MBSE – a historical perspective promises and pitfalls

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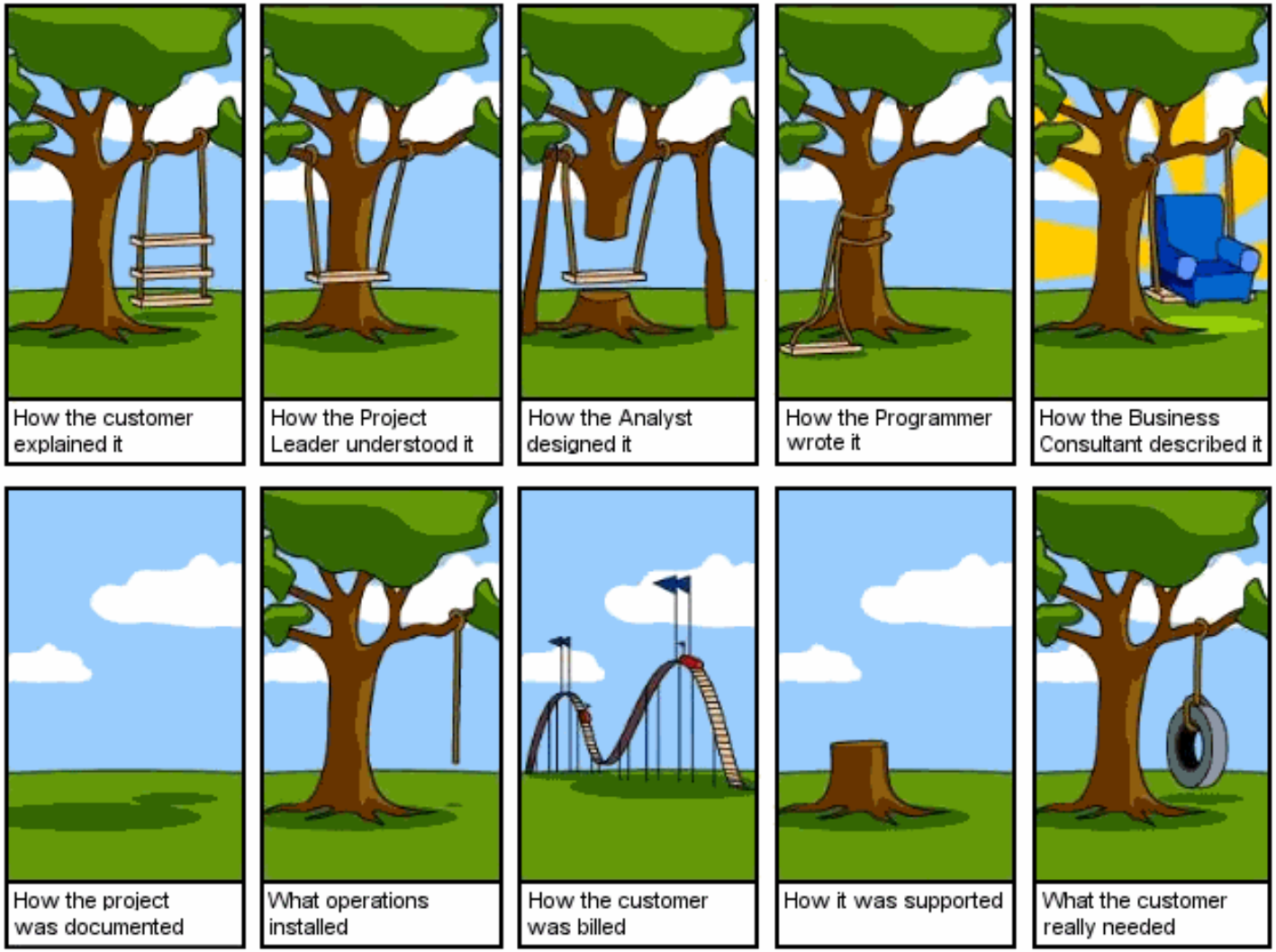
From the INCOSE forum

- "… I could never read a long document without scribbling some diagrams…"
- "… is there any such thing as Non Model-based Systems Engineering?"
- "It's hard to imagine the Apollo program not having been an example of SE because they used paper-based documents as a basis for models."
- " … we are using models, as Moliere's M. Jourdain was using prose, without knowing it."

… you have all seen this one



Topics

- Introduction
- Theory and practice
- Historical perspectives
- Root causes of low adoption
- Overcoming barriers
- Closing encouragement

MBSE – INCOSE definition

- Model-based systems engineering is the formalized application of modeling to support
- System requirements, design, analysis, and V&V activities
- Beginning in the conceptual design phase and continuing throughout development and later lifecycle phases.

The promise

- Improved communications facilitated by models that can be evaluated for consistency, completeness, correctness
- Improved ability to cope with complexity in systems and to analyze change impacts
- Improved system quality
- Improved knowledge capture and reuse leading to reduced cycle time and lower maintenance costs
- Improve capacity to teach and learn SE, to integrate new team members, to minimize loss of knowledge as team members leave, to establish shared mental models

Beginning with the end in mind

- Quality – “creating cost-effective solutions to practical problems in the service of mankind.” (SEI, 1990)
- Risk reduction with a lifecycle perspective
- Understanding before implementation
- Good tools are necessary but not sufficient
- MBSE does not guarantee good SE

Umbilical bond in MBSE

- All engineering finds some foundation in scientific knowledge
- There exist gaps between scientific research and knowledge employed by engineers, which is derived from
  - Invention
  - Theoretical engineering research
  - Experimental engineering research
  - Design practice (reflective)
  - Production and deliberate trials
- Closing this gap requires a close cooperation between theorists and practitioners

SE is a human activity

- Difficult to map human cognition and resulting activities – abstraction is invisible, not always logical, individualistic, and based on imprecise rules (e.g. for decomposition)
- Lacking principles for how to determine system boundaries, interfaces, contexts and organizations
- Humans with the aid of computers can make errors and generate artifacts at a faster rate than non-computer-based activities

Contributions from the 1960's

- Database design / information repository
- Early user involvement recognized as Critical Success Factor
- Structured methods / functional decomposition and rules for modularity
- Formal methods
- Software lifecycles first conceived

Modularity

- Modularity in physical systems facilitates design and manufacture
  - Provide economies of scale in production
  - Simply the design challenge by decomposing a system into units with clearly defined interfaces through which they interact with each other

Organizations are a factor

- Conway's Law is named after Melvin Conway, who published the idea in 1968:
- Any organization that designs a system will inevitably produce a design whose structure is a copy of the organization's communication structure
- Consequences for systems acquisition and the creation of project teams

Contributions from the 1970's

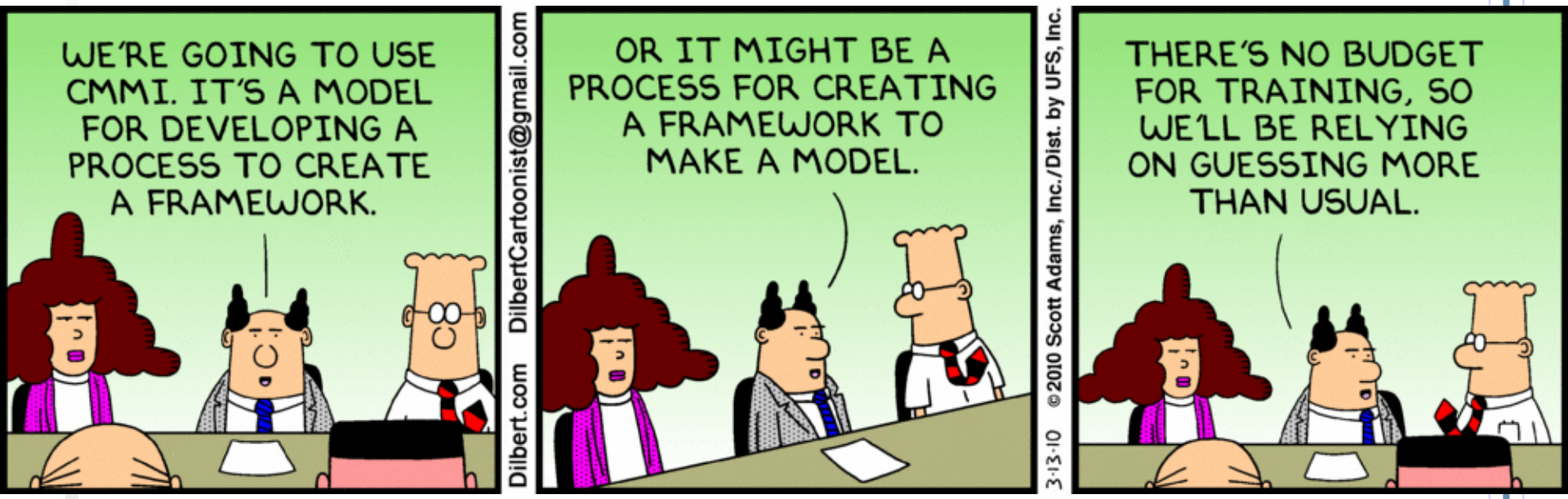
- Iterative and evolutionary lifecycles
- Walkthroughs and inspections (peer reviews to guard against individual bad judgment)
- HIPO / Hierarchy-Input-Process-Output
- Object-oriented methods
- CASE / computer-assisted software engineering (starting with requirements engineering in 1971)
- Definition of essential and accidental SE
- Maturity grid / uncertainty, awakening, enlightenment, wisdom, certainty

System Dynamics

- Initially conceived in 1950's (MIT) as a method for understanding the dynamic behavior of complex systems using feedback loops and stocks and flows in executable models
- In 1970, Jay Forrester created a model for the Club of Rome (an organization devoted to solving the global crisis caused by the demands being placed on the Earth's carrying capacity by the world's exponentially growing population
- WORLD models the world's socioeconomic systems and has been remarkably accurate in its predictions
- And an example of good modeling and poor usage

Newer events and findings

- Unified modeling language ended the OO methodology wars in 1997
- Software reuse
- CMM and CMMI
- Rapid system development methods
- Architecture / domain analysis, product lines, strategic management role
- Agile methods / prototyping, Scrum, lean
- Understanding of the close bond between specification and implementation
- Safety (for people and natural environments) must be built-in during requirements and early system design


WE'RE GOING TO USE CMMI. IT'S A MODEL FOR DEVELOPING A PROCESS TO CREATE A FRAMEWORK.
OR IT MIGHT BE A PROCESS FOR CREATING A FRAMEWORK TO MAKE A MODEL.
THERE'S NO BUDGET FOR TRAINING, SO WE'LL BE RELYING ON GUESSING MORE THAN USUAL.
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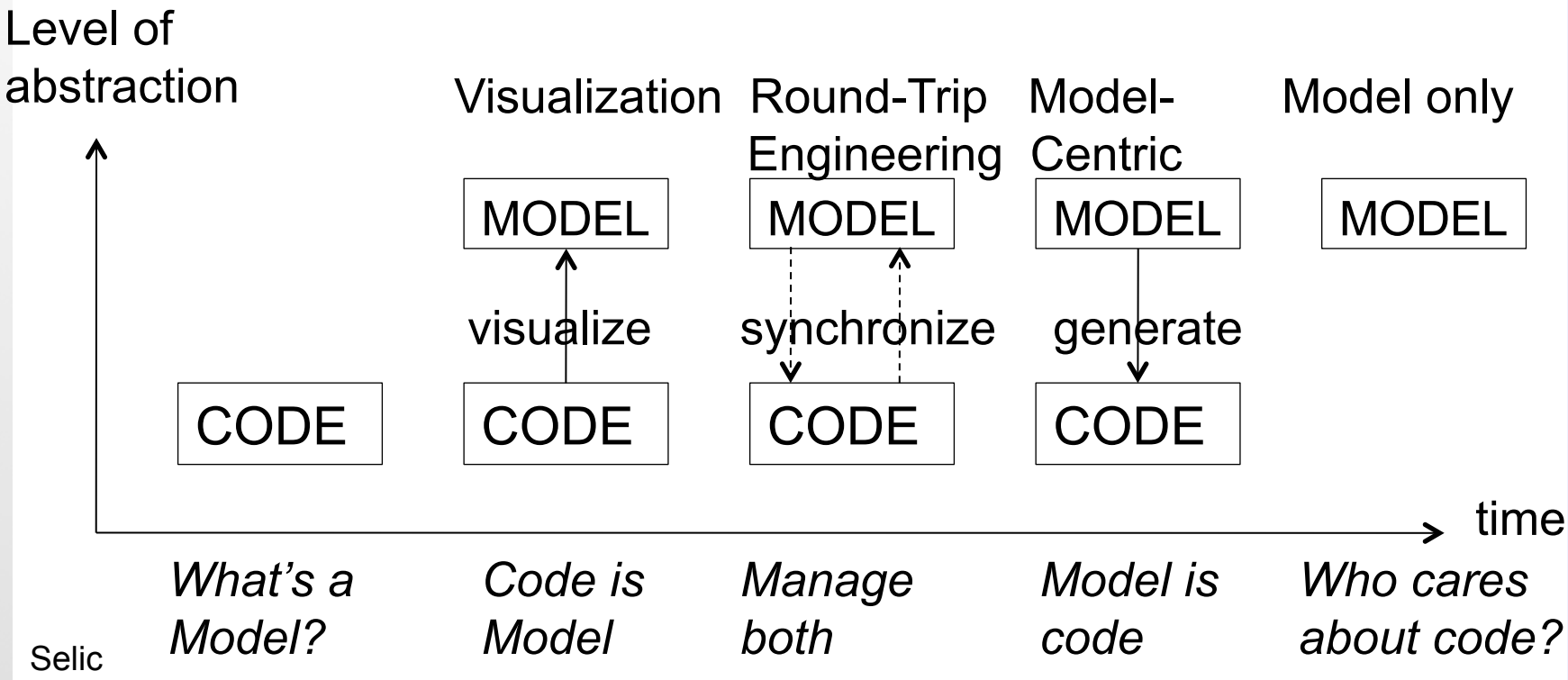
Model-driven development

- Continuation of trend toward increasing levels of abstraction and automation



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Executable models

- Evaluate critical design choices early and mitigate risk
- Validate requirements with stakeholders
- Automated design analysis using formal methods and inter-model transformations
- **Paradox: need to provide sufficient detail at the same time need to abstract and communicate**
- **Paradox: need for informal modeling that is precise and unambiguous**
- Suggests the need for multiple tools and varying degrees of formalism enforcement

Root causes of low adoption

- Technical
  - Usability, integration into legacy environments
  - Technology advancements and immaturity
  - Lack of interoperability and standardization
- Cultural
  - Lack of awareness
  - The mind-set and comfort of practitioners
  - Short-termism in business decisions
- Economic
  - Initial investment
  - Risk both perceived and actual

Cultural barriers

- Uncertainty surrounds the capabilities and achievements of MBSE
  - Need for published verifiable evidence
- Psychological barriers
  - Practitioners filter out unfamiliar ‘news’
  - Communication across multiple disciplines
  - Comfort zone of staying with familiar technologies leads to professional as well as product obsolescence
  - Lack of understanding of the problem domain

Competency (talent) required

- Formal capture of knowledge using a model-based approach requires a higher level of expertise and additional effort to capture knowledge that might be otherwise implicitly assumed
- This is both good – and problematic
- Requires models that can be defined unambiguously and precisely such that they can be understood by multiple stakeholders along the lifecycle

Overcoming barriers

- Education
  - The next generation of practitioners will work in an MBSE world that demands respect for the social, cultural and economic context of its systems
  - Need for a more use-centered culture with corresponding domain understanding
  - Mathematics as a foundation for abstraction skills
  - Need for higher levels of general literacy (writing)
- Research
  - Multidisciplinary – this is not a technology-only challenge!
  - Invest in establishing theoretical foundations for modeling semantics –formal domain specific languages and model transformations are needed
- Standardization – continue development

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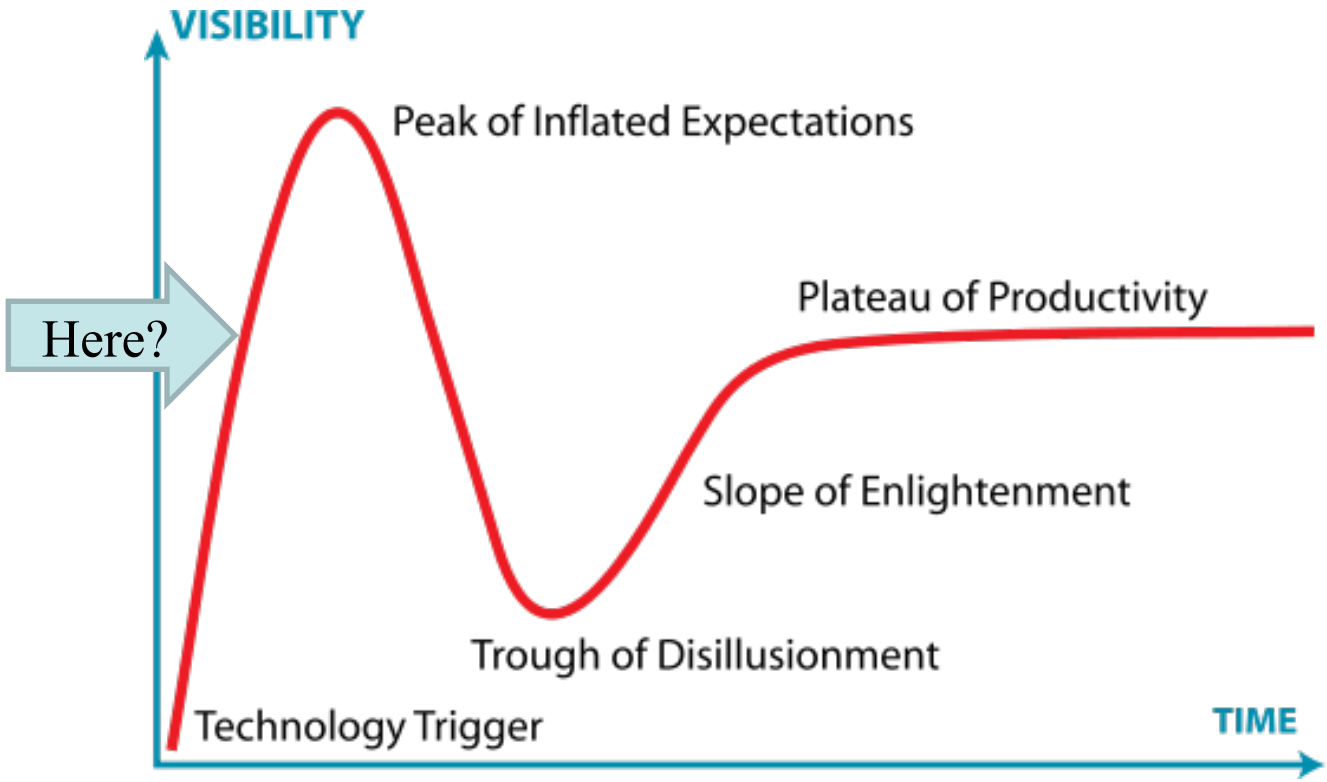
Apply KISS before adopting a methodology

- Avoid using methods and techniques just because others do
- A methodology is more likely to be used when it is simple, clearly effective, and generates a number of work products appropriate to the task
- Models are not a panacea

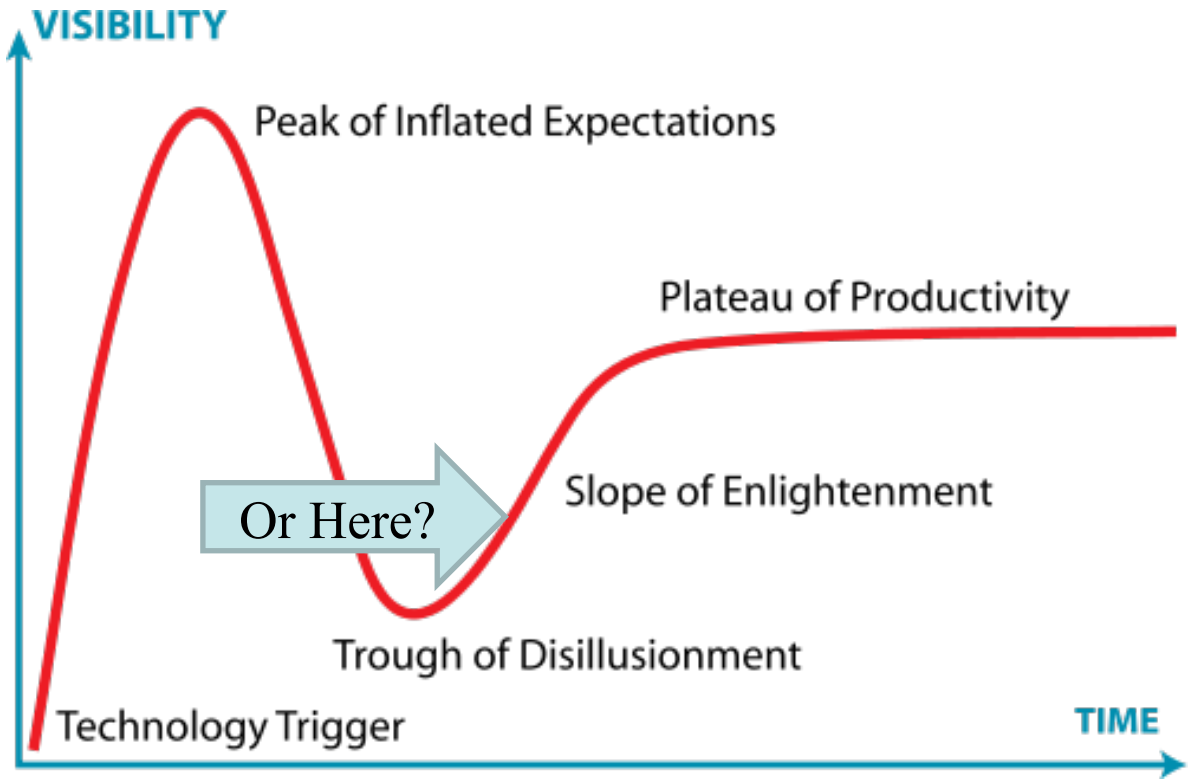
Technology hype curve

- Where is MBSE? Have we really just begun, or…



Technology hype curve

- Where is MBSE? Or is it too hard to track because of the near-continuous technology advancements?



Closing encouragement

- The MBSE promises are significant and worthwhile
- The INCOSE MBSE initiative needs to broaden to bring other stakeholders into the project such that all products reflect the importance of MBSE, e.g. the competency framework

Contributions needed!

- MBSE driven by the emergence and maturation of modeling languages and information exchange standards
- The continuing evolution of information technology is a necessary enabler of improved modeling techniques
- Future MBSE demands domain-specific modeling languages and visualizations that support SE in the problem domain
- Future MBSE will benefit from the creation and reuse of model repositories, taxonomies and design patterns

Thank you!

Questions?