~~Best~~ *Recommended* Practices for Defining Requirements in a Digital Enterprise

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Disclaimer

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What is a Requirement?

- A **condition** or capability that is required to be present in a product, service, or result to satisfy a business **need**.
  - PMBOK, 7th ed.

- A statement that identifies a system, product or process characteristic or **constraint**, which is unambiguous, clear, unique, consistent, stand-alone (not grouped), and verifiable, and is deemed **necessary** for stakeholder acceptability.
  - INCOSE SE Handbook (2010)

- Statement that identifies a product or process operational, functional, or design characteristic or **constraint**, which is unambiguous, testable or measurable, and **necessary** for product or process acceptability.
  - ISO/IEC 42010:2007.

- State which translates or expresses a **need** and its associated **constraints** and **conditions**.
  - ISO/IEC/IEEE 29148:2018

Really, what is a requirement?

For today,

- *A thing that constrains the conditions and capabilities of a system to satisfy a stakeholder's need.*

Defining a requirement reduces the solution space---never expands it.

Requirements, who needs them?

- The System's (e.g., software, product, platform)
  - Buyer
  - User
  - Designer
  - Maintainer

- I.e., the Stakeholders!

Trivia: What year was the "first" public work related to system requirements modeling?

- 1962

- Adams, J. H., & Brewer, D. D. (1962). *MODEL SPECIFICATION - R+D PROTOTYPES FOR WING II MISSILES, S-133-1000-0-1* (No. AD0413437). Boeing Company. https://apps.dtic.mil/sti/citations/AD0413437

"If you are having difficulty understanding a problem, try drawing a picture."

--George Polya

Polya, G. (1945). *How to Solve It: A New Aspect of Mathematical Method*. Princeton University Press.

More History…

Figure 1 - Separation of Views in Requirements Specification
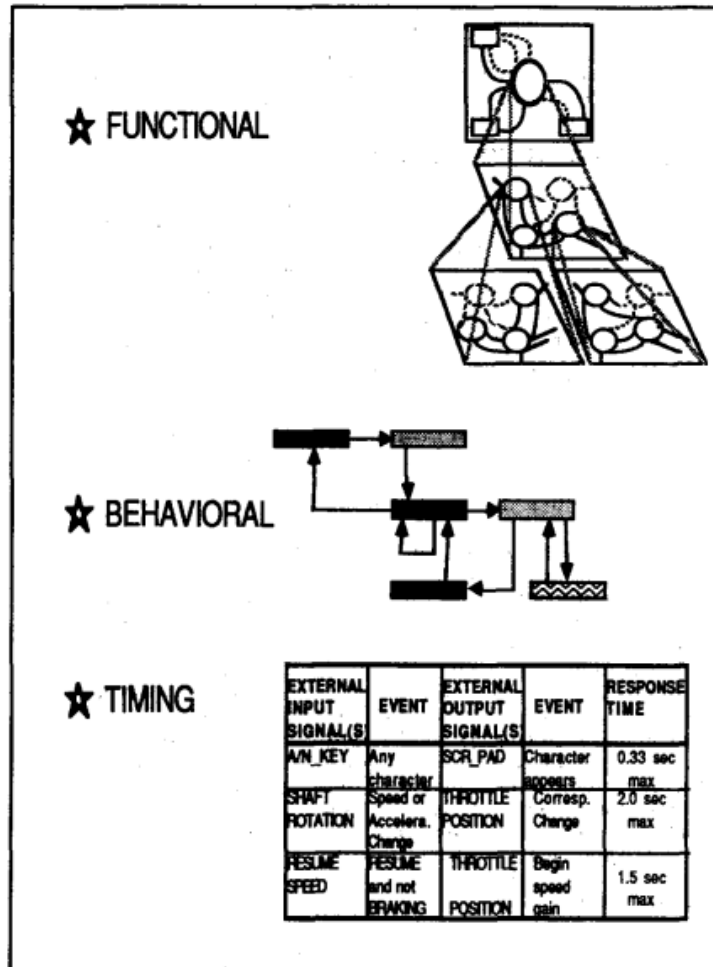
- Concept of separating *Requirements* views emerged in late-1970s to mid-1980s
  - *Structured Analysis*
  - *Systems Specification*

Requirements in a "Digital Enterprise"… Circa 1989

- "The only clear relation between a functional requirements model and a design model which we must demonstrate is one of accountability, which is often termed 'Traceability'."

- "A digital flight control system ('fly-by-wire') is a typical 'hard real time' application. Results which are supplied either too early or too late are Incorrect, and they will endanger the stability in the air of the aircraft which the system is required to control."
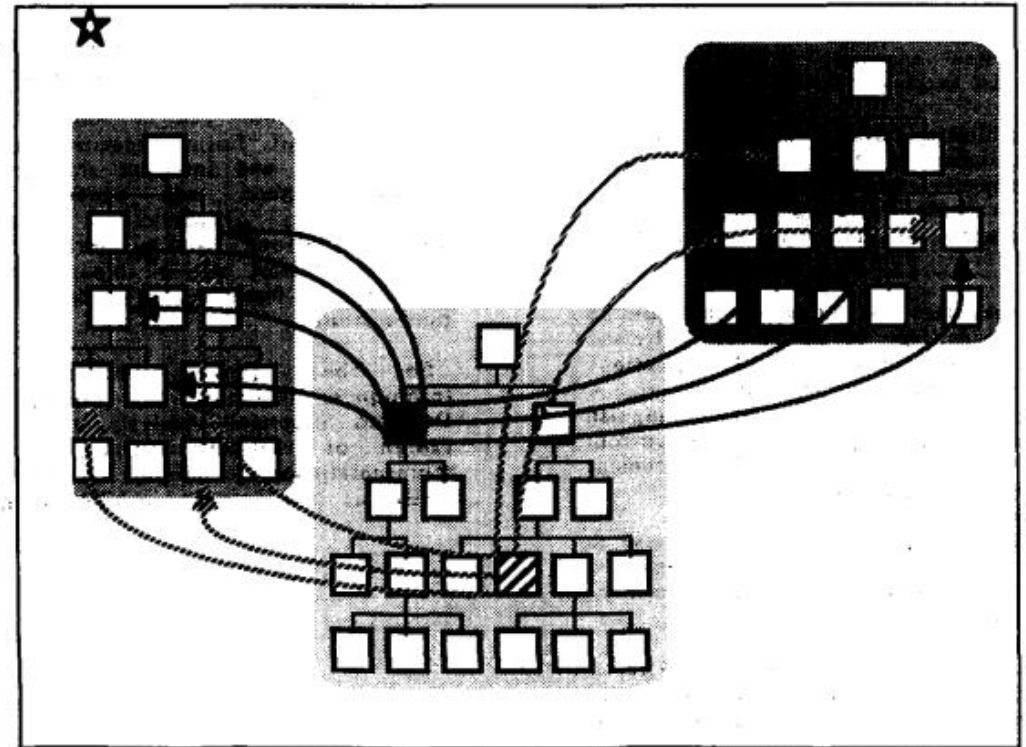

Figure 2 - Traceability ties Requirements and Design models

Kalinsky, D., & Ready, J. (1989). Distinctions between requirements specification and design of real-time systems. *Second International Conference on Software Engineering for Real Time Systems, 1989*., 26–30.
https://ieeexplore.ieee.org/abstract/document/51714/
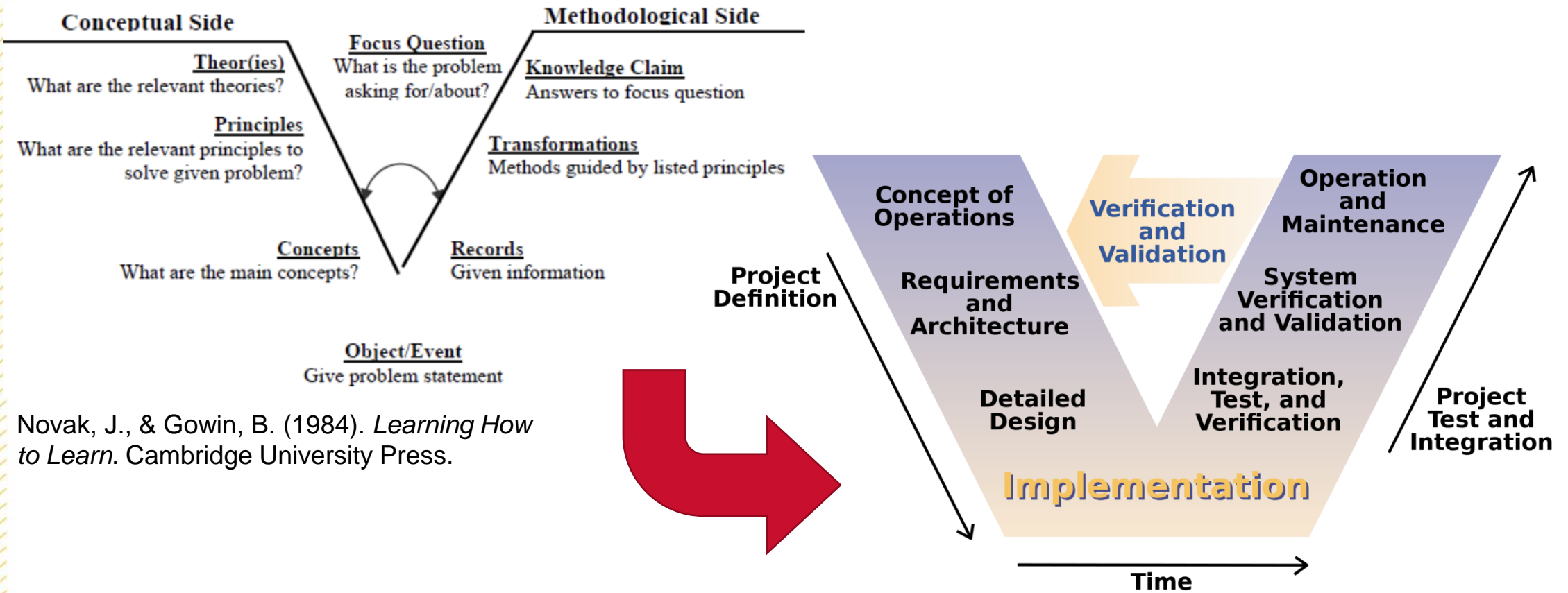
Context of 'our' Digital Enterprise?

- An industrial undertaking with an operating environment consisting of digital technologies used across a life cycle for succeeding in a digital economy

ISO/IEC TR 24748-1 System Life Cycle (SLC)

NEED | Concept | Development | Production | Utilization & Support | DISPOSAL

The Vee Diagram

1984 to 2022, What's Changed?

Conceptual Side   **Methodological Side**

Focus Question
What is the problem asking for/about?

Theor(ies)
What are the relevant theories?

Knowledge Claim
Answers to focus question

Principles
What are the relevant principles to solve given problem?

Transformations
Methods guided by listed principles

Concepts
What are the main concepts?

Records
Given information

Object/Event
Give problem statement

Novak, J., & Gowin, B. (1984). *Learning How to Learn*. Cambridge University Press.

Project Definition

Concept of Operations

Verification and Validation

Operation and Maintenance

Requirements and Architecture

System Verification and Validation

Detailed Design

Integration, Test, and Verification

Project Test and Integration

Implementation

Time

Osborne, L., Brummond, J., Hart, R., Zarean, M., & Conger, S. (2005). *Clarus: Concept of Operations* (No. FHWA-JPO-05-072). Federal Highway Administration.

Time Check… Where are we?

- The Vee diagram is our 40-year-old state of the art

- SysML Req Relationships: Satisfy, Verify, Trace

- Model-based requirements have been around for a long time
  - Intra-model relations are semantically weak
  - Inter-model relations are digitally disconnected from design and implementation

Linking to needs

Faisandier, A. (2013). *Systems architecture and design*. Sinergy'Com Belberaud, France.
https://mapsysteme.com/wp-content/uploads/Systems-Architecture-Design-v1-Table-Content.pdf

Got Research?

- Pub/sub of requirements across lifecycle

- Model-based V&V of requirements

- Integration and semantics

Pub/Sub Requirements Service

- Need requirements linking across domains and tools

- Near-real-time tracking of sources and destinations

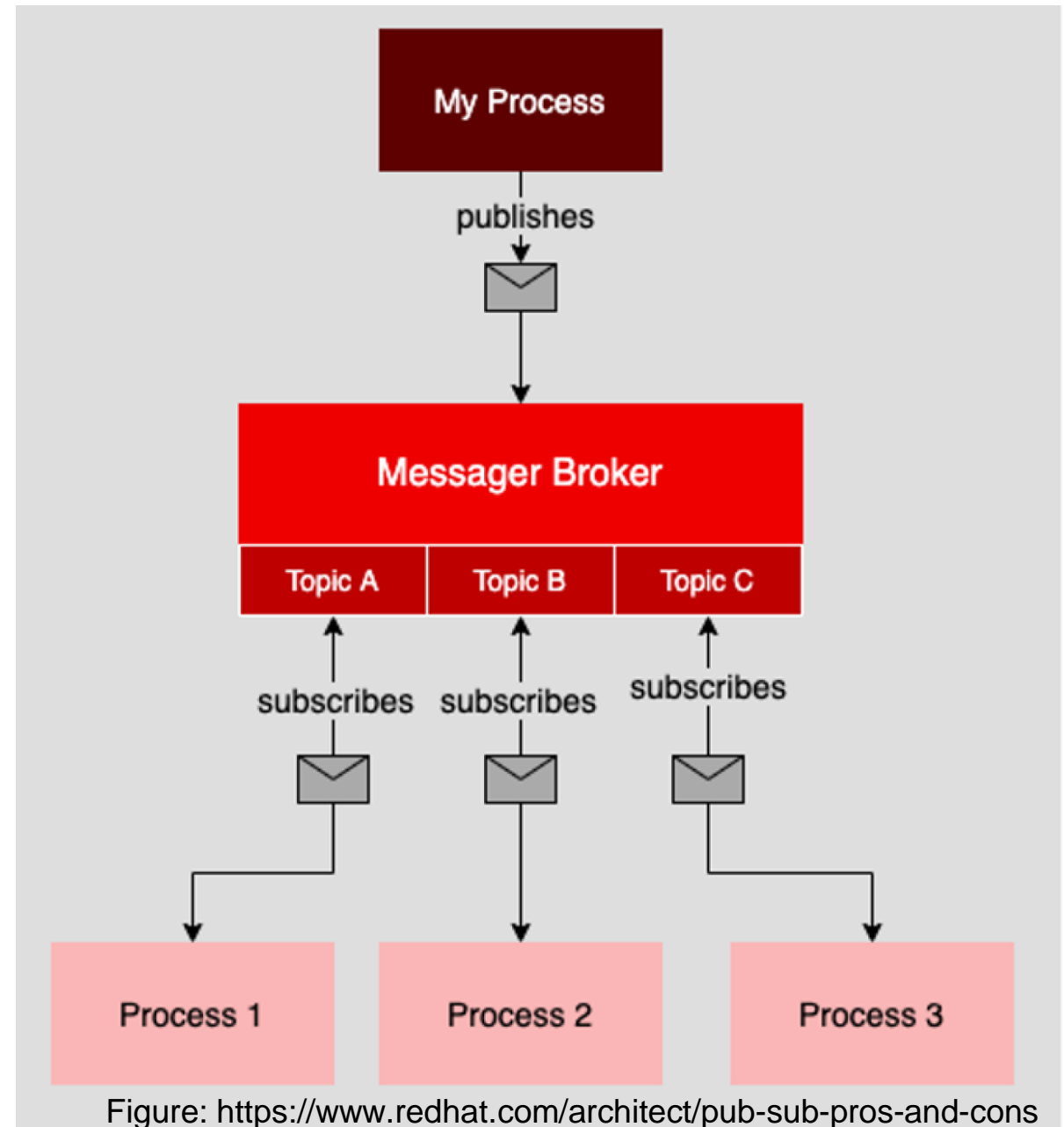- Automate notification of changes in requirements or domain-specific decisions

Figure: https://www.redhat.com/architect/pub-sub-pros-and-cons

Model-Based V&V

- Expand testing automation concepts from software domain (e.g., req. traceability matrices, test-case generation, codeless testing)

- Link V&V to more simulation tools to reduce physical testing needs---does the system do what you intend it to do?

Integration and Semantics

- Need methods and apparatus that can link requirement models to design, manufacturing, and sustainment models

- Need refined specification of SysML requirements relationships to capture the semantics (i.e., meaning) of satisfy, verify, trace

In Summary,

- Requirements are meant to restrict the solution space of a system---choose wisely

- Our approach to modeling standards has not changed much in the last 40 years

- A digital enterprise brings an opportunity to better integrate requirements modeling, traceability, and auto-V&V with the entire lifecycle

Thank you! Questions?

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Snapshot About Me

Education

Ph.D., Industrial and Systems Engineering
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M.Eng., Engineering Management
from The Pennsylvania State University, University Park PA

B.S., Aeronautical & Astronautical Engineering
Minor in Political Science focused on Science and Technology policy
from Purdue University, West Lafayette IN

Professional Experience

- Current: Mission Lead, UMD ARLIS

- 2014-2020: Prog. Manager, NIST

- 2005 to 2014, Aerospace Sector, Phoenix, Arizona

- Model-Based Enterprise Evangelist

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