0802
Applying holistic thinking to the problem of technology maturity

Joseph Kasser
Version 1.1.1

Topics

- The undesirable situation
- The non-holistic approach to remedying the problem
- The holistic approach to remedying the problem
- Benefits of holistic thinking
- Summary
- Questions and comments

The undesirable situation

- Technology Readiness Levels (TRL) were developed to solve the problem of not having a developed technology when it was needed
- The TRL approach is flawed
  - Sauser, Verma, Ramirez-Marquez and Gove, *From TRL to SRL: The Concept of Systems Readiness Levels*, proceedings of Conference on Systems Engineering Research, Los Angeles, CA., 2006.
- "*Program managers underestimate the time and technical effort needed to mature technologies above TRL = 6 to achieve higher levels of maturity*".
  - Katz, Sarkani, Mazzuchi and Conrow, *The Relationship of Technology and Design Maturity to DoD Weapon System Cost Change and Schedule Change During Engineering and Manufacturing Development*, Systems Engineering Vol. 00, No. 0, 2014, published online
- Single data point provides information on currents status, cannot predict future

0802- 3

TRL's NASA*

9	**Actual system "flight proven" through successful mission operations**
8	**Actual system completed and "flight qualified" through test and demonstration (ground or space)**
7	**System prototype demonstration in a space environment**
6	**System/subsystem model or prototype demonstration in a relevant environment (ground or space)**
5	**Component and/or breadboard 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 formulated**
1	**Basic principles observed and reported**

* TECHNOLOGY READINESS LEVELS A White Paper, April 6, 1995, John C. Mankins, Advanced Concepts Office, Office of Space Access and Technology, NASA

0802- 4

DOD TRLs*

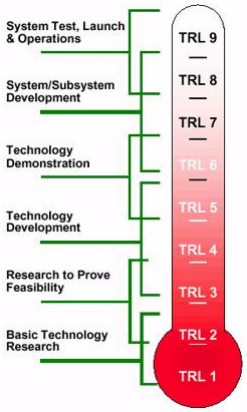
9	Actual system "flight proven" through successful mission operations
8	Actual system completed and "flight qualified" through test and demonstration
7	System prototype demonstration in an operational environment
6	System/subsystem model or prototype demonstration in a relevant environment
5	Component and/or breadboard 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 formulated
1	Basic principles observed and reported

* GAO, BEST PRACTICES Better Management of Technology Development Can Improve Weapon System Outcomes, United States General Accounting Office, 1999

0802- 5

Using the TRL

- Current situation
  - It is 2014
  - System is to be deployed in 2016
  - There is no suitable technology at TRL 7, 8 or 9
  - A technology is currently at TRL 6
- Problem (short process)
  - Do we use the technology or look for an alternative?



NASA TRL Meter

0802- 6

Pre-TRL
Non-holistic problem-solving approach

- Undesirable situation
  - Need technology for a product
  - Technology is under development, maturity unknown
  - Risk: technology may not be ready when needed
- FCFDS
  - Technology is ready when needed
- Problem
  - Need to know maturity of technology
- Solution
  - Technology Readiness Level (TRL)
    - NASA
    - DOD
    - Approve technology above a certain TRL

Wrong question when not starting with situations

Need to predict maturity in future. Not know it now

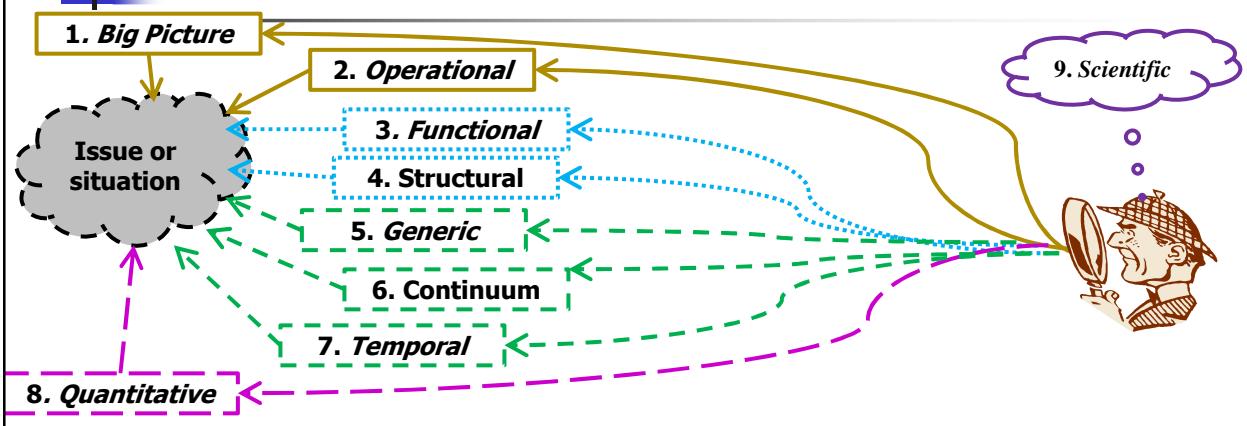
0802- 7

Topics

- The undesirable situation
- The non-holistic approach to remedying the problem
- **The holistic approach to remedying the problem**
- Benefits of holistic thinking
- Summary
- Questions and comments

0802- 8

Systems thinking : The Holistic Thinking Perspectives*



External	Internal	Progressive	Remaining
1. Big picture	3. Functional	5. Generic	8. Quantitative
2. Operational	4. Structural	6. Continuum	9. Scientific
		7. Temporal	

0802- 9

Big Picture perspective

- Assumptions about need of technology for a product
- Technology is still under development at some level of maturity
- Environment in which product will be used
- Users of the product
- External systems interfacing product
- Technology is only available for a limited time once ready for use in products
- Etc.

0802- 10

Operational perspective

- Product (technology) use in different categories of missions
  - One-of-a-kind, single use – short and long term
    - NASA planetary space explorers in the 20th Century
    - Military targets of opportunity
      - Operation Chastise, May 16th, 1943
      - Operational at "TRL 6"
  - Many uses over long period of time
    - Commercial products
    - Military products
  - Various in-between scenarios

Continuum perspective

- Technology
  - Maturity readiness and obsolescence considered independently
    - TRL
    - Diminishing Manufacturing Sources and Material Shortages (DMSMS)

Quantitative perspective

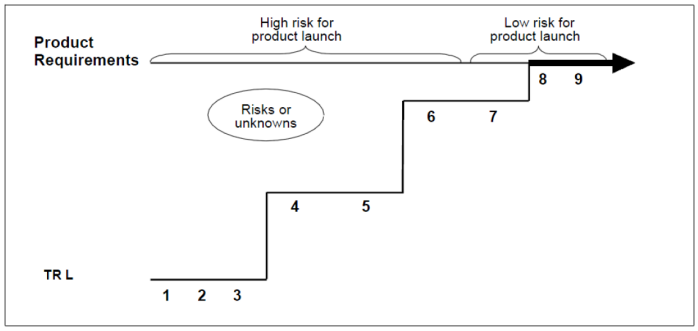


Figure 2. Programmatic Risk as a Function of TRL
(GAO, 1999, p. 24)

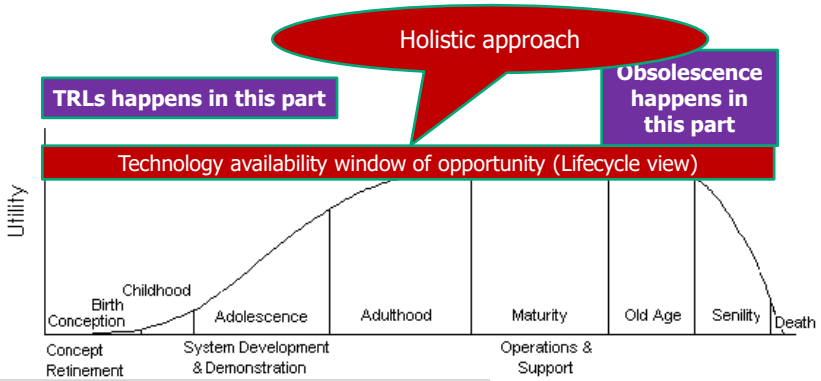
- Not actually measured, used as a representation
- Not a timeline either

Better Management of Technology Development Can Improve Weapon System Outcomes, GAO NSIAD-99-162, Jul 30, 1999.

0802- 13

Temporal perspective
The Technology Lifecycle*

Many products use technology represented by sequential 'S' curves inside whale



* Whale diagram from "TRL Calculator", William L. Nolte, AFRL at Assessing Technology Readiness and Development Seminar, 4/28/05

0802- 14

Scientific perspective

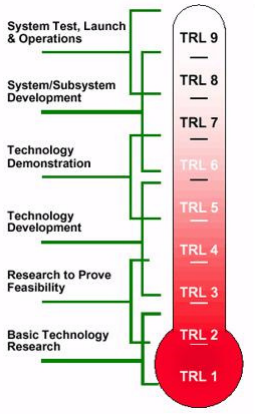
- Problem
  - How to determine if technology will be available when needed
    - For the duration of all categories of missions
  - Need to consider
    - Time to advance maturity to a *useable* TRL (UTRL)
      - UTRL depends on category of mission
    - Obsolescence issues
      - Diminishing manufacturing sources and material shortages (DMSMS)
- One solution?
  - The Technology Availability Window of Opportunity (TAWOO)
    - Showing rate of change of maturity
    - Showing period of time in production before obsolescence

Notice: problem has been stated differently

0802- 15

Re-examine using the TRL

- Current situation
  - It is 2014
  - System is to be deployed in 2016
  - There is no suitable technology at TRL 8 or 9
  - A technology is currently at TRL 6
- Problem - uncertainty
  - Do we use the technology or look for an alternative?
- Derived problem
  - How to determine if technology will be available when needed



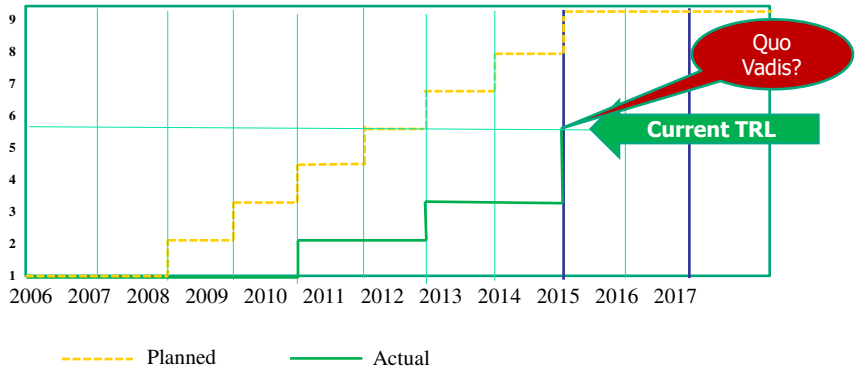
NASA TRL Meter

0802- 16

Change of TRL 2016 – 2014 ext 2017

"Program managers underestimate the time and technical effort needed to mature technologies above TRL = 6 to achieve higher levels of maturity".

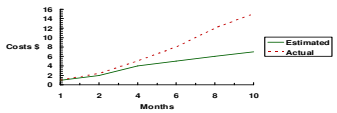
TRL = 6 in 2014, needed in 2016



0802- 17

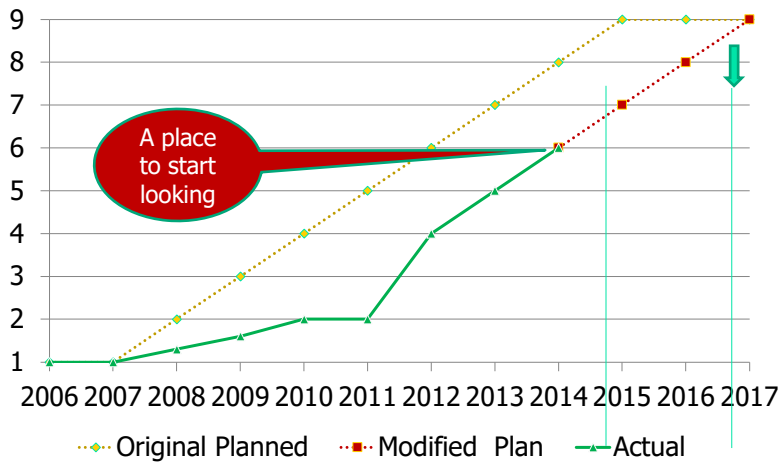
Combine Holistic Thinking Perspectives

- *Temporal*
  - Historic rate of change of maturity
    - Helps to
      - Identify factors preventing increase in maturity level
        - No funding
        - Technical issues
        - Political concerns
    - Estimate future rate of change of maturity level
  - Predict (perhaps delay) obsolescence
- *Generic*
  - Compares planned and actual
    - Earned Value Analysis



0802- 18

Dynamic TRL (dTRL)



TRL is an aggregate

0802- 19

TAWOO and whales

- Development: TAWOO (TRL) 1-8
  - Maturity readiness expressed as dTRL
- Operational: TAWOO (TRL) 9
  - Available for use in new products (in general)
- Approaching obsolescence: TAWOO 10
  - Use in existing products but not in new products
  - Plan for replacement
- Obsolete: TAWOO 11
  - Some spares available, maintenance is feasible
- Antique: TAWOO 12
  - Few if any spares available in used equipment market, phase out or operate until run out of spares

0802- 20

Discussion and directions for future research?

- Adding levels to TRL does not provide dTRL information
- Need for additional data, but should be available in research records
- Are there alternatives to the TAWOO?
- Develop generic TAWOO template for different types of technology?
- Information display
  - Table, line graph, pie chart, bar charts, traffic light, whale chart, etc. ?
- Ways of predicting when obsolescence will occur?
- Is the 'S' curve (innovation domain) useful?
- Etc.

Benefits of holistic thinking

- Asking good questions
- Posing the right (a better) problem
  - What is the maturity of the technology?
    - TRL
  - When will the technology be ready for use?
    - dTRL
  - When will the technology be available for use?
    - When will it be ready and for how long?
    - TAWOO
- Out of box solution
  - Combination of *Generic* and *Temporal* perspectives

Summary

- The undesirable situation
  - State FCFDS
- The non-holistic approach to remedying the problem
- The holistic approach to remedying the problem
- Benefits of holistic thinking
- Summary
- Questions and comments

0802- 23

Questions and comments

0802- 24