



Engineering, Operations & Technology
Information Technology

A Hitch-hikers Guide to:
**Knowledge Based Engineering in Aerospace
(& other Industries)**

Do not Panic!!

Definition, History, Value, Technology, and Resources

Presented to: INCOSE NM Enchantment Chapter, March 9, 2011
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Knowledge Based Engineering in Aerospace (& other industries)

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Engineering Systems Domain Architecture

Goal:

Understanding, Awareness of Potential

Approach:

- Emphasis on Business Value and Implementation Issues
- Attempt to limit jargon, but emphasize System Lifecycle and SE terminology wherever possible.
- Target Audience: Practicing specialty engineers; SE's; IT; Technical project management.
- Take-aways: Basic understanding, Resources for further Investigation.

Knowledge Based Engineering (KBE)

Topical Outline:

- **Business Context: Business & Lifecycle Drivers**
"What problem are we trying to address??"
- **Definition & Value**
"What is this KBE thing ... exactly (more or less)"
- **Application in Industry**
"Not new, 25+ years and counting"
- **KBE Technology Evolution Roadmap**
"Multiple viable COTS vendors out there to be leveraged"
- **Current KBE Strategies & Challenges**
"Leveraging KBE and Challenges in doing so"
- **KBE and SE, KM, Process Automation, Standards**
"Where is KBE is headed...."
- **Summary & Resources**

KBE and Systems Engineering (SE): Current Challenges to SE Value

Situation: SE's Changing Universe: Increasing Complexity & Velocity:

- **Increasing Complexity: Creation of SoS from already complex Existing Systems;**
- **Rapid Disruptive Change: Technology, Requirements, Configuration Change faster than process for creating system and responding to changes;**
- **Business Value of SE (From: INCOSE/Eric Honour):**
 - SE has value, but does not contribute to Technical System value/merit;**
- **SE value across Defense, Infrastructure, & Industrial Systems is increasing:**
 - > **Greatly increased intensity and speed of interaction between and among systems;**
- **New and powerful System description, analysis, and synthesis tools:**
 - > **UML2.x, SysML1.x, AP233, AP239, Lattix, Rhapsody, MML, KBE System Design Languages, Process Description/ Execution languages (BPML...);**

Target: Leverage KBE to allow rapid JIT System design synthesis and design artifact creation:

- **Change the system dynamics - incorporate changes and generate designs rapidly, keep pace with change rate.**

Knowledge Based Engineering (KBE) - In a Nutshell.....

What is KBE?

Engineering / Product Development Lifecycle Perspective:

- Capture, formalization, automation, and reuse of complex design processes and associated rules that are CAD-system independent and re-usable over decades.
- Engineering development of applications and integration scripts using IT guidance and infrastructure.

Technology Development / Support Perspective:

- Acquisition & Integration of KBE COTS Technology.
- Integration infrastructure development for CAD, CAM, CAE, PLM, & Enterprise Resource Planning systems.
- Leverage of Knowledge Management Products and Services.
- Engagement with Engineering & Global Partners in terms of application creation, compliance, and integration.

What does KBE do??

... captures the knowledge of aircraft development and applies that to produce specific aircraft configuration.

Ex: Aircraft development

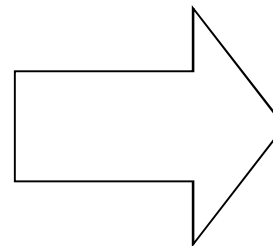
KNOWLEDGE

Embedded within KBE

**Generative KBE
Product Models –
Fuselage, Wing,
Stringer, Skin, Ribs etc.**

Design intent, geometrical
knowledge, explicit rules,
thumb rules, reasoning
methods and expert
heuristics, design decision
criteria, optimization
considerations

**ICAD, Stringer Application,
Skin Application etc.**



**Re-generate
the data in
any CAD /
PLM
System**

DATA

Expressed within CAD
/ PDM / PLM Systems

Specific Design Data

**3-D Geometric
models**

FEA Models

Detail Drawings;

Bill of Materials.

**Manufacturing
instructions.**

Product Definition

**CATIA v5, Unigraphics,
ProE, AutoCAD, etc.**

So What Does a KBE Application Look Like?

Example Notional Code (Loosely based on ICAD Design Language (IDL) family that includes ICAD, Intent, AML, & KnowledgeFusion)

Integrated-Airplane-Fuselage-Monocoque

:Attributes

(:weight....
:mfg-cost)

:Inputs

(:Stress-tables ...
:Gauges...
:Material-properties...)

: Rules:

(:Derive-allowable-rivet-margin (.....))
:Calculate-frame-hoop-stress (....) ...)

:Parts

(:Stringers (...)
:Frames (...)
:Shear-ties (...)
:Skin-Panels (...)
:System-transport-elements (...))

:Input-reader

(:Stress-table-reader (...)
:Outer-mold-line-geometry (...)
:Stringer-centerlines (...))

:Output-writer

(:Stringer-CAD (...)
:Frames-CAD (...)
:Shear-tie-CAD (...)
:Skin-Panels-CAD (...)
:System-transport-elements-CAD (...)
:Stringer-MFG (...))

What Does KBE do for Product Development?

KBE helps programs reach their Productivity & Agility Goals

Increased NRE productivity:

- Effective way of automating engineering design processes with a high degree of reuse
- 20 years of success on multiple Programs

Reduced design cycle:

- Product Development (Conceptual, Preliminary Design)
- Detailed Design (Structures, Tooling, Systems)

Reuse of Automated Design Processes with Global Partners

Increased Quality

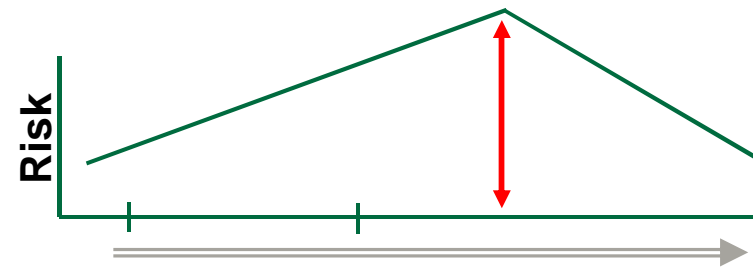
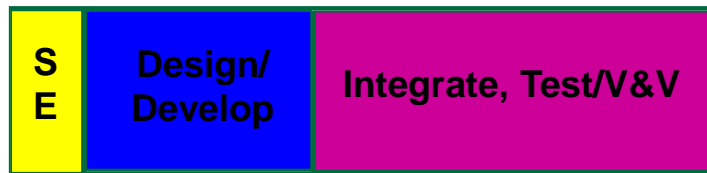
Return on investment

Value of SE & KBE JIT System Synthesis

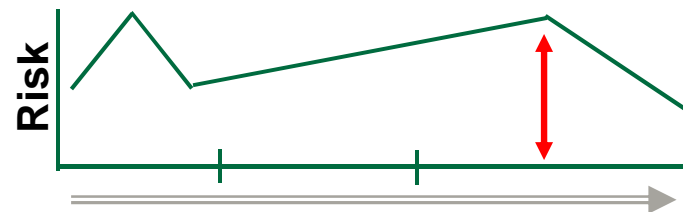
Relative Effort, Time, & Risk to System Realization

(Inspiration & Thanks to: E. Honour, INCOSE)

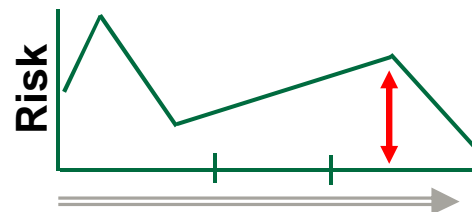
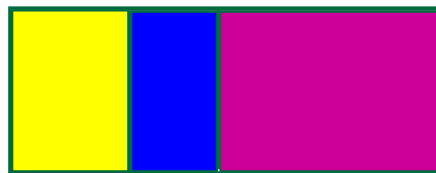
Case 1: Suboptimal SE, no KBE



Case 2: Optimal SE, no KBE



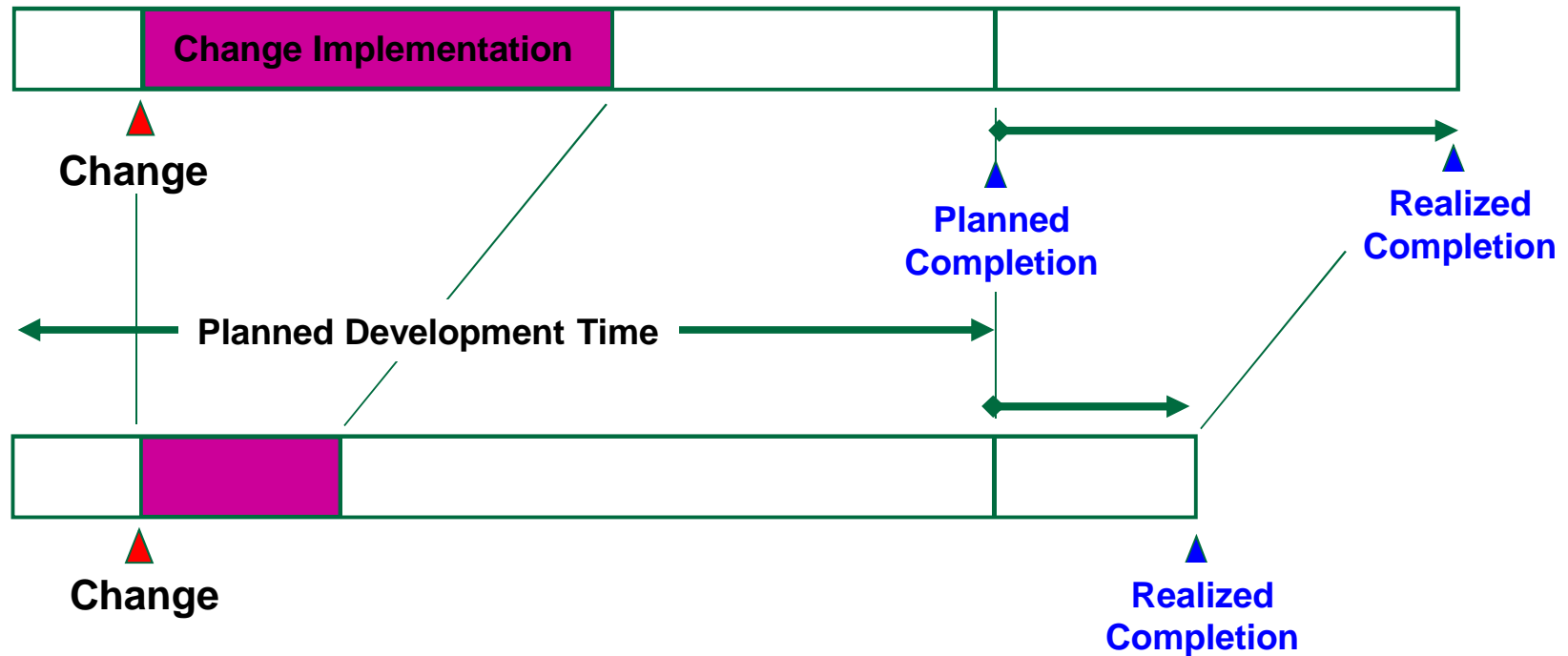
Case 3: Optimal SE, KBE Implemented



KBE JIT System Synthesis - Impact on Design Flow Time/Risk

Notional, Assume Critical Path Impacts

Case 1: No KBE Generative Design Capability



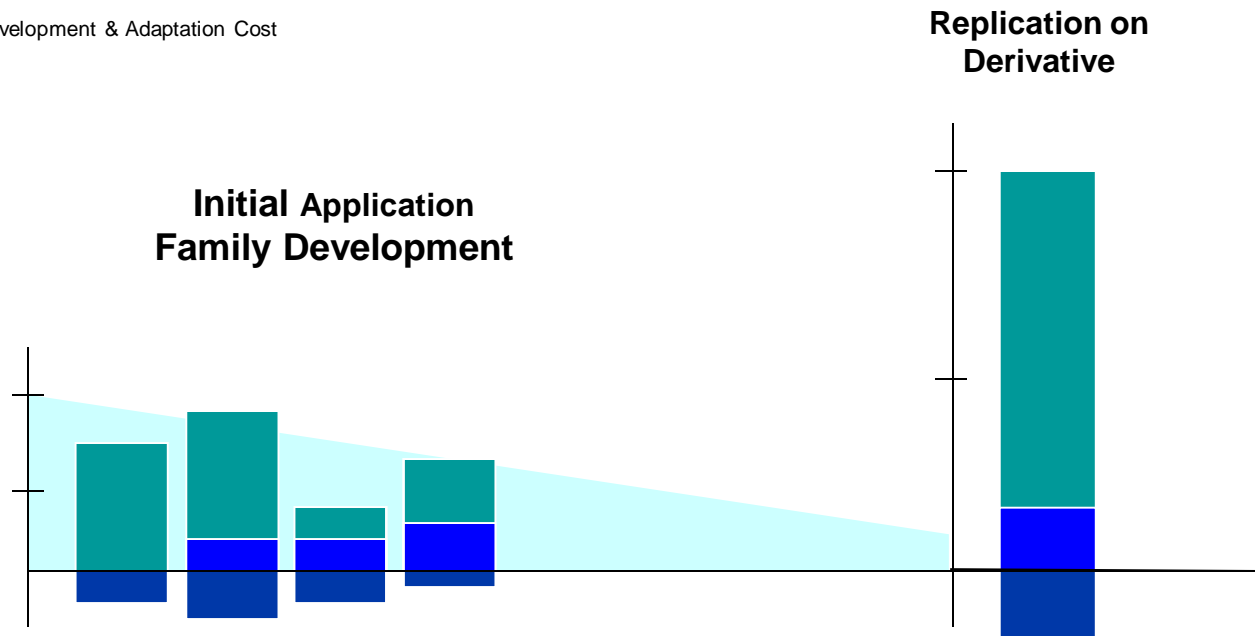
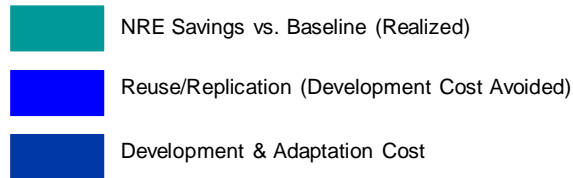
Case 2: With KBE Generative Design Capability

KBE Value (Detailed Design) Reuse & Replication over Life of Program

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KBE Application Development, Re-use, and Efficiency Costs (Notional)

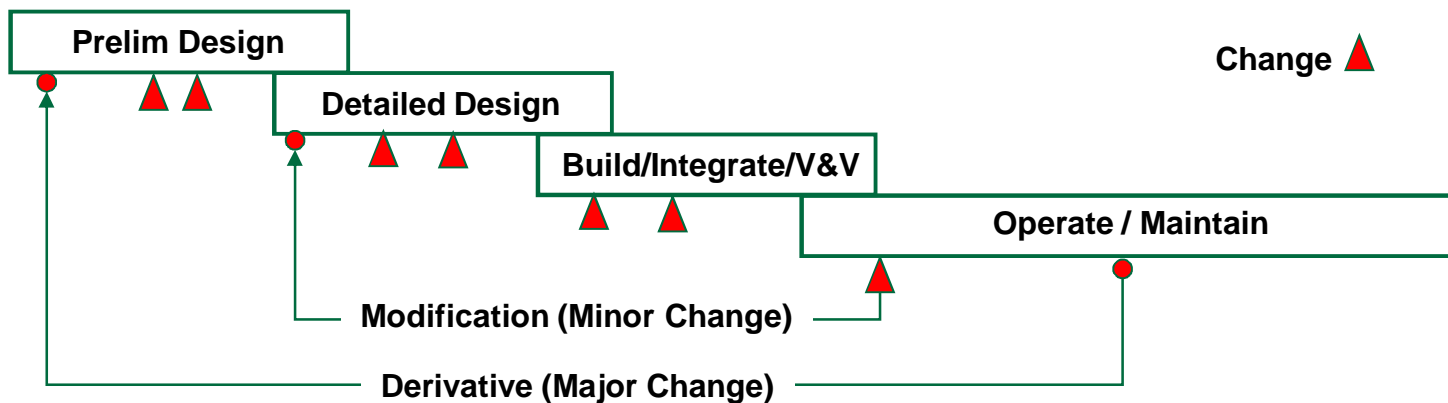


KBE Application in Industry - Historical Overview

Time Interval	KBE Usage in Industry
1980 - 1985	Exploratory Usage: <ul style="list-style-type: none"> - Sail & Complex Airfoil Design - Jet Engine Design
1985 - 1990	Initial Adoption: <ul style="list-style-type: none"> - Aerospace: Integrated Conceptual/Preliminary Design, Fuselage Structures Detailed Design, Engines - A&E: Rapid Design: HVAC System, Cooling Towers, Bridges - Automotive: Concept Car Spatial Integration - Specialty Engineering: Pump, Turbine, Valve
1990 - 2000	Global Adoption: <ul style="list-style-type: none"> - Aerospace: Fuselage, Wing Structures Detailed Design, Systems-Structure Integration, Design Recovery - Automotive: Drive Train Configuration, Platform-Component Integration, Tooling Design - A&E: Building Structure, Systems, HVAC; Chemical Plant Design
2000 - 2010	Absorption by CAD/CAM Vendors: <ul style="list-style-type: none"> - Specialization into CAD Vendor Markets: Aerospace, Automotive, A&E - Expansion into Asian / Global Supplier & Design Chains - Leveling off of usage growth in Aerospace & Automotive
2010-->	??Development of Standards Based KBE Capabilities??

KBE Usage in Industry: Lifecycle / Value Illustration

Aerospace: Complex, Long-lived Products with multiple Derivatives and Modifications over Decades

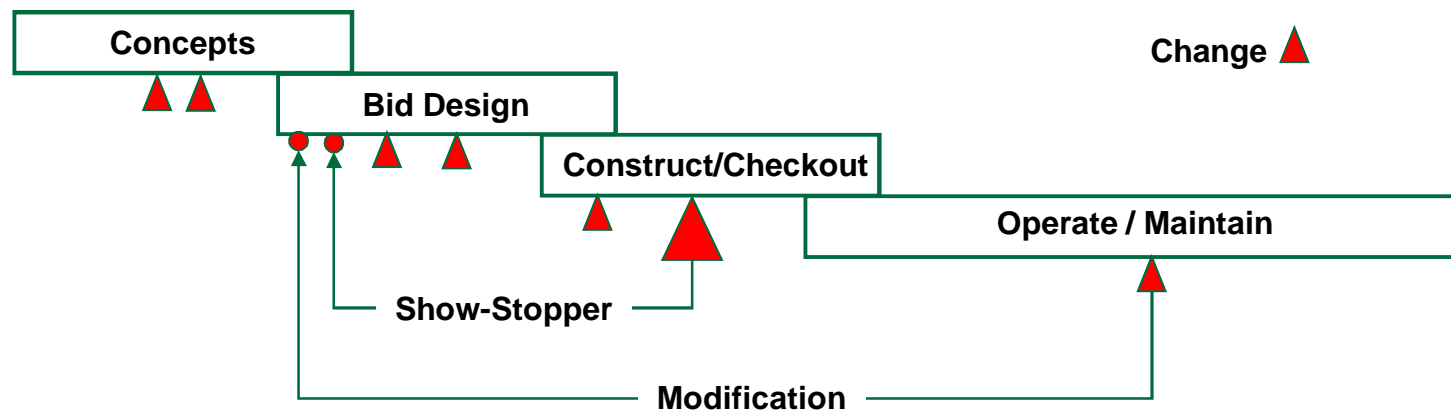


Value:

- Across Lifecycle: As-Late-As-Possible (ALAP) generation of complete and correct set of design artifacts (geometry, drawings, BOM...)
- **Conceptual/Preliminary Design: Effective integration of multiple specialty design disciplines and models in correct configuration.**
- **Detailed Design: ALAP generation of complete designs, rapid response to changes (with limits to be discussed).**
- **Build/Integrate/V&V: ALAP creation of build plans, tooling definition...**

KBE Usage in Industry: Lifecycle / Value Illustration

A&E: Unique, Long-lived Products using standard components with Upgrade/Modification Aftermarket



Value:

- **Across Lifecycle: As-Late-As-Possible (ALAP) generation of complete and correct set of design artifacts (geometry, drawings, BOM...)**
- **Concept Design: Effective integration of multiple specialty design disciplines and models in correct configuration.**
- **Bid Design: Rapid ALAP generation of complete, correct designs, rapid response to changes (within limits to be discussed).**
- **Construction/Checkout: ALAP creation/update of build plans, BOM, schedules; Rapid-redesign due to mid-project "show-stoppers"**

Challenges to Successful KBE Application in Industry

Challenges to KBE ROI:

- **KBE Generative Design / Downstream Design Change
(the "Re-Attachment" challenge)**
- **COTS KBE Vendor Viability: IT Industry Business Model Issues**
- **Factors Impacting Long-term ROI of KBE**
 - > **Managing Continuous CAD/CAM/CAE/PLM Technology
and Vendor Evolution**
 - > **Long-term Re-use of KBE Applications & Engineering
Knowledge Capture**

KBE Generative Design / Downstream Design Change Challenge

The 80/20 Rule applies to KBE:

KBE can Generate Design artifacts, but there are always post-generation changes (generally new features) added before final design completion.

The Problem:

If global constraints change, KBE re-generation is required - this causes the manual/interactive downstream changes to parts/assemblies to be lost.

The Challenge:

How to minimize NVA re-work in re-attaching those downstream additions/changes:

- Institute CAD model construction and config. mgmt. standards to allow scripted re-attachment;**

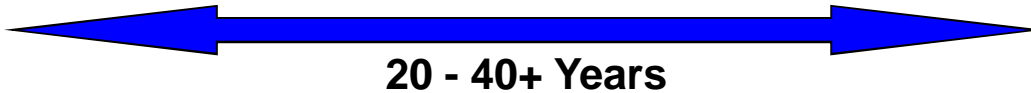
and

- Leverage the "Adoption" feature of latest KBE tools.**

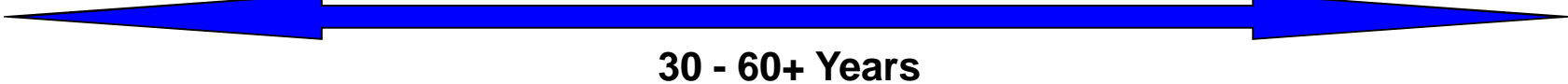
Challenge: Sustainable Product Definition in Digital Authority Future

Example: Commercial Jet Transport Model

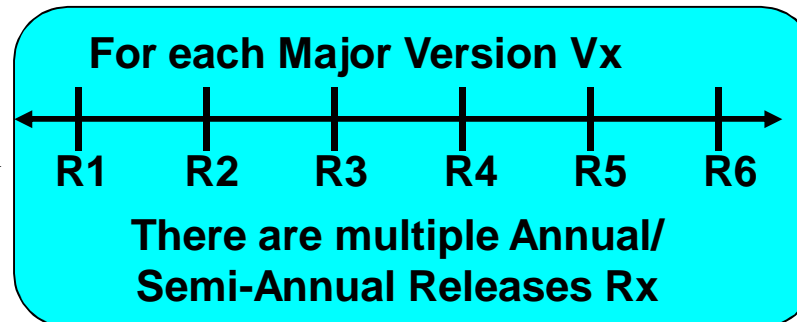
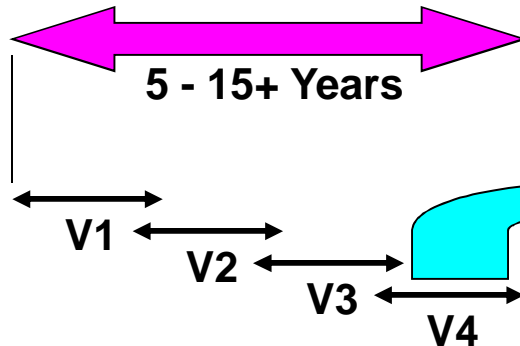
Design & Production (including Derivatives)



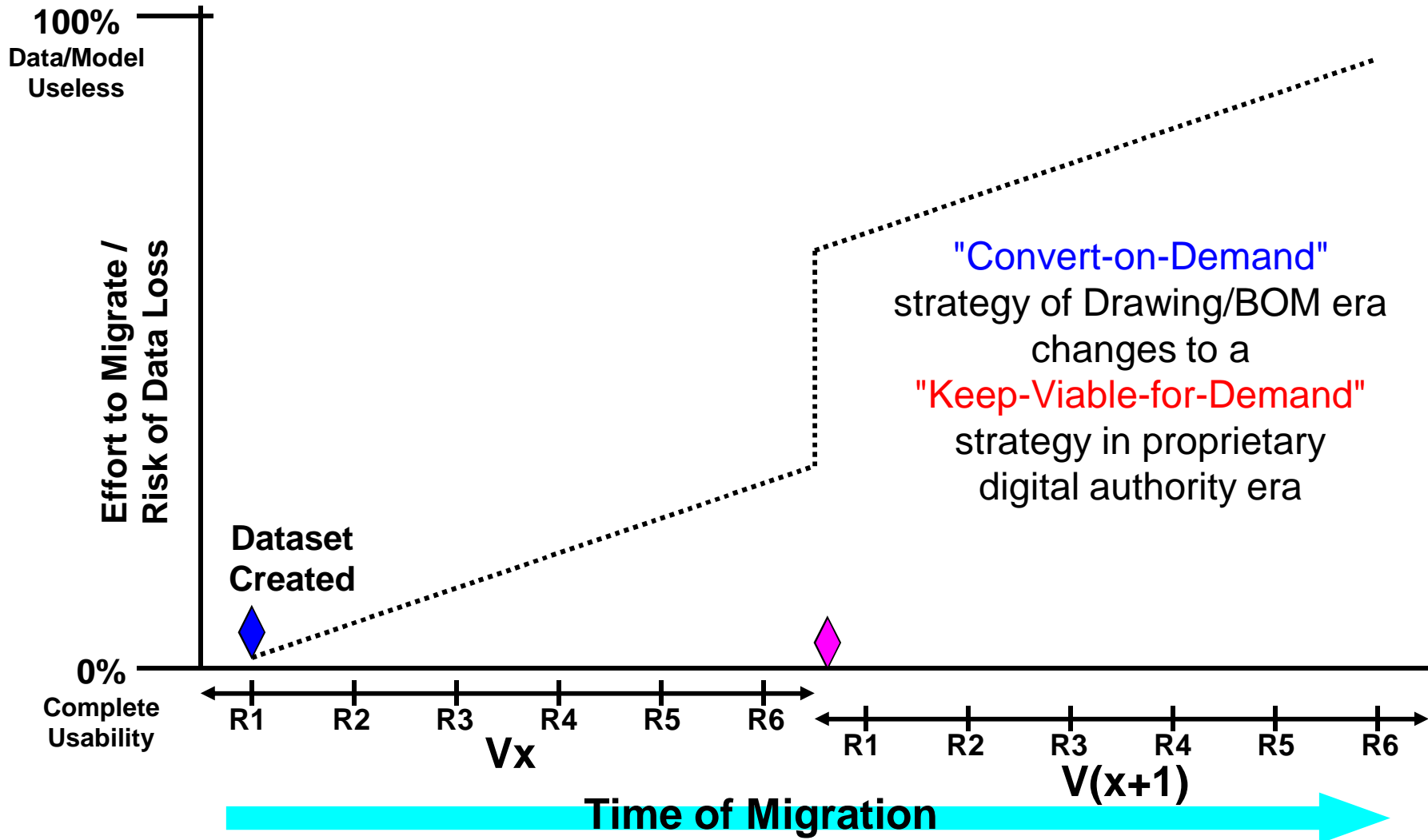
In-service Support



COTS CAD/CAM/CAE/PDM Vendor/Technology



Proprietary Product Definition Degradation Curve

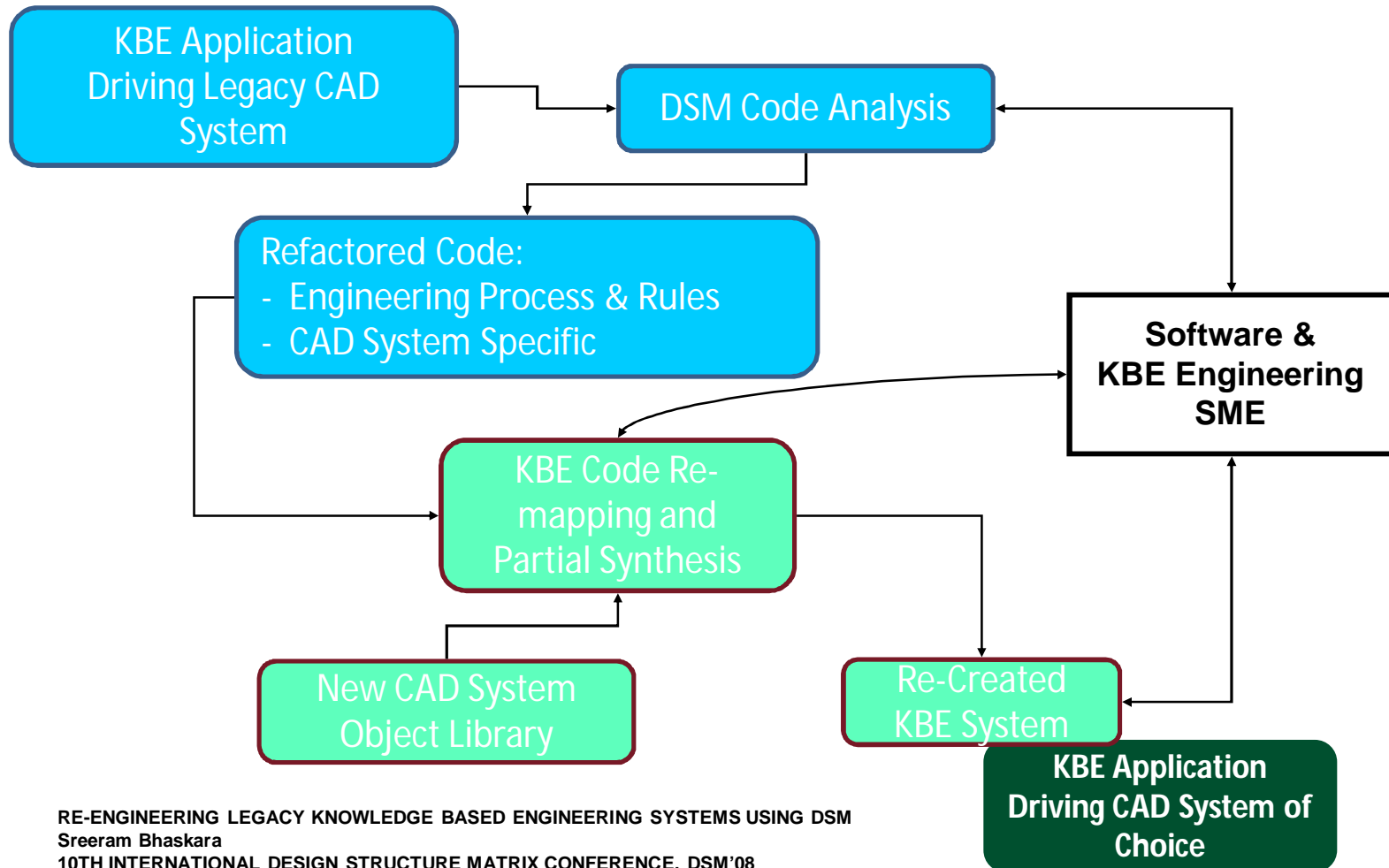


Long-term Viability of KBE Applications & Engineering Knowledge - KBE Application Migration

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Migration of Legacy KBE Applications to work with New CAD Systems



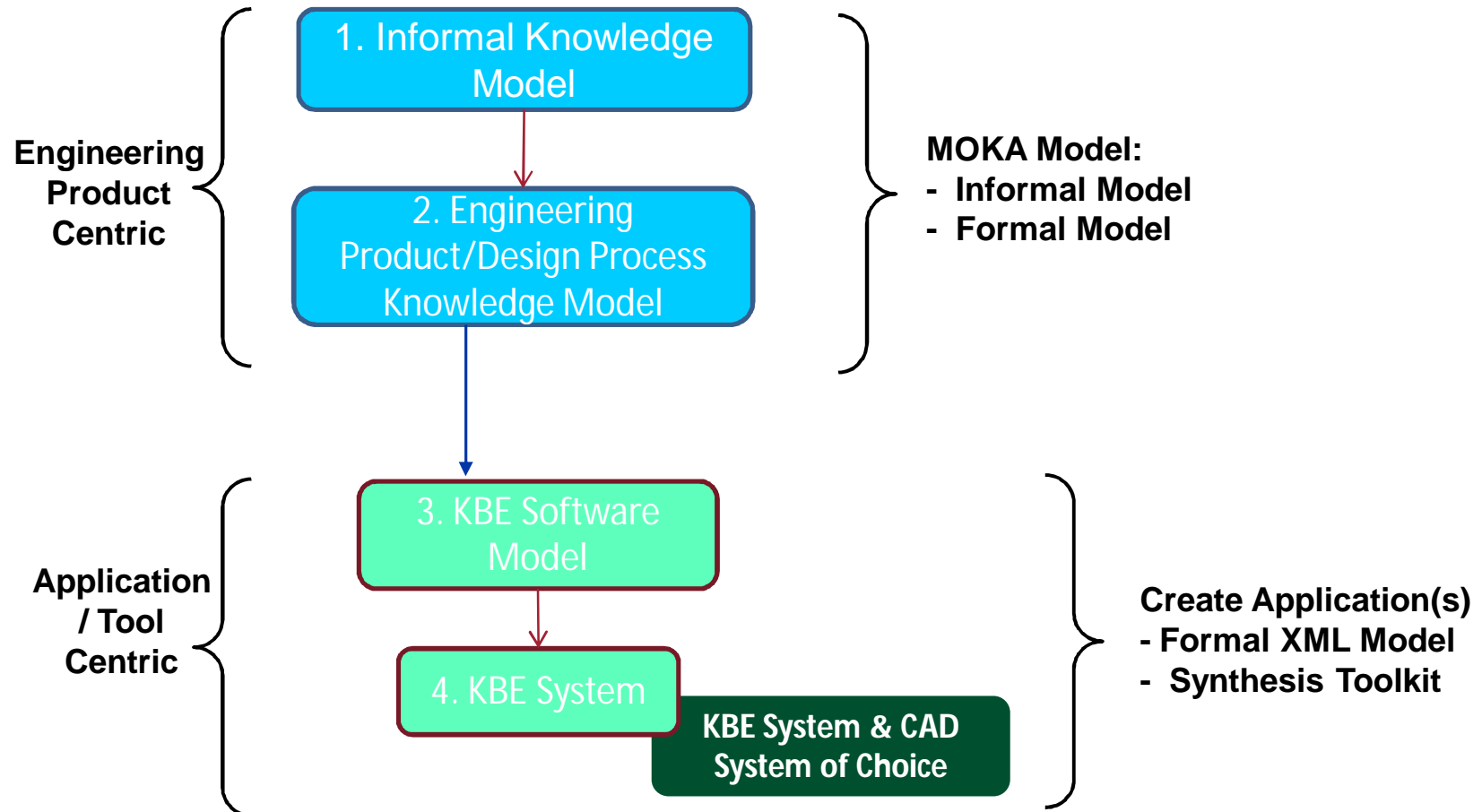
RE-ENGINEERING LEGACY KNOWLEDGE BASED ENGINEERING SYSTEMS USING DSM
Sreeram Bhaskara
10TH INTERNATIONAL DESIGN STRUCTURE MATRIX CONFERENCE, DSM'08
11 – 12 NOVEMBER 2008, STOCKHOLM, SWEDEN

Long-term Viability of KBE Applications & Engineering Knowledge: Process Knowledge Capture

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Or, How to Capture, Automate, and Re-use Engineering Process and Design Knowledge using MOKA Modeling Language



The Future of KBE

KBE is just getting started:

- **A useful and powerful tool in the SE toolkit, specially in the early lifecycle stages;**
- **Maturing vendor-neutral Digital Design Standards (STEP), XML, and UML supports increased KBE application re-use and ROI;**
- **Capture of Design Intent and Process via MML, SysML, and BPML enables creation of formal, executable design processes;**
- **Use of Software Analysis, Restructure, and Migration tools / techniques, along with UML/XML increases long-term re-use and lowers long-term maintenance costs for KBE applications as CAD/CAM/CAE/PLM tools evolve;**
- **As STEP/XML capabilities and toolsets mature, Open Source CAD and Open Source KBE systems become viable.**

Getting Started: References and Resources

Genworks International

<http://www.genworks.com/sessions/23fd0e2e018/index.html>

Siemens NX/KnowledgeFusion

http://www.plm.automation.siemens.com/en_in/products/nx/prog_custom/kbp.shtml

TechnoSoft:

<http://www.technosoft.com/>

Bentley:

<http://www.bentley.com/en-US/>

AutoDesk Intent:

<http://usa.autodesk.com/adsk/servlet/pc/index?id=8057864&siteID=123112>

MOKA Modeling Language:

<http://academic.research.microsoft.com/Paper/5084825.aspx>

<http://web1-eng.coventry.ac.uk/moka/Documents/Papers/ekaw2000.pdf>

SysML:

<http://www.omgsysml.org/>

Lattix DSM Tool (For both Engineering and Software DSM Analysis):

<http://www.lattix.com/>

Rhapsody (Common tool for system synthesis from formal model):

<http://www-01.ibm.com/software/awdtools/rhapsody/>

Engineering workflow tool: Modelcenter

http://www.phoenix-int.com/software/phx_modelcenter.php

Engineer's Knowledge Management toolkit with MOKA and CommonKADS:

Nigel Shadbolt's toolkit "PCPACK"

<http://www.epistemics.co.uk/Notes/207-0-0.htm>