

MBSE at the Age of Eight

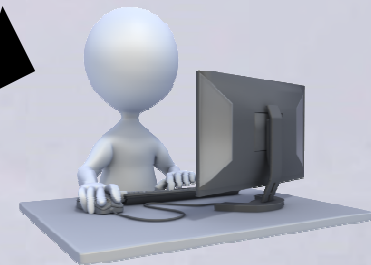
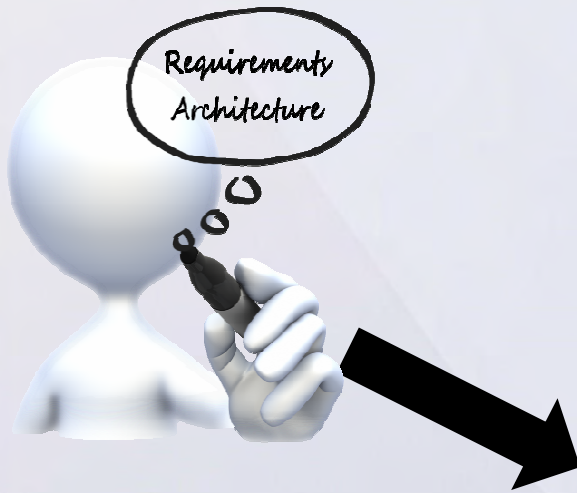
David Long

President, Vitech Corporation

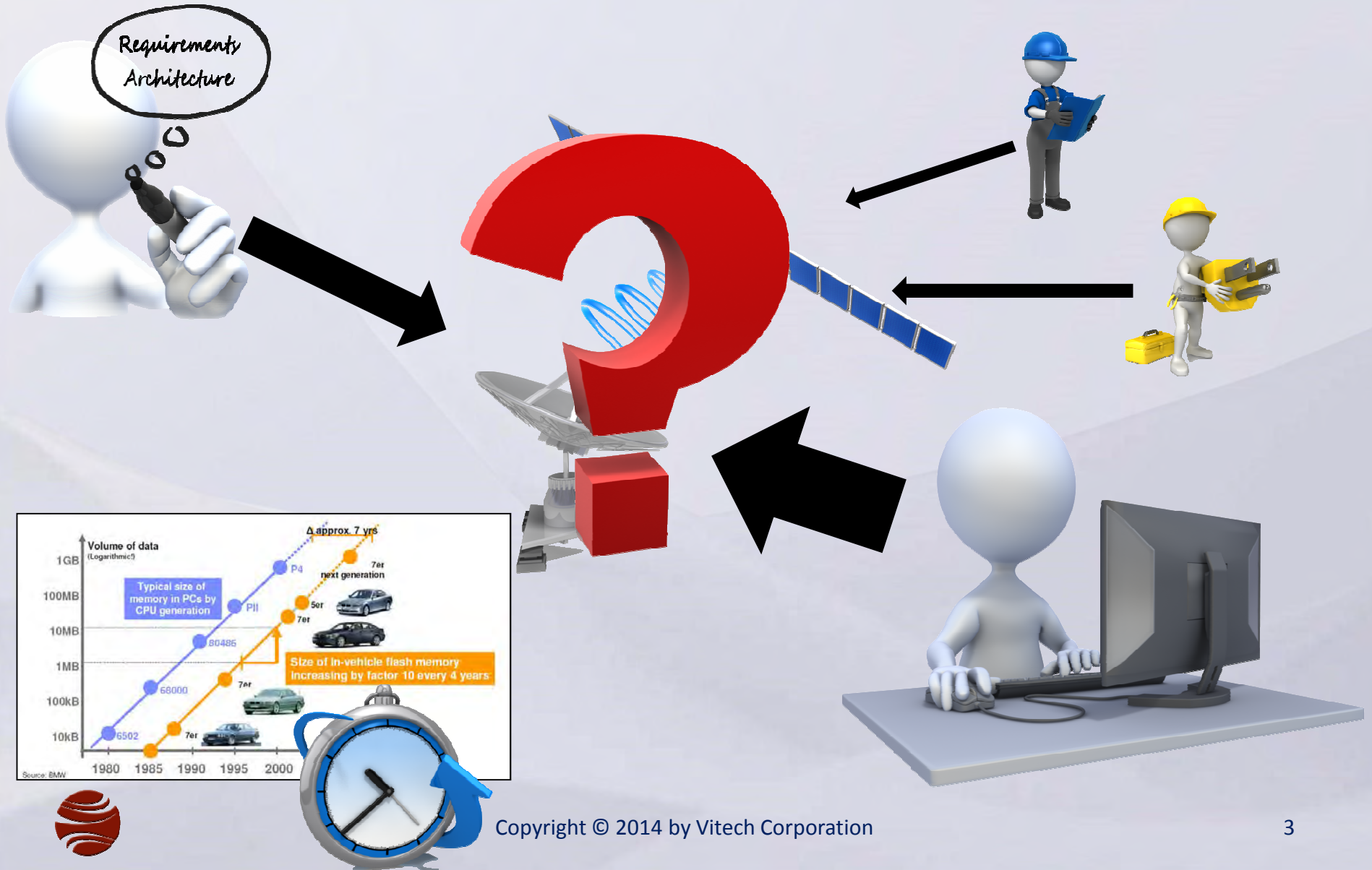
President, INCOSE (2014 & 2015)



The Old Days

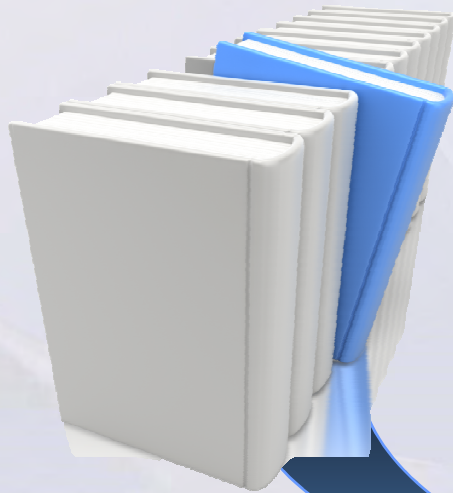


The New Reality



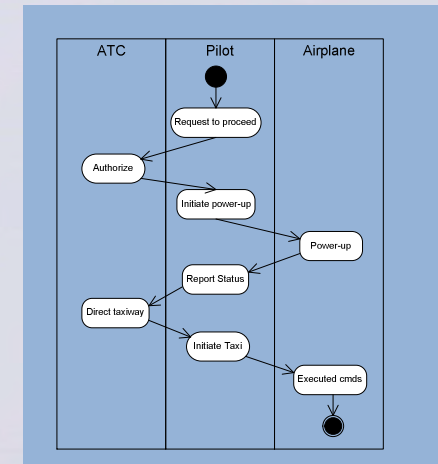
Systems Engineering: A Practice in Transition

Traditional



- Specifications
- Interface requirements
- System design
- Analysis & Trade-off
- Test plans

Future



Moving from document-centric to model-centric



Models and Model-Based Systems Engineering

A graphical, mathematical (symbolic), physical, or verbal representation or simplified version of a concept, phenomenon, relationship, structure, system, or an aspect of the real world.

www.businessdictionary.com

A physical, mathematical, or otherwise logical representation of a system, entity, phenomenon, or process.

DoD5000.59-M 1998

Model-based systems engineering (MBSE) is the formalized application of modeling to support system requirements, design, analysis, verification and validation activities beginning in the conceptual design phase and continuing throughout development and later life cycle phases.

“INCOSE Systems Engineering Vision” 2020 INCOSE-TP-2004-004-02 September, 2007



Casting an Initial Vision

Control System Diagram:

```

    graph LR
        DD[Desired Distance] --> Sum((+))
        Sum --> Int[Integrator]
        Int --> G2[Gain2]
        G2 --> Torque[Torque]
        Sum --> G1[Gain1]
        G1 --> Plant[Plant Block]
        Sum --> G3[Gain]
        G3 --> Plant
        Plant --> Dist[Distance]
        Plant --> Vel[Velocity]
        Dist --> DS[Data Scope]
        Vel --> DS
    
```

Routing Diagram: Shows a yellow path on a blue car model, with a zoomed-in view of the path.

FMEA Table:

Item	Recommended Actions	Responsibility & Target Date	Action Results	S	O	D	R
80	Add laboratory accelerated	A. Tate-Body Eng 8/9/04	Based on test results upper	4	2	3	24
160	Add laboratory	Combine w/test for	Test results (Test No. 1481)	4	1	2	8
20	None			3	1	4	12
200	Add team evaluation using	Body Eng. & Assembly		7	2	2	28
15	None		Based on test, 3 additional vert	7	2	2	28
100	Add team evaluation using	Body Eng. & Assembly	Evaluation (moved)	7	3	2	42
160	Add laboratory accelerated	A. Tate-Body Eng 8/9/04	Based on test results upper	3	2	3	18
48	None	Combine w/test for	Test results (Test No. 1481)	7	1	4	28
216	None			7	6	3	126
100	Add team evaluation using	Body Eng. & Assembly	Based on test, 3 additional vert	7	4	1	28
112	None			7	7	4	56
96	Add team evaluation using	Body Eng. & Assembly	Evaluation (moved)	7	3	2	42

Life Expectancy Tables:

Table 1 - Ordinary Joint Life and Last Survivor Annuitants - Two Lives - Expected Return Multiples

Ages		Male												
Male	Female	35	36	37	38	39	40	41	42	43	44	45	46	47
35	40	46.2	45.7	45.3	44.8	44.4	44.0	43.6	43.3	43.0	42.6	42.3	42.0	41.8
36	41	45.7	45.2	44.8	44.3	43.9	43.5	43.1	42.7	42.3	42.0	41.7	41.4	41.1
37	42	45.3	44.8	44.3	43.8	43.4	42.9	42.5	42.1	41.8	41.4	41.1	40.7	40.4
38	43	44.8	44.3	43.8	43.3	42.9	42.4	42.0	41.6	41.2	40.8	40.5	40.1	39.8
39	44	44.4	43.9	43.4	42.9	42.4	41.9	41.5	41.0	40.6	40.2	39.9	39.5	39.2
40	45	44.0	43.5	42.9	42.4	41.9	41.4	41.0	40.5	40.1	39.7	39.3	38.9	38.6
41	46	43.6	43.1	42.5	42.0	41.5	41.0	40.5	40.0	39.6	39.2	38.8	38.4	38.0
42	47	43.3	42.7	42.1	41.6	41.0	40.5	40.0	39.6	39.1	38.7	38.2	37.8	37.5
43	48	43.0	42.3	41.8	41.2	40.6	40.1	39.6	39.1	38.6	38.2	37.7	37.3	36.9
44	49	42.6	42.0	41.4	40.8	40.2	39.7	39.2	38.7	38.2	37.7	37.2	36.8	36.4
45	50	42.3	41.7	41.1	40.5	39.9	39.3	38.8	38.2	37.7	37.2	36.8	36.3	35.9
46	51	42.0	41.4	40.7	40.1	39.5	38.9	38.4	37.8	37.3	36.8	36.3	35.9	35.4
47	52	41.8	41.1	40.4	39.8	39.2	38.6	38.0	37.5	36.9	36.4	35.9	35.4	35.0

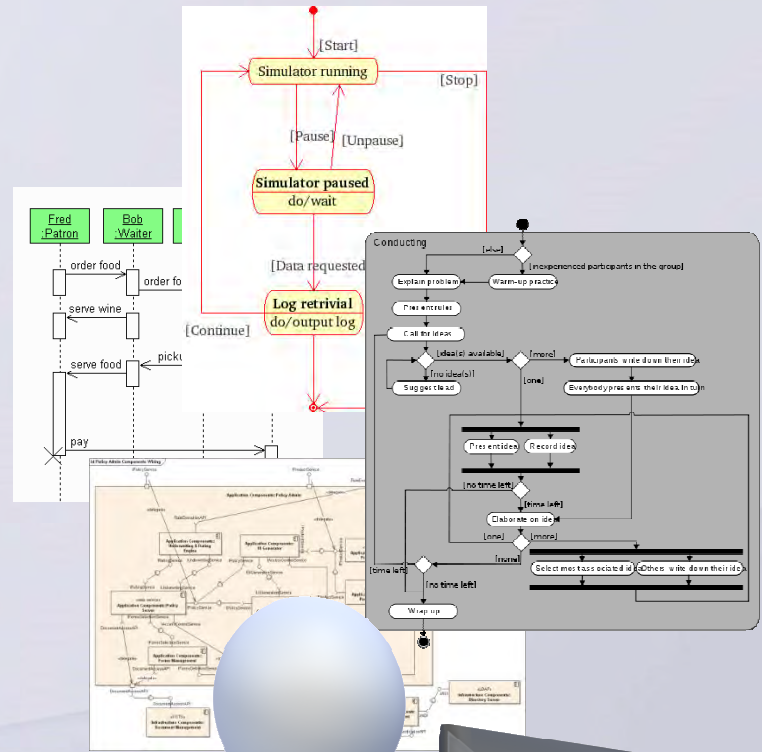
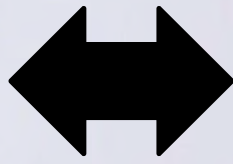
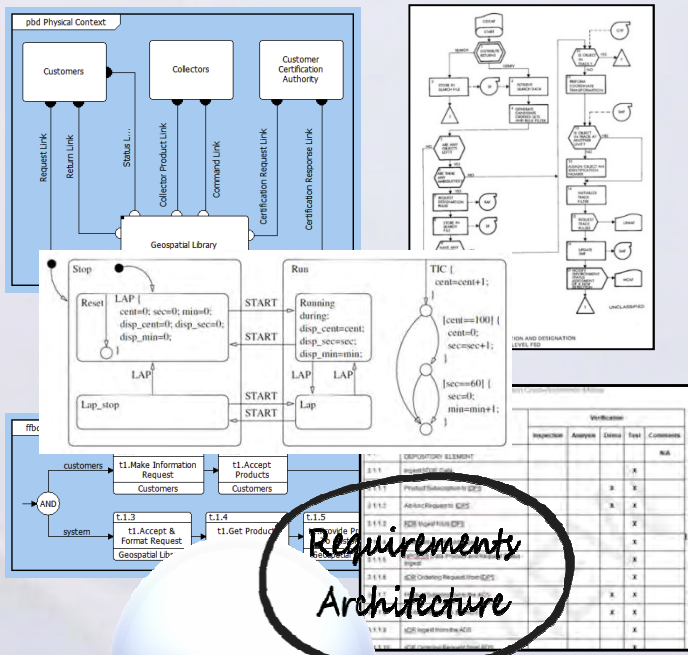
Table 2 - Ordinary Joint Life and Last Survivor Annuitants - Two Lives - Expected Return Multiples

Ages		Male												
Male	Female	48	49	50	51	52	53	54	55	56	57	58	59	60
35	40	41.5	41.3	41.0	40.8	40.6	40.4	40.3	40.1	40.0	39.8	39.7	39.6	39.5
36	41	40.8	40.6	40.3	40.1	39.9	39.7	39.5	39.3	39.2	39.0	38.9	38.8	38.6
37	42	40.2	39.9	39.6	39.4	39.2	39.0	38.8	38.6	38.4	38.3	38.1	38.0	37.9
38	43	39.5	39.2	39.0	38.7	38.5	38.3	38.1	37.9	37.7	37.5	37.3	37.2	37.1
39	44	38.9	38.6	38.3	38.0	37.8	37.6	37.3	37.1	36.9	36.8	36.6	36.4	36.3
40	45	38.3	38.0	37.7	37.4	37.1	36.9	36.6	36.4	36.2	36.0	35.9	35.7	35.5
41	46	37.7	37.3	37.0	36.7	36.5	36.2	36.0	35.7	35.5	35.3	35.1	35.0	34.8
42	47	37.1	36.8	36.4	36.1	35.8	35.6	35.3	35.1	34.8	34.6	34.4	34.2	34.1
43	48	36.5	36.2	35.8	35.5	35.2	34.9	34.7	34.4	34.2	33.9	33.7	33.5	33.3
44	49	35.9	35.6	35.3	34.9	34.6	34.3	34.0	33.8	33.5	33.3	33.0	32.8	32.6
45	50	35.3	35.1	34.7	34.4	34.0	33.7	33.4	33.1	32.9	32.6	32.4	32.2	32.1
46	51	35.0	34.6	34.2	33.8	33.5	33.1	32.8	32.5	32.2	32.0	31.7	31.5	31.3
47	52	34.5	34.1	33.7	33.3	32.9	32.6	32.2	31.9	31.6	31.4	31.1	30.9	30.6
48	53	34.0	33.6	33.2	32.8	32.4	32.0	31.7	31.4	31.1	30.8	30.5	30.2	30.0
49	54	33.6	33.1	32.7	32.3	31.9	31.5	31.2	30.8	30.5	30.2	29.9	29.6	29.4
50	55	33.2	32.7	32.3	31.8	31.4	31.0	30.6	30.3	29.9	29.6	29.3	29.0	28.8
51	56	32.8	32.3	31.8	31.4	30.9	30.5	30.1	29.8	29.4	29.1	28.8	28.5	28.2
52	57	32.4	31.9	31.4	30.9	30.5	30.1	29.7	29.3	28.9	28.6	28.2	27.9	27.6
53	58	32.0	31.5	31.0	30.5	30.1	29.6	29.2	28.8	28.4	28.1	27.7	27.4	27.1
54	59	31.7	31.2	30.6	30.1	29.7	29.2	28.8	28.3	27.9	27.6	27.2	26.9	26.5
55	60	31.4	30.8	30.3	29.8	29.3	28.8	28.3	27.9	27.5	27.1	26.7	26.4	26.0
56	61	31.1	30.5	29.9	29.4	28.9	28.4	27.9	27.5	27.1	26.7	26.3	25.9	25.5
57	62	30.8	30.2	29.6	29.1	28.6	28.1	27.6	27.1	26.7	26.2	25.8	25.4	25.1
58	63	30.5	29.9	29.3	28.8	28.2	27.7	27.2	26.7	26.3	25.8	25.4	25.0	24.6
59	64	30.2	29.6	29.0	28.5	27.9	27.4	26.9	26.4	25.9	25.4	25.0	24.6	24.2
60	65	30.0	29.4	28.8	28.2	27.6	27.1	26.5	26.0	25.5	25.1	24.6	24.2	23.8

Minimum Turn Radius: 24 ft.
 Dry Pavement Braking Distance
 at 60 MPH : 110 ft. 90 ft

3000 hrs

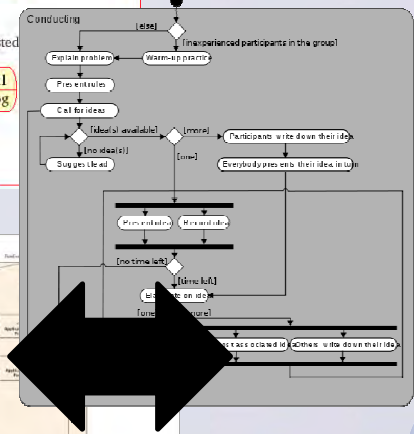
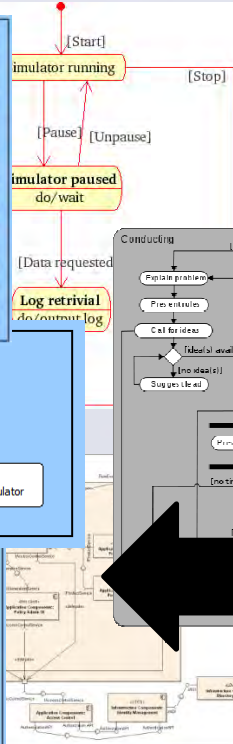
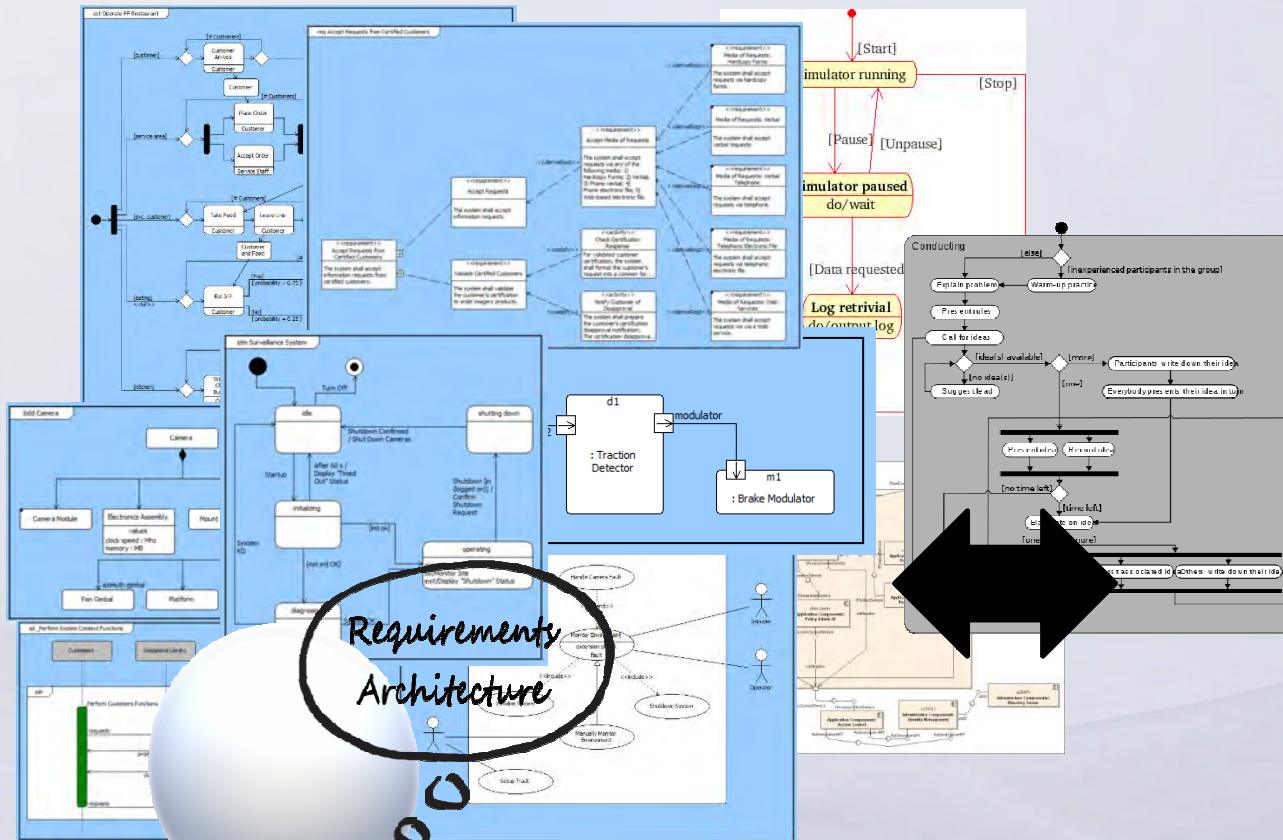
Solution Attempt #1: Adopt UML



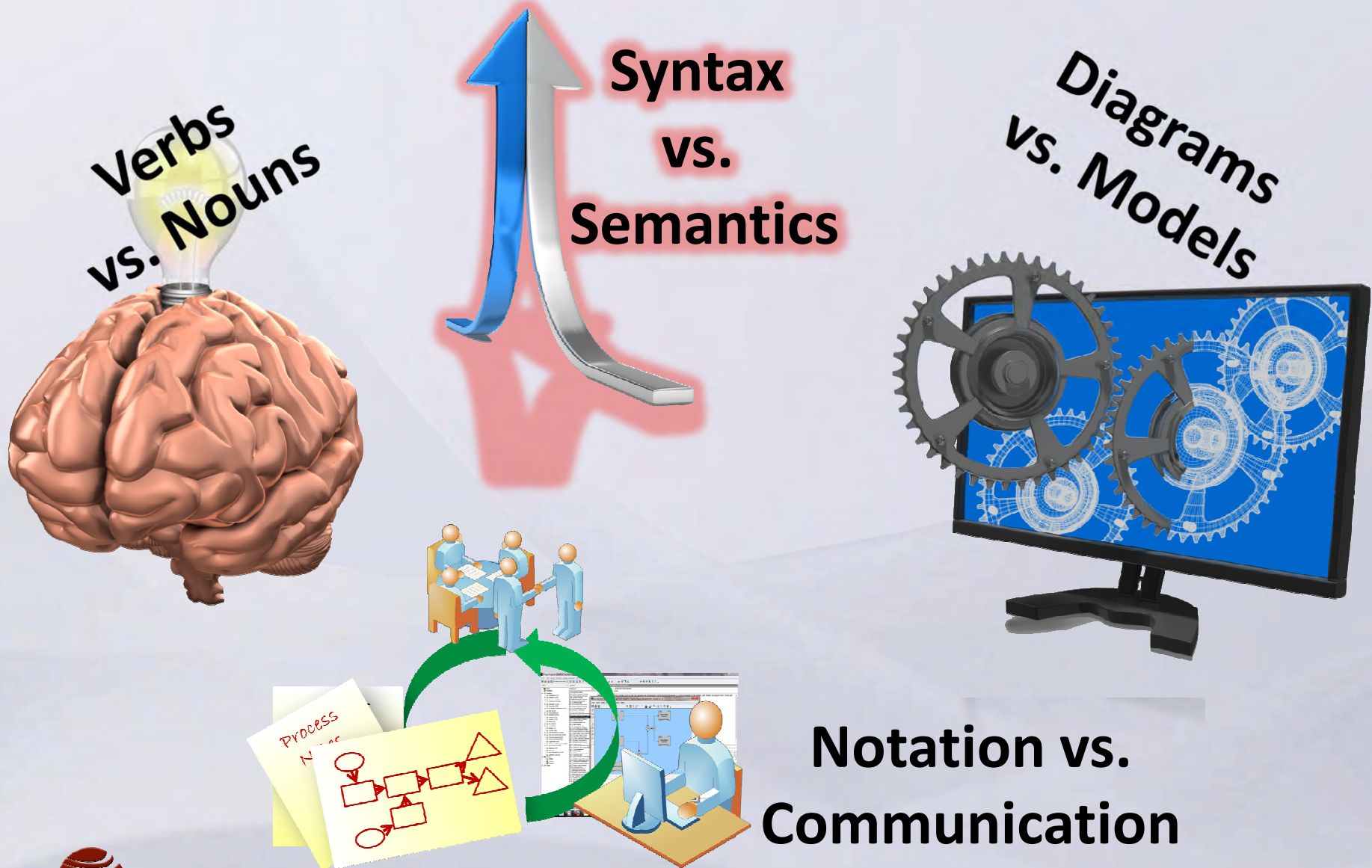
Requirements
Architecture



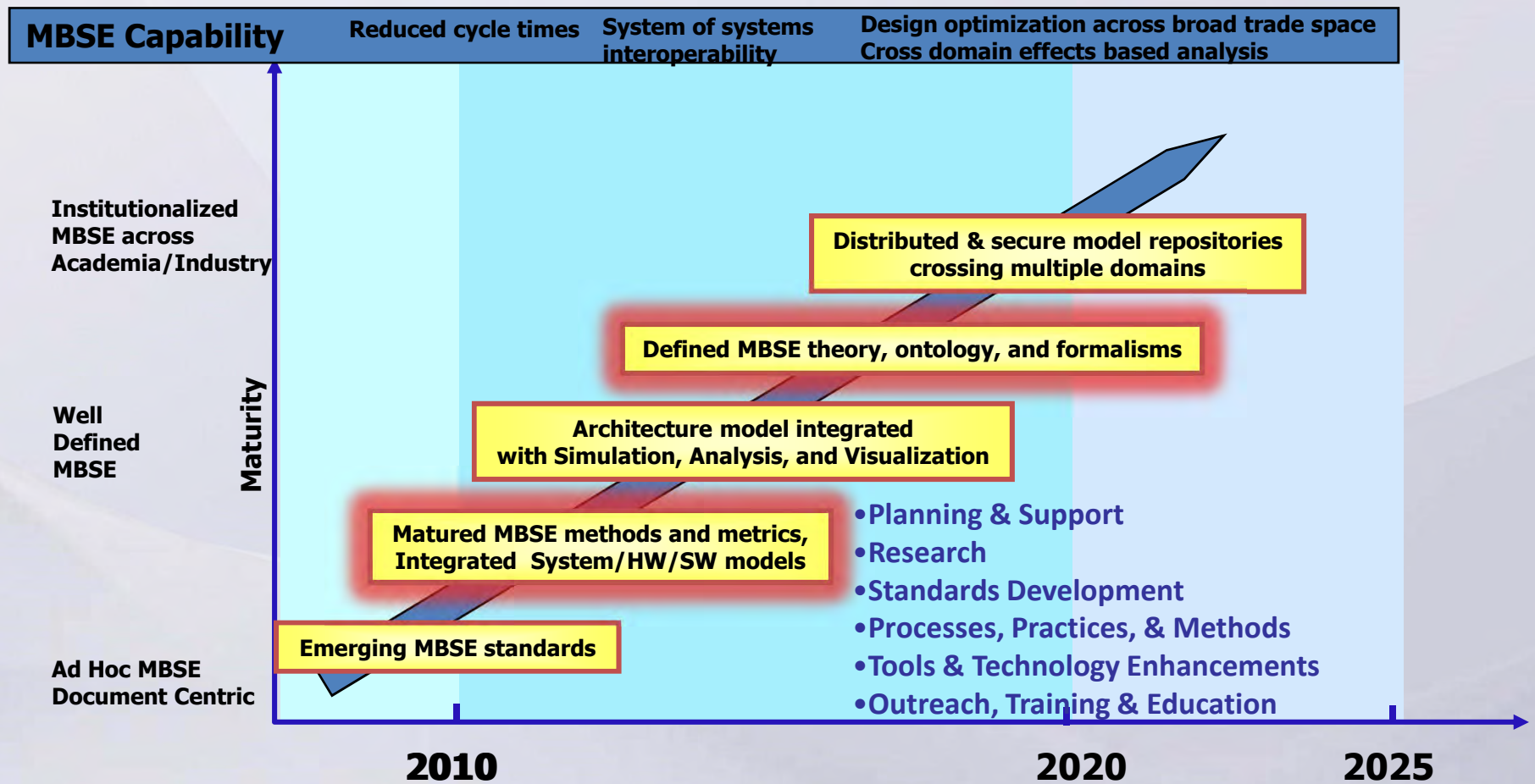
Solution Attempt #2: Leverage SysML



Four Fundamental Problems



A Disconnect in Our Roadmap

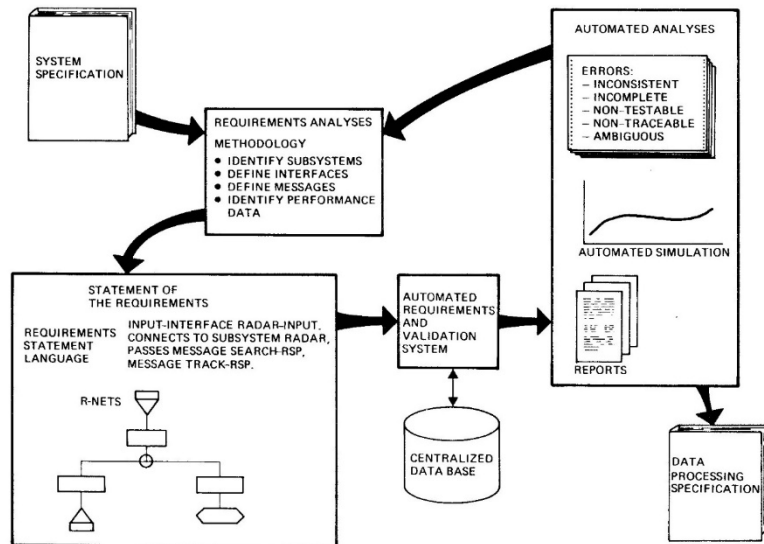


Reprinted from INCOSE MBSE Workshop, February 2010



Recalling History: SREM (early 1970s) and AP233 (early 2000s)

SREM: A TOTAL REQUIREMENTS ENGINEERING METHODOLOGY

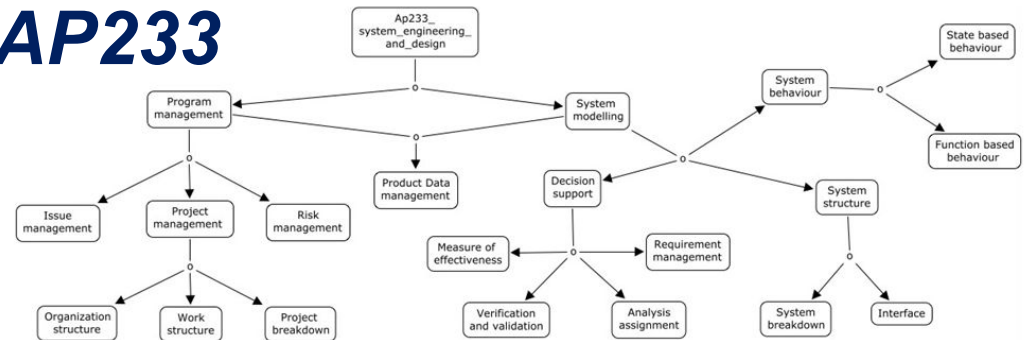


SREM automation features

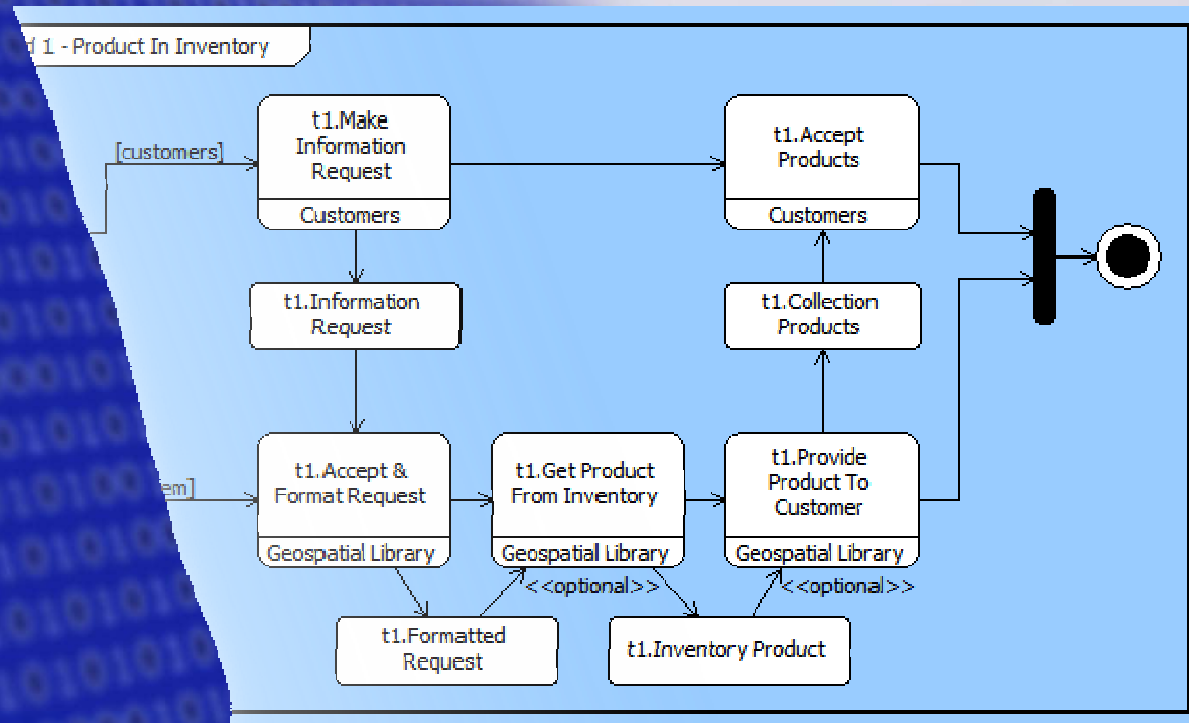
- Executable design language and repository
- Design methodology
- Report generator
- Graphics generator
- Automatic simulator

AP233 – exchanging information within systems engineering and across the engineering lifecycle

AP233

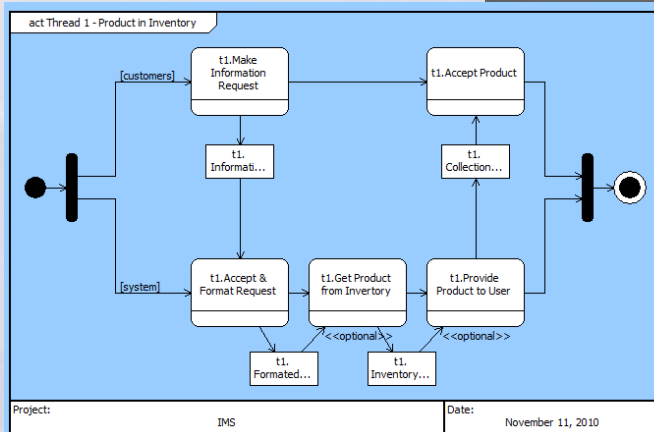


Differentiating Views and Models

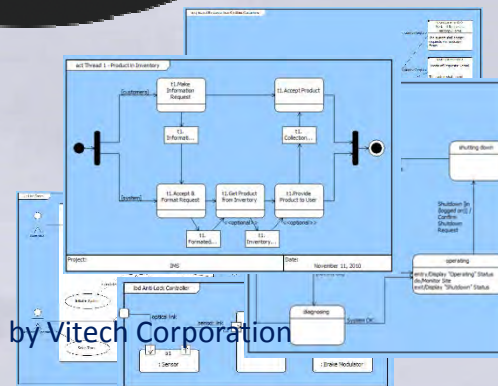


Views DO NOT Equal A Model

MODEL



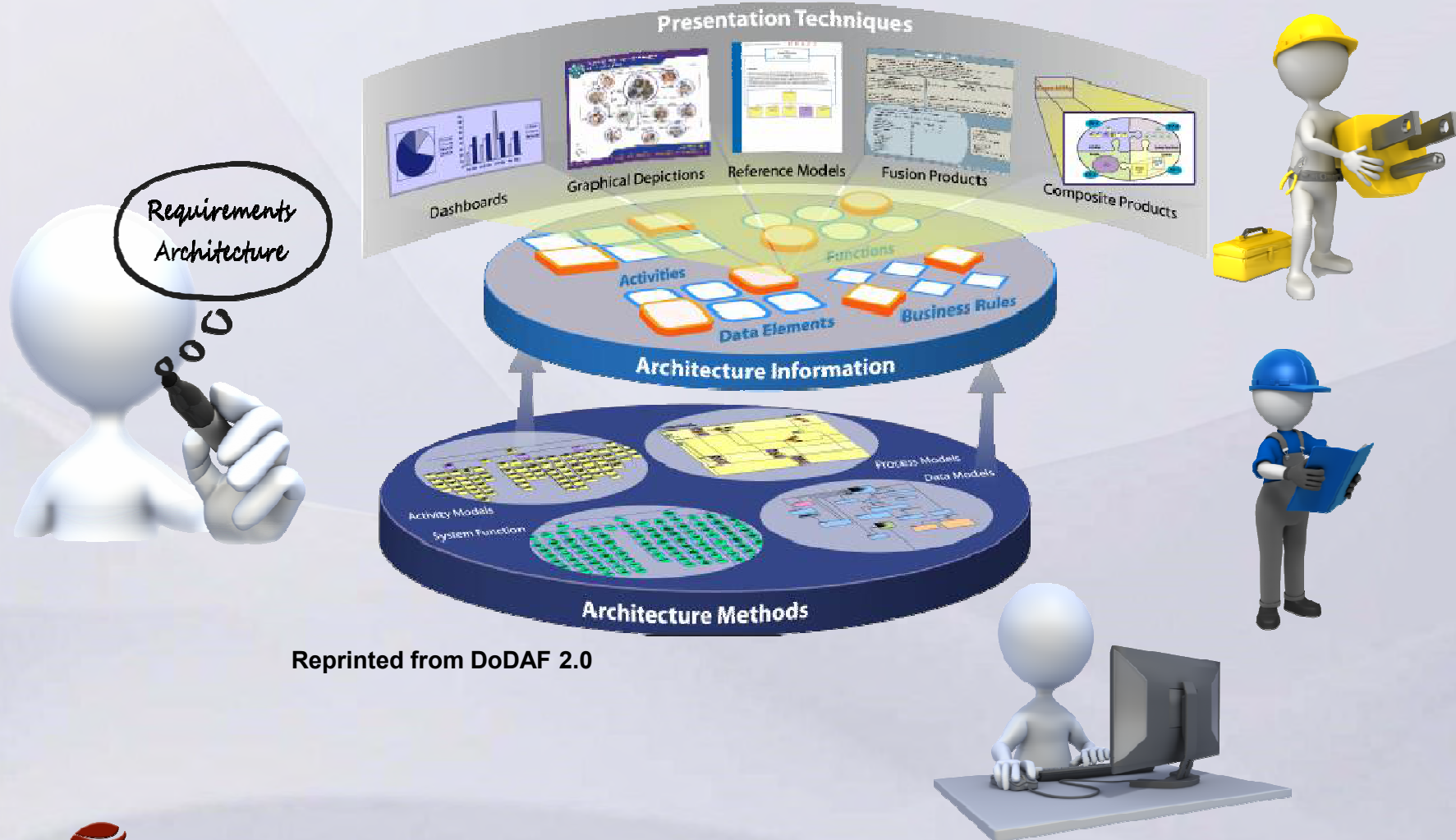
VIEW



≠



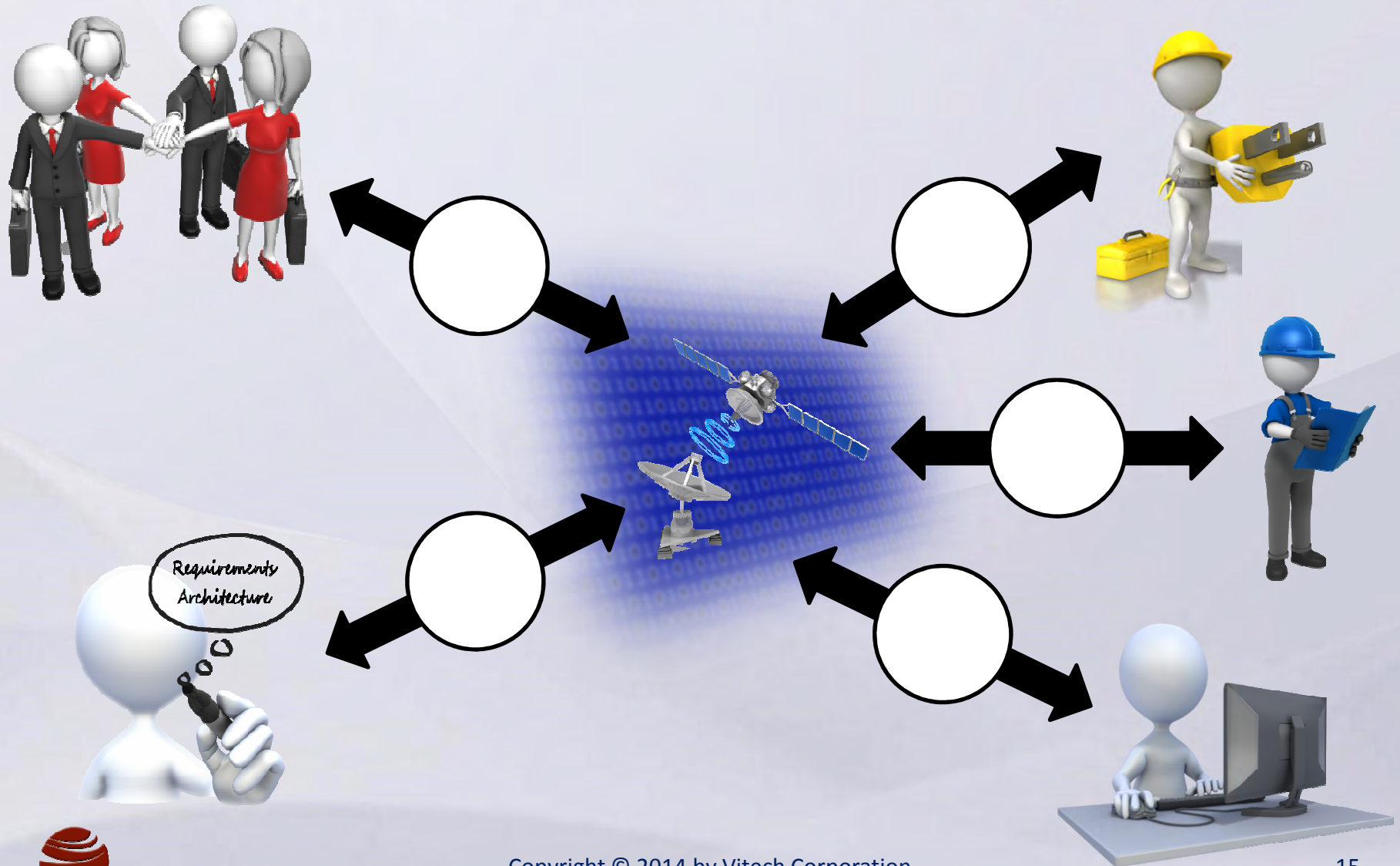
Fit-for-Purpose Tools, Techniques, and Representations



Reprinted from DoDAF 2.0



Communications & Connection Requires Semantics and Syntax



Begin with the End in Mind: Putting the Systems Thinking and Engineering Back into SE

Process Standards

Representation and Interchange

GEIA STANDARD
ANSI
INTERNATIONAL STANDARD
ISO/IEC 26702
IEEE Std 1220-2005
INTERNATIONAL STANDARD
CMMI 15288
CMMI[®] for Development, Version 1.2
CMMI-DEV, V1.2
OMG SYSTEMS MODELING LANGUAGE
Unified Profile for the Department of Defense Architecture Framework (DoDAF) & Ministry of Defence Architecture Framework (MoDAF)
Date: December 2007

AP233

Frameworks

modaf
The Ministry of Defence Architecture Framework

DoDAF V2.0

TOGAF™ Version 9

Treasury Enterprise Architecture Framework
July 2000 Version 1.0

FEA Consolidated Reference Model Document
Version 2.3
October 2007



Achieving Vision 2025: Architecting Systems to Address Multiple Stakeholder Viewpoints

Engineering
Views



Construction
Views



Science
Views



Maintenance
Views



Management-
Views



The European Extremely Large Telescope

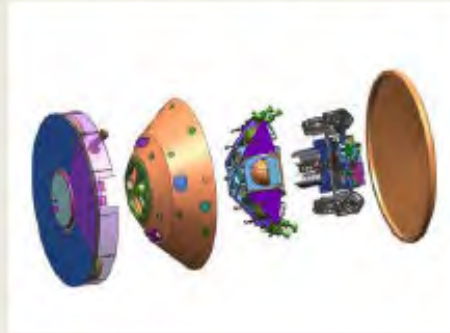
Courtesy of the European Southern Observatory.



Source: SE Vision 2025.
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Achieving Vision 2025: Adaptable and Scalable Methods

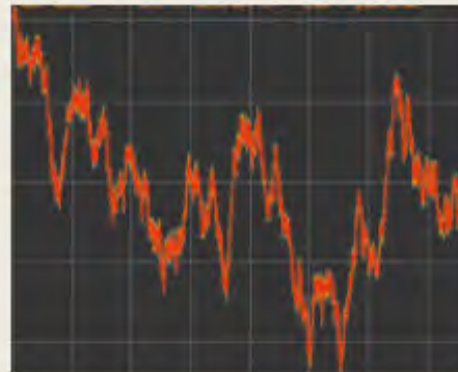
TAILORED TO THE DOMAIN



SCALED TO PROJECT SIZE



SCALED TO SYSTEM COMPLEXITY



Source: SE Vision 2025.
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Achieving Vision 2025: Leveraging Technology for Transformation

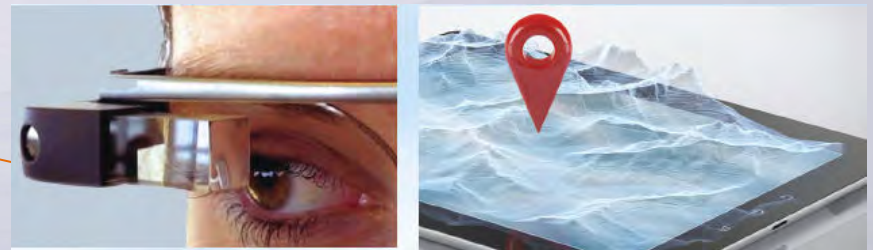
Cloud-based high performance computing support high fidelity system simulation



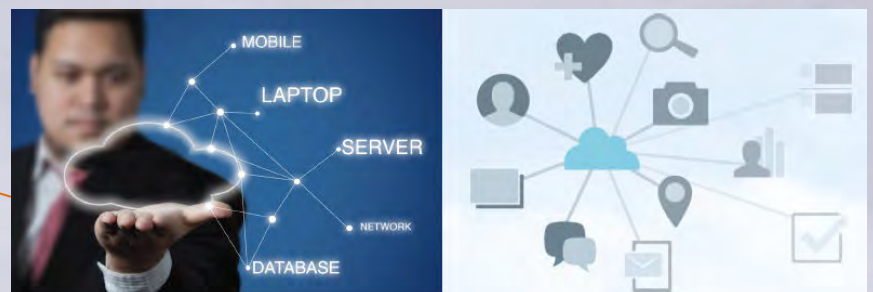
Advanced search query, and analytical methods support reasoning about systems



Immersive technologies support data visualization



Net-enabled tools support collaboration

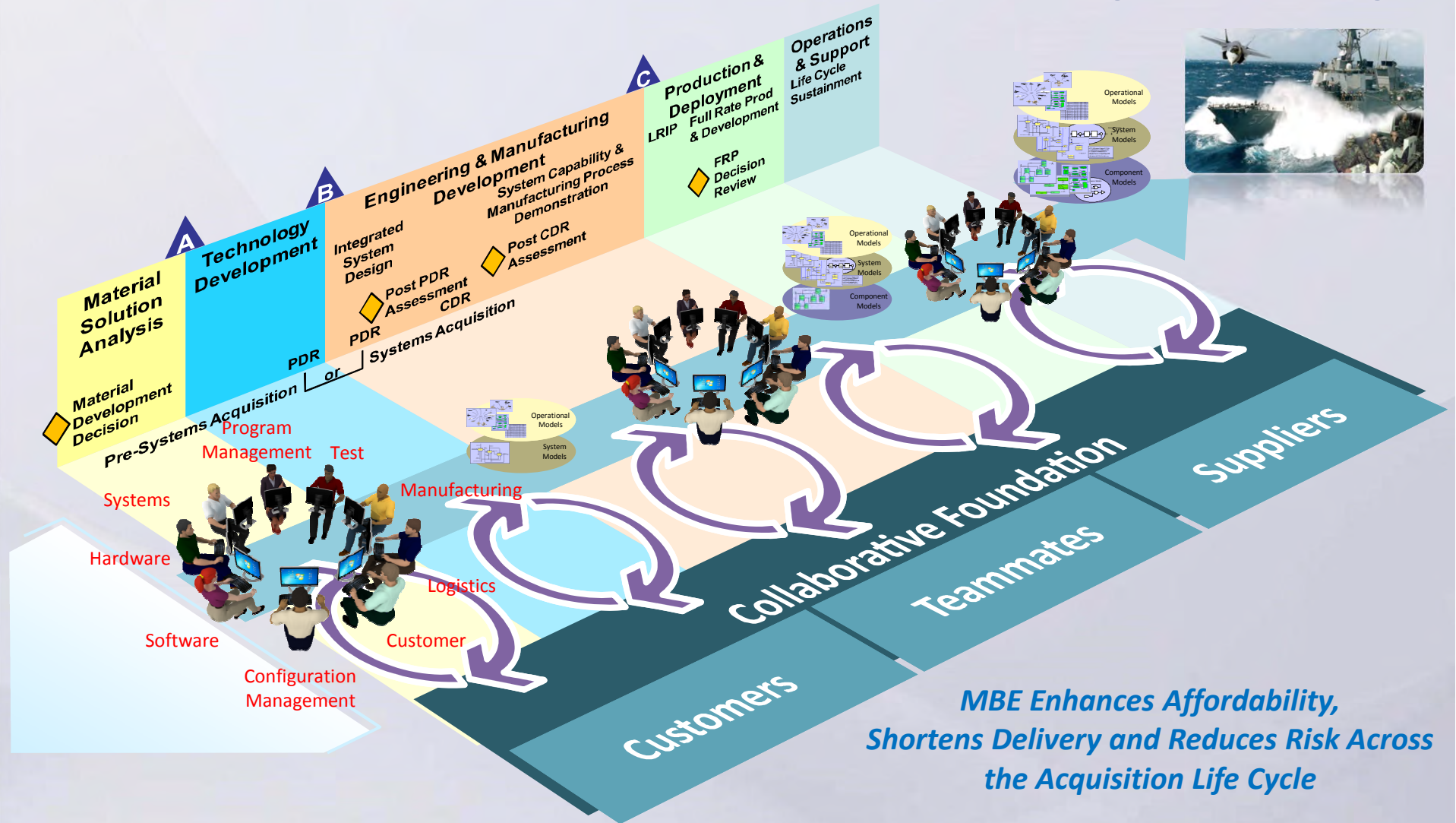


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Achieving Vision 2025: Transformation Requires a Community



To-Be State for Model-Based Engineering



NDIA Model-Based Engineering Final Report, February 2011



MBSE: The Path to the Future



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