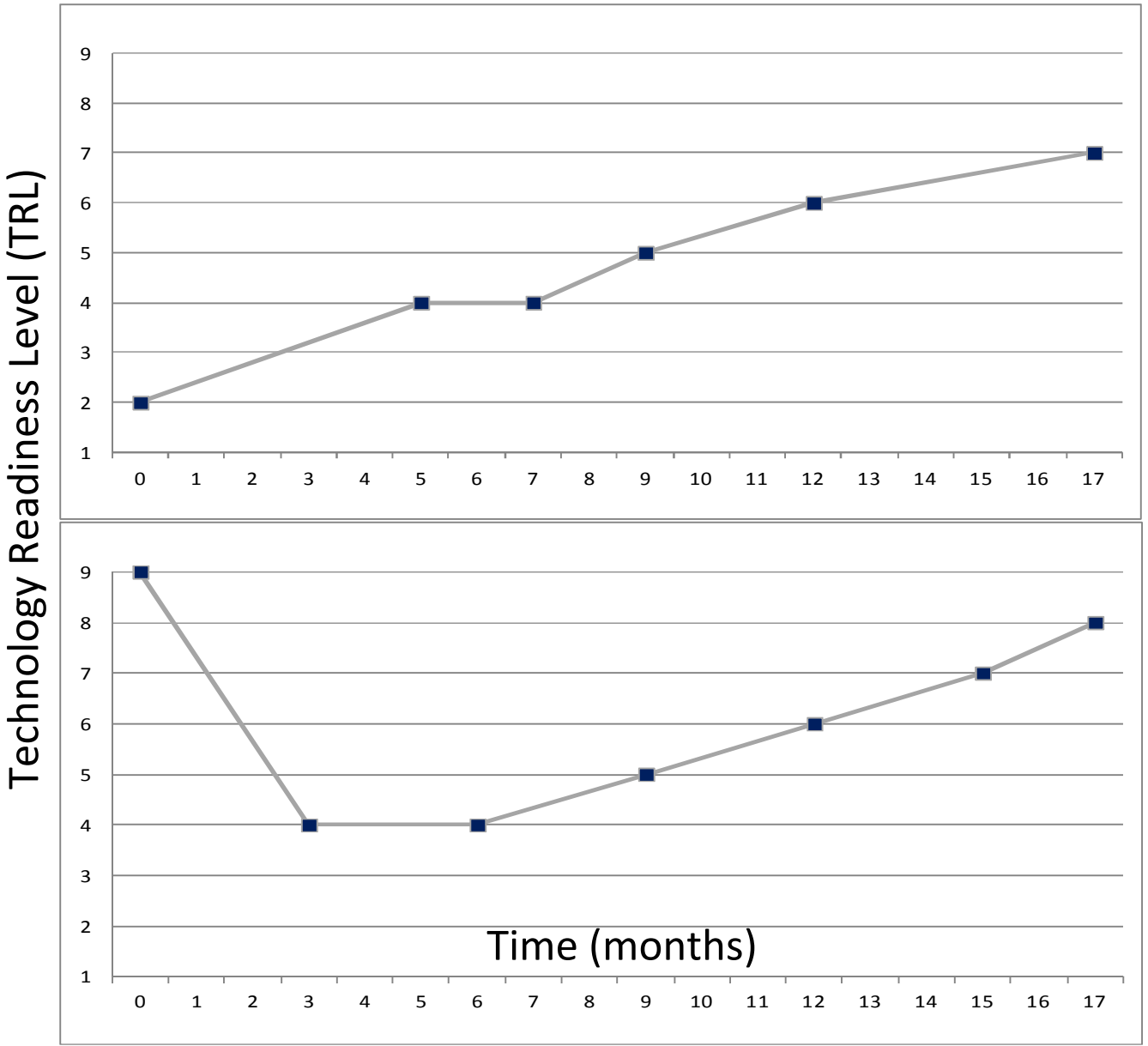
- **Follow-on studies recommended:**
  - To evaluate effectiveness of vector-based metrics
  - To establish a technology maturation database
    - TRL, MRL, Vectors, etc. versus technology categories
    - would support predictive modeling of technology maturation

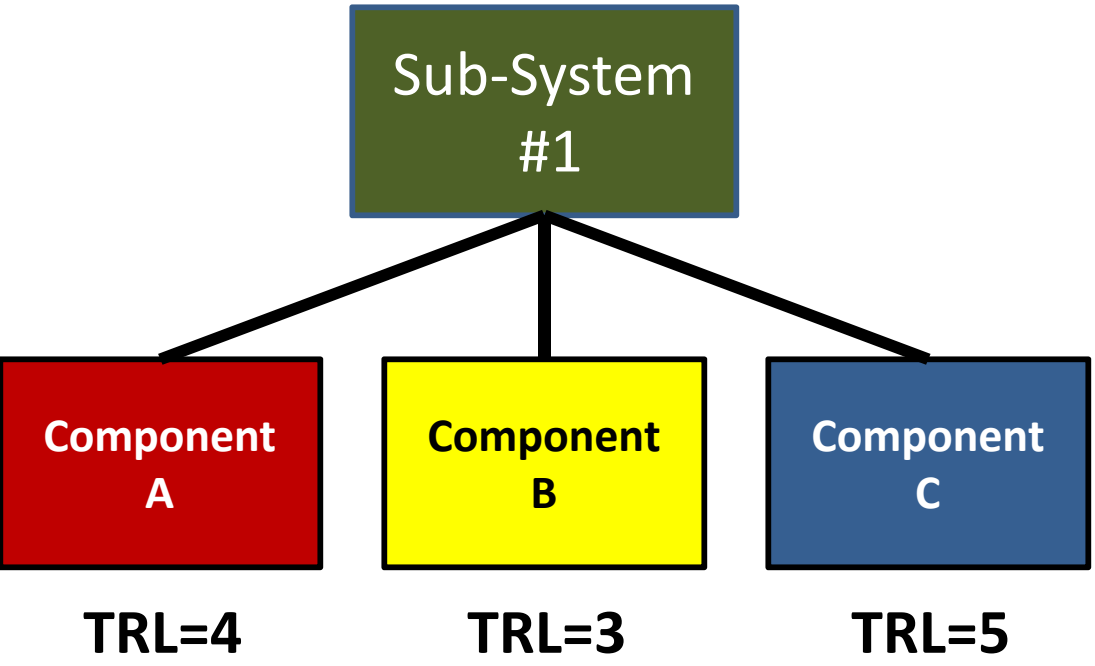
Backups

TRL History: MEMS vs COTS

MEMS

COTS




Sub-System #1
Component A
Component B
Component C
TRL=4
TRL=3
TRL=5