National Aeronautics and Space Administration

Layered Systems Engineering Engines

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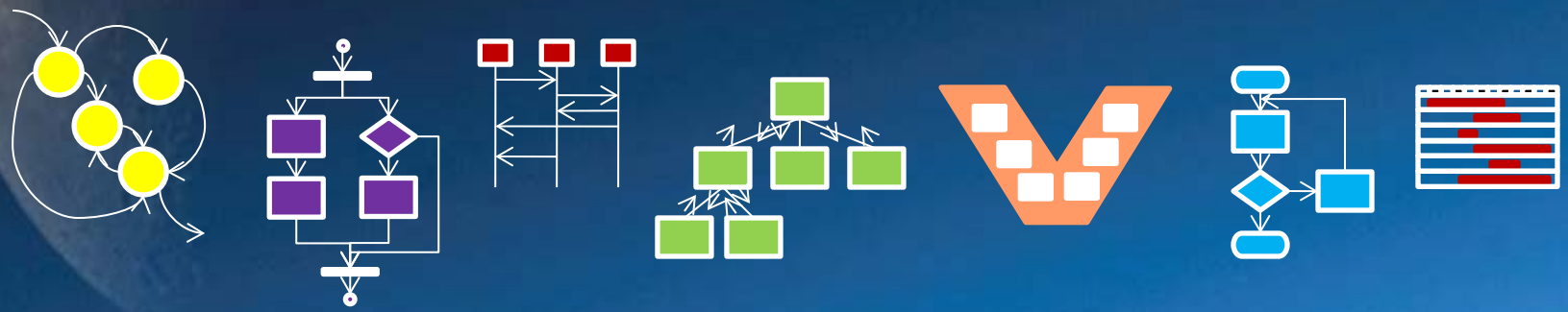
CONSTELLATION

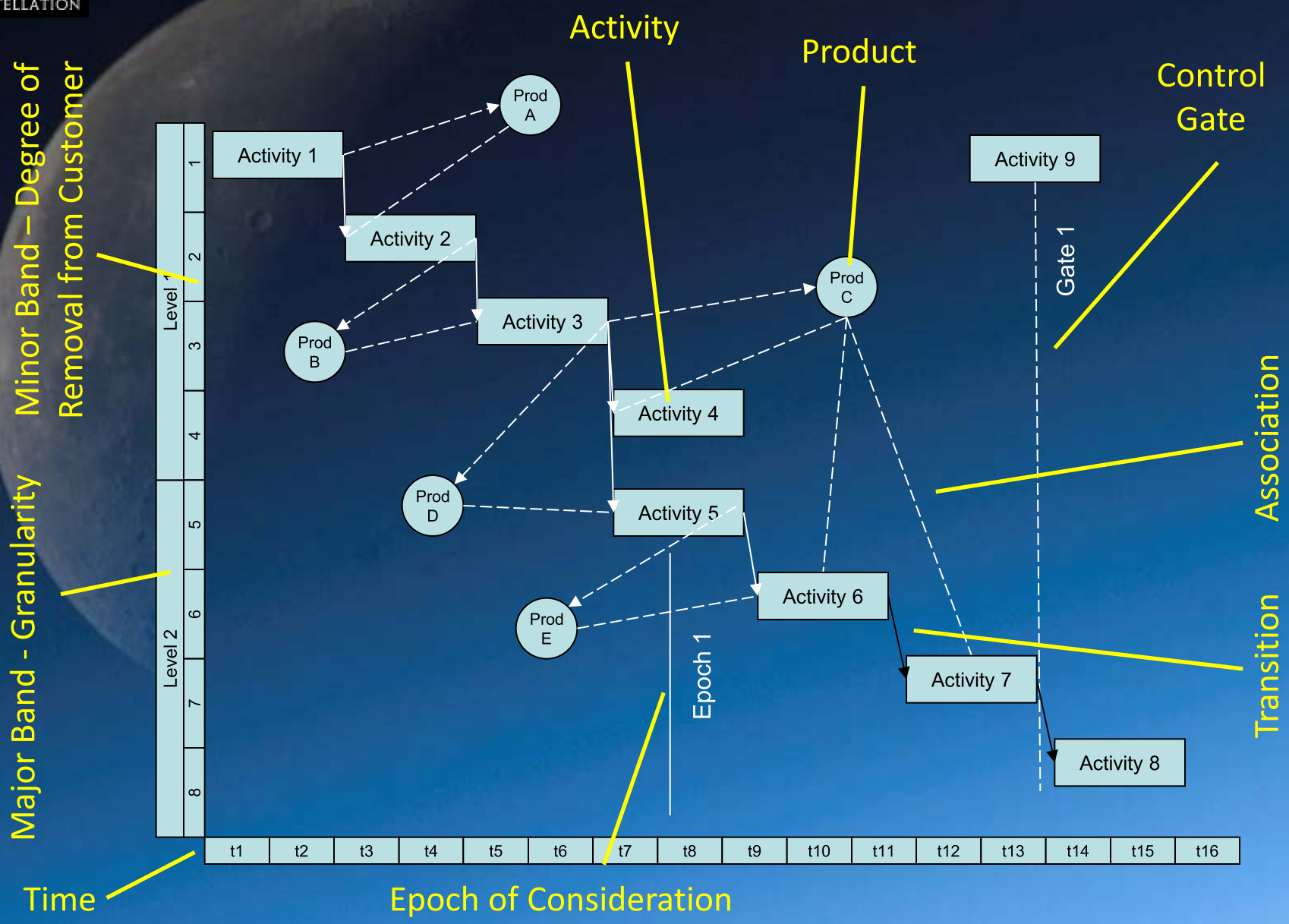
Introduction

- **The Problem: Management of System-of-Systems Engineering Effort**
  - Independent systems engineering management plans
  - Contemporaneous engineering operations
  - Many layers
- **How Visualize the Complex Relationships?**
  - Activity, level of granularity, product exchanges, timing
  - Existing notations address parts of the problem, but not all simultaneously

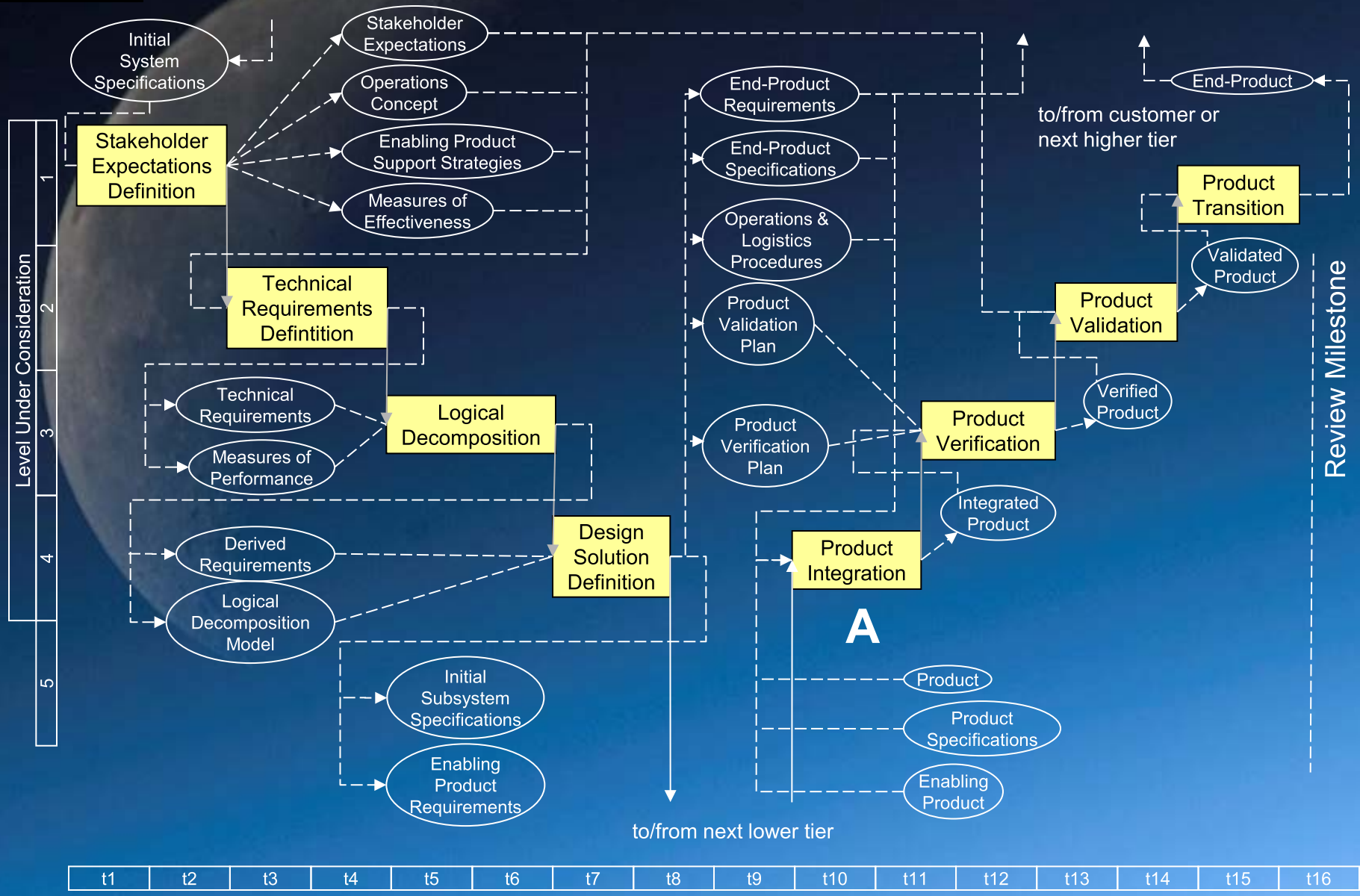


- **The Solution: A Novel Notation Capable of Expressing All the Necessary Relationships Efficiently: "Layered Vee Diagram"**
- **Applied the Notation to Typical "Chaining" Strategies**
  - Obtained key insights into costs, durations, risks, and opportunities

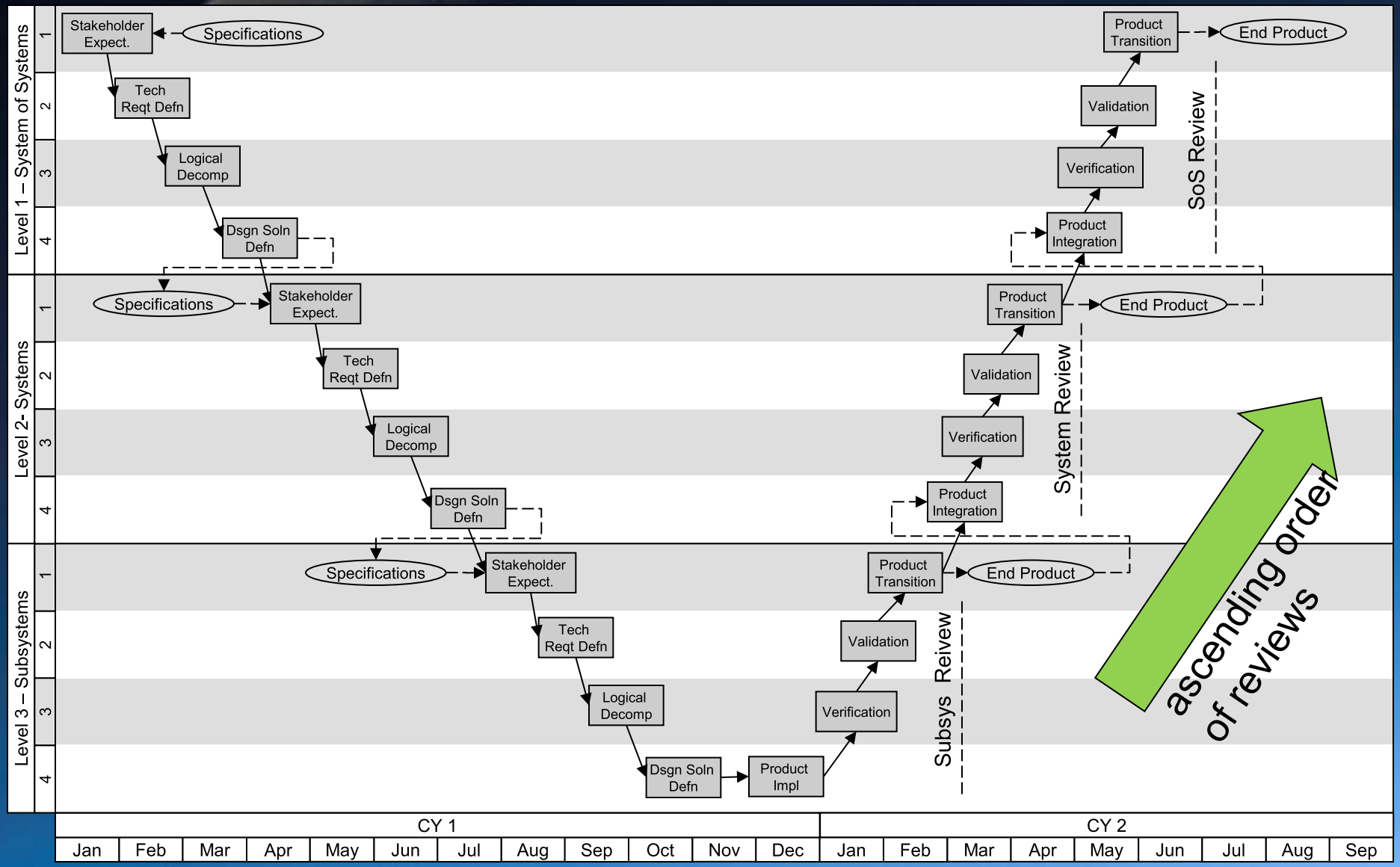
Elements of the Notation



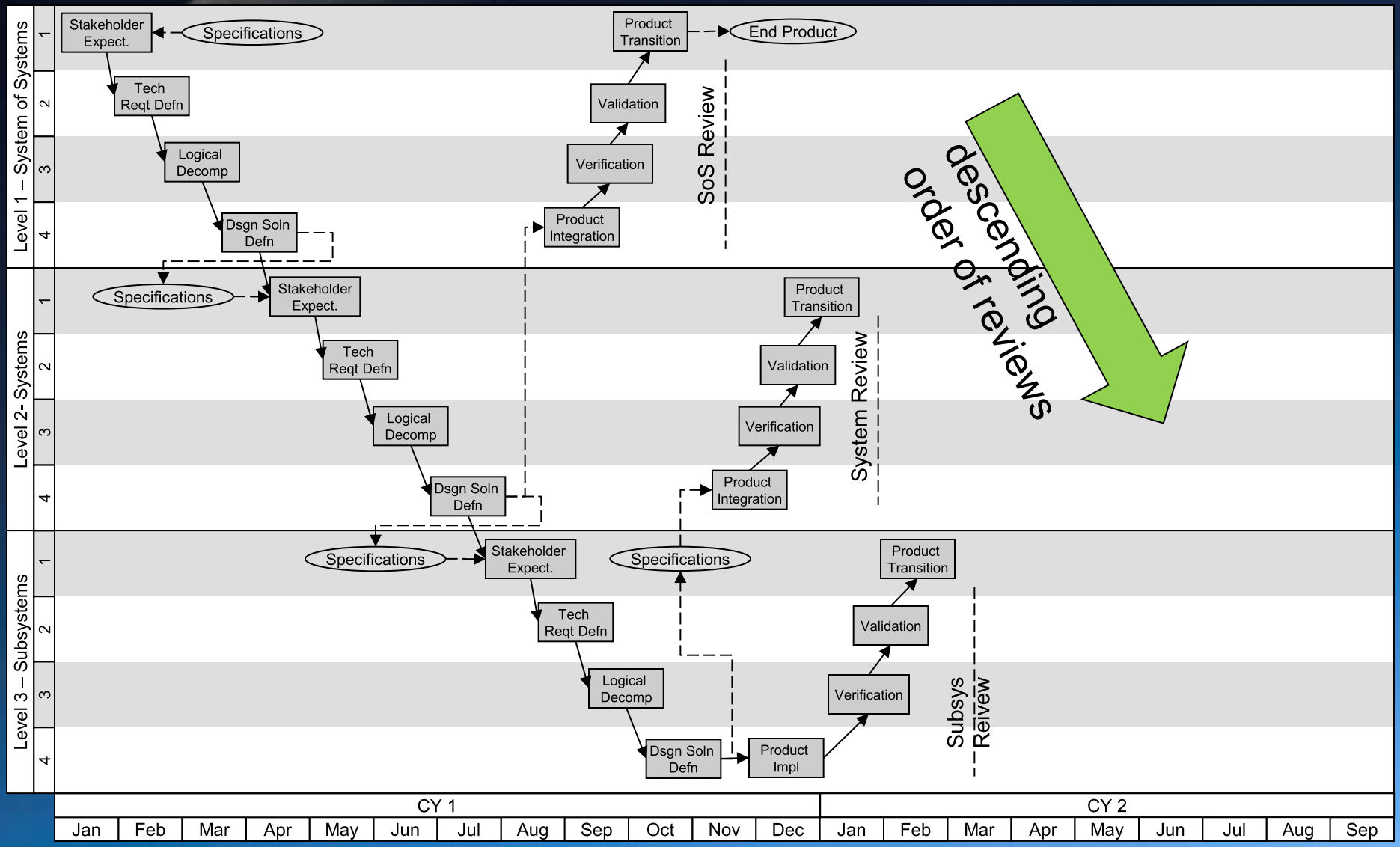
Sample Application to NASA SE Model



Chaining of Layered SE Engines – After End Products

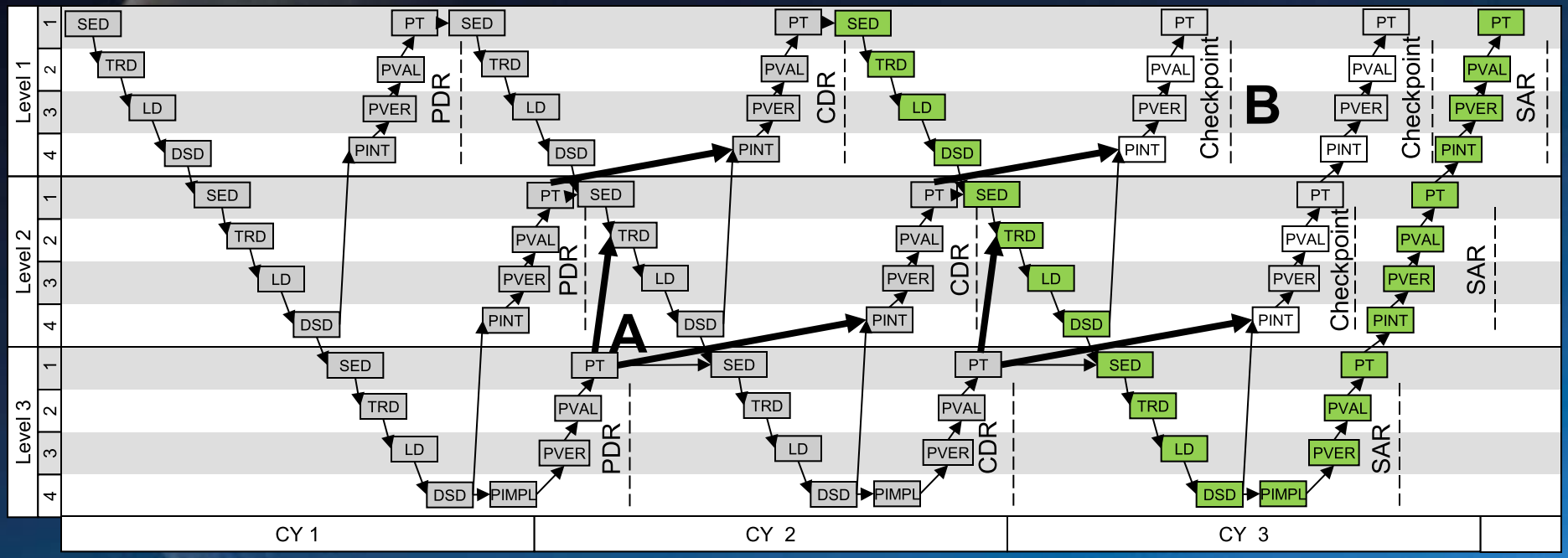


Chaining of Layered SE Engines – After Final Designs



Resolve "Dangling" Products with Iteration

- Early Iterations – Final Design Chaining
- Last Iteration – End Product Chaining

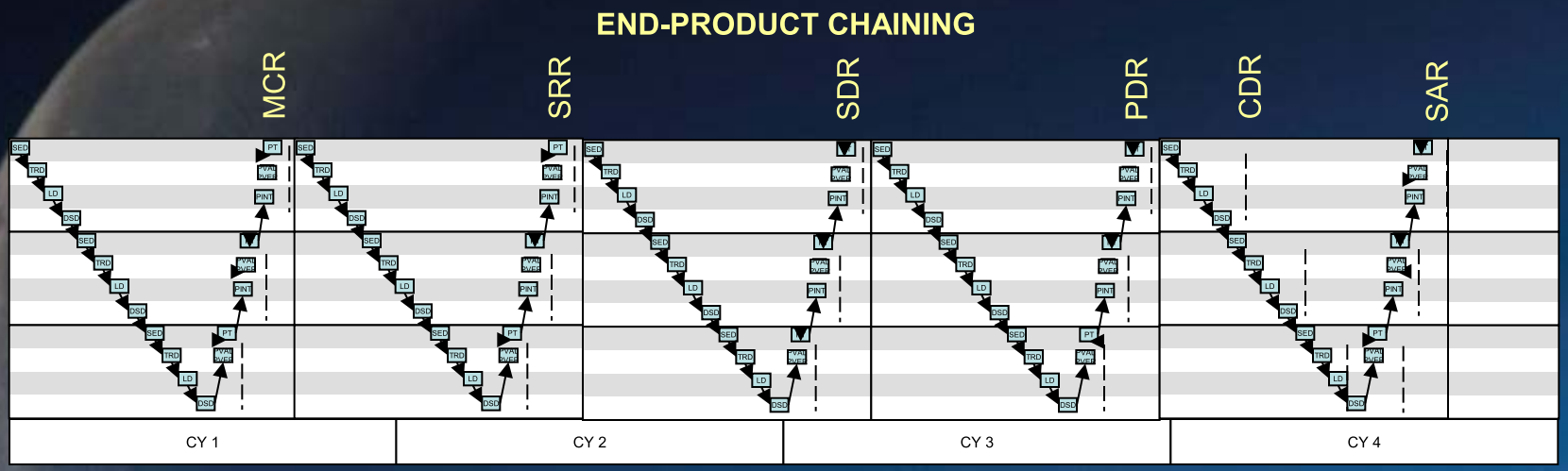


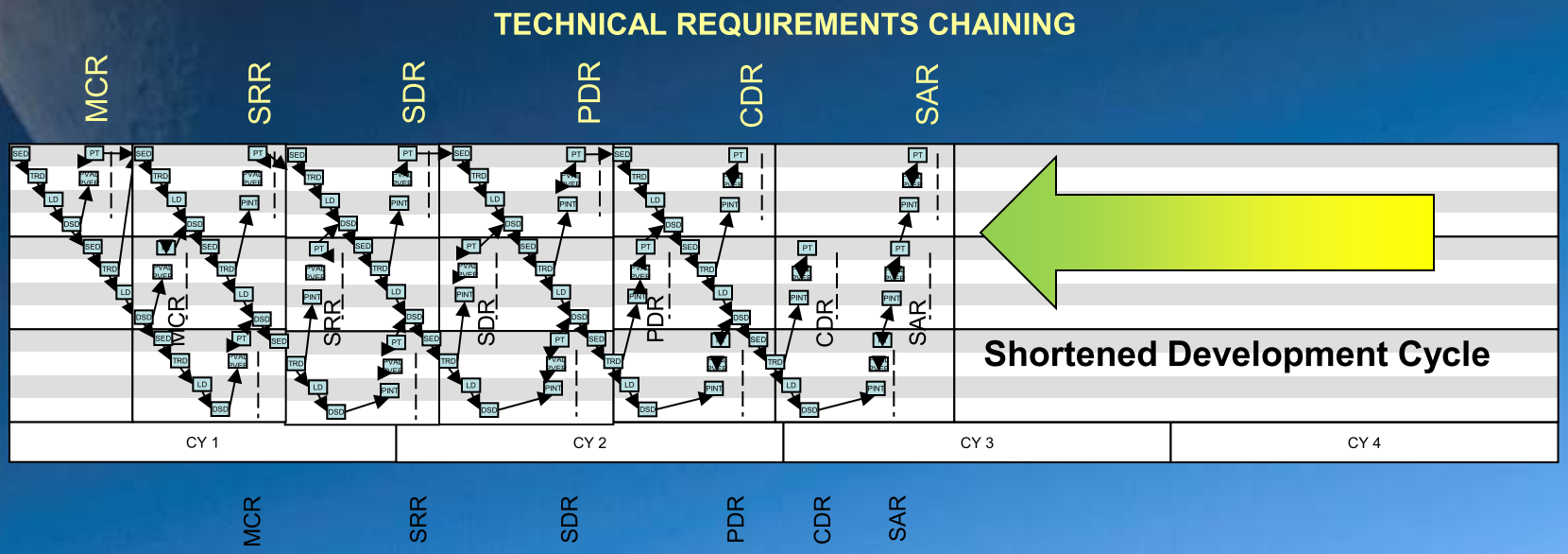
- **Point A – Early opportunities to include lower level design information**
- **Point B – Opportunities for pre-delivery checkpoints**

Comparison of Chaining Options

Chaining Strategy	Costs	Durations	Opportunities	Risks
End Product	Normal	Longest	• Simple engineering operations • Lower peak staff, if personnel move between layers	• Longest time to first validation • Bathtubs of employment • Longest time to detect lower-level implementation errors
Technical Requirements	Normal	Shortest if there are many iterations	• Fastest detection of errors • Earliest validation of end product	• Lower authenticity of early products (correctable by the last iteration) • Requires organization to work on many layers simultaneously

Impact of Chaining Strategy on Duration





Conclusion

- **We developed a new notation for describing systems engineering activity**
  - Unambiguously relates activities, time, level of system decomposition, process, and product relationships
  - Aids systems engineering managers to express and understand the relationships between many systems engineering engines
  - Easy to translate to schedules, costing, work agreements, and decision-making activities
- **Chaining strategies for layered SE engines can influence the overall performance of the organization**
  - Duration
  - Risk of misunderstanding, or mistargeting of the system design
  - Risk of early implementation errors
  - Early detection of implementation errors
  - Early validation of the end product

Acknowledgement

- ***The research described in this publication was carried out at the Jet Propulsion Laboratory, California Institute of Technology, under a contract with the National Aeronautics and Space Administration***
  - J. C. Breidenthal would like to thank David Petri and Jeff Schutter at the Johnson Space Center, Terry Morris at the Langley Research Center, and Dan Dvorak of the Jet Propulsion Laboratory for helpful discussion in development of this paper

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