Re-Use Libraries: Leveraging MBSE to greatly increase engineering productivity

Warren B. Smith
wsmith@vitechcorp.com
wsmith@wrayn.com
(480) 560-2655 (cell)

http://www.is2014proceedings.com/download.php?id=paper_92

Why Re-Use Design?

- Over time, re-use promises reduced development time & cost
- Provides a technological advantage over competitors
- Reduces risk
- Design represents a significant cost investment

Product Designs are an Organizational Asset

Savings from Re-Using System & Subsystem Design

- **Design Re-Use…**

  …reduces specification and implementation time and cost for those subsystems by 71.5%.

INCOSE
International Council on Systems Engineering

What is "Re-Use"?

- This term means different things to different people
  - *Clarify the definition today*
- Transfer of product designs across projects and product variants within a company
  - Leverage mature system designs over-and-over again in product lines, similar systems or variants
  - Accommodate variations in design or application
- Transfer of common design information from one project to another or between product variants, for instance:
  - Use or application
  - Requirements
  - Behavior
  - Test descriptions

INCOSE
International Council on Systems Engineering

How is this often done today?

2012

2015

Where did the re-usable content reside?

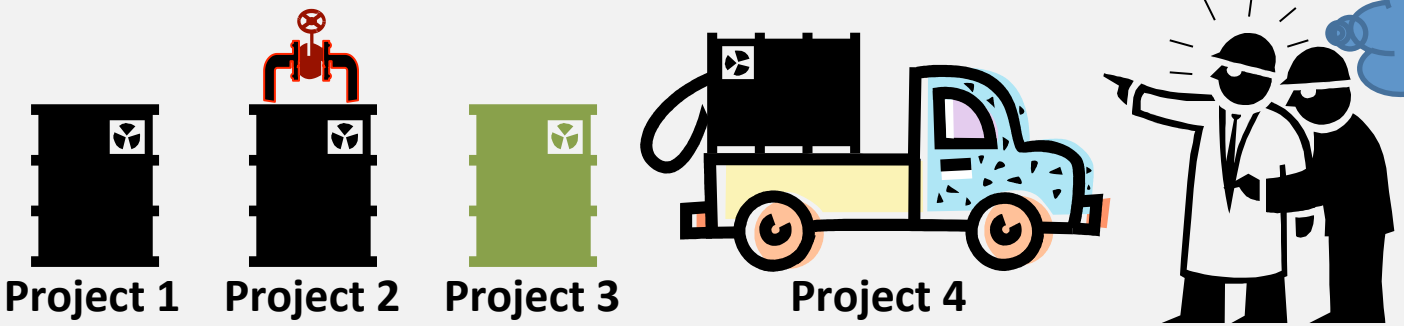
- Engineer knows where data resides
- Engineer knows how to read data
- Engineer can find "golden nuggets"

- Engineer's brain:
  - Incorporates experience informing future decisions
  - Acts as a body of knowledge
  - Acts as a search engine
  - Acts as a repository of implications and rationale

Risks of today's approach: Spending the same money twice

- Risk of lost or incomplete documentation

- Risk based on limitation of Engineer's time



- Risk of Engineer "moving on"….

Characteristics of a Re-Use Library

- A Re-use library transforms individual product knowledge into organizational knowledge
  - Corporate or Organizational Asset
- A Re-use library contains design information common to the organization's products
- Information in a Re-use library is organized in accessible elements.
  - Contains technical description of the re-usable elements
- Information is enabled by model-based systems engineering
  - Performing engineering from re-usable elements an/or
  - Platform for retaining re-use library
  - Design repository or product data management system.
- Searchable

INCOSE
International Council on Systems Engineering

Exploring the relationship with MBSE

Manual System Design:

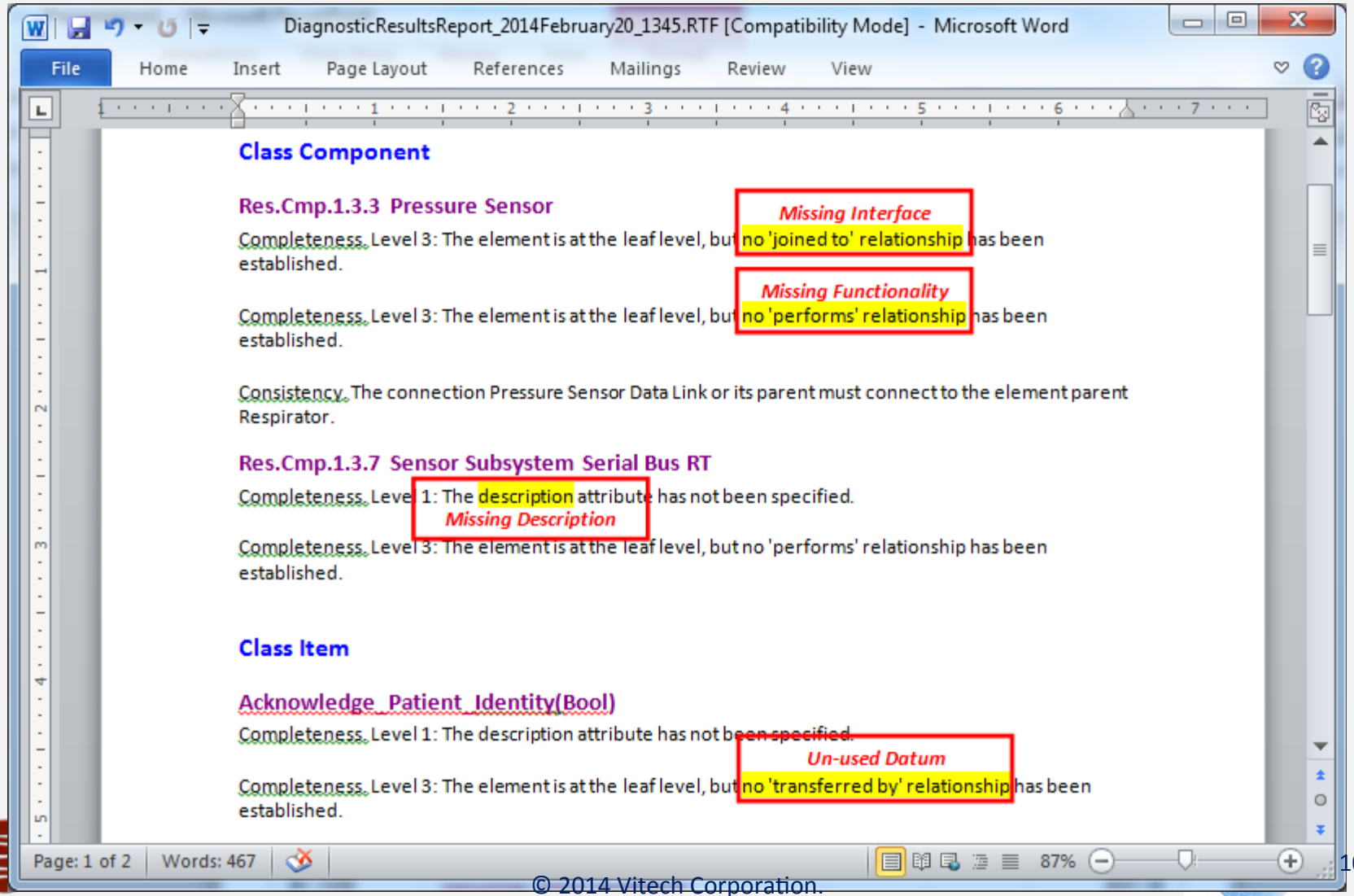
- Drawing or document-based tools
  - Hundreds of pages
  - Inconsistencies
  - Incomplete
  - Limited access concurrency
- Manually documenting complex systems is arguably impossible
  - Too many interrelated design aspects
  - Change management
  - Incomplete technical description
  - Finding and accessing critical information is difficult beyond patience

Model-based System Design:

- Model-centric tools
  - Auto-Generating documents and drawings from the model
  - Inconsistency identifier
  - Design completeness checks
  - Concurrent, shared access by the team
- Automating complexity management
  - "Technical booking" of interrelated design aspects
  - Ensures changes to *any* part of the system design is traced to *all* parts of the design
  - Finds and reports design omissions
  - Ability to find data

MBSE enables a once-in-a-generation opportunity to dramatically improve engineering productivity by re-using common design elements.

Sample
CORE Design Diagnostics Report



Characteristics of Re-use Library *Elements*

- The elements in a re-use library are:
  - Model-Based Reusable Elements **MBRE**
- MBRE – Elements in the Re-Use Library
- MBRE – Comprehensive Definition
  - Encompasses all Systems Engineering facets
  - Technical description
  - Intended application
  - "How to use" instructions

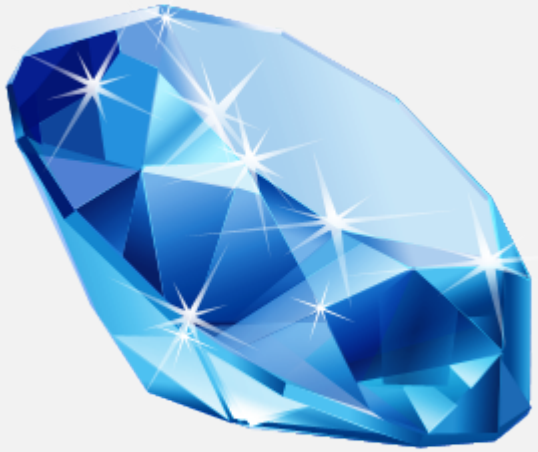
Why MBSE enables re-use libraries

- A MBSE-base Re-Use Library now enables:
  - Finding where data resides
  - Formatting MBREs to read data
  - Isolating "golden nuggets" for re-design
  - Acting as a body of knowledge
  - Acting as a search engine
  - Acting as a repository of implications and rationale
  - Providing traceability to related design aspects

Engineers retain experience to inform future decisions

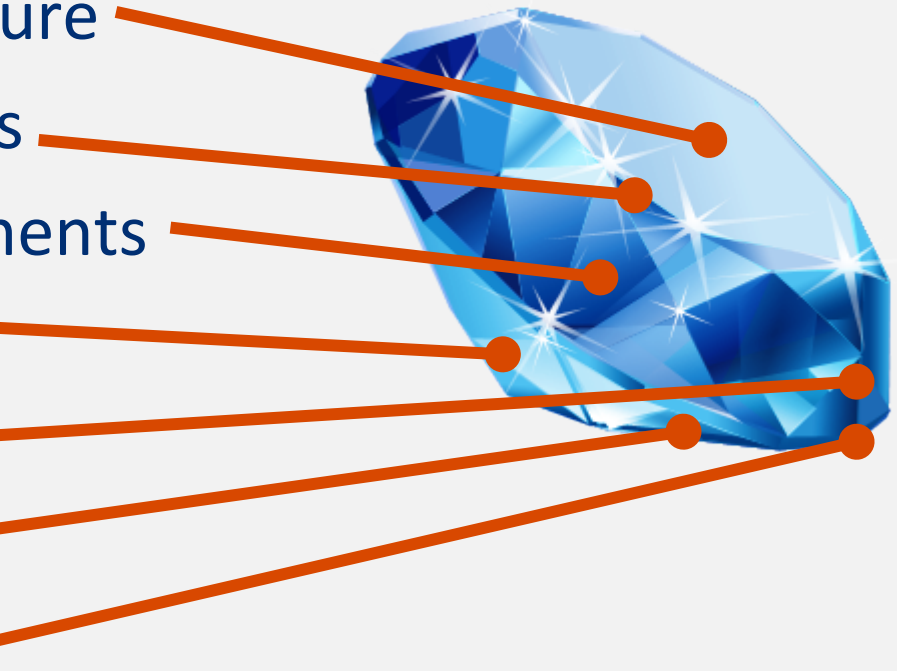
Facets

- MBSE is Systems Engineering, powered by a model
- MBSE therefore includes *all* systems engineering information
- This includes, but is not limited to:
  - Requirements
  - Architecture
  - Interfaces
  - Behavior
  - Subsystem verification methods
  - System validation methods
  - Trade studies
  - Risk analysis
  - Change management



MBRE Definition

- For systems engineers to apply models of re-usable elements, they must therefore contain:
  - Common Architecture
  - Common Interfaces
  - Common Requirements
  - Common Behavior
  - Common Tests
  - Common Risks
  - Common Trades



Two types of re-use

- Re-use of "Common" design aspects
  - Many organizations include "common" elements
  - Common requirements
  - Common architectures
- Element Re-use
  - Product Variants
  - Re-usable 'components'
  - Product Lines

Defining the MBRE

- System Boundary
  - Each MBRE must have a boundary that cuts across all facets
    - Architectural
    - Behavioral
    - Requirements
    - Verification and Validation
  - MBRE must be defined within each facet

INCOSE International Council on Systems Engineering

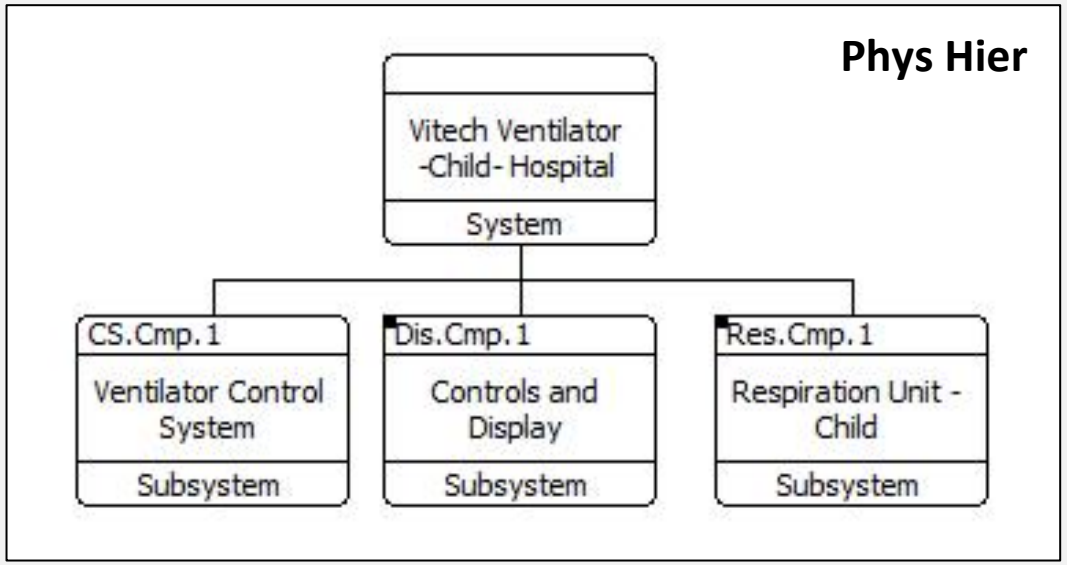
Re-Usable Architecture
Defining the Boundary

The MBRE will have architecture

Structure of internal components and interfaces that support its functionality

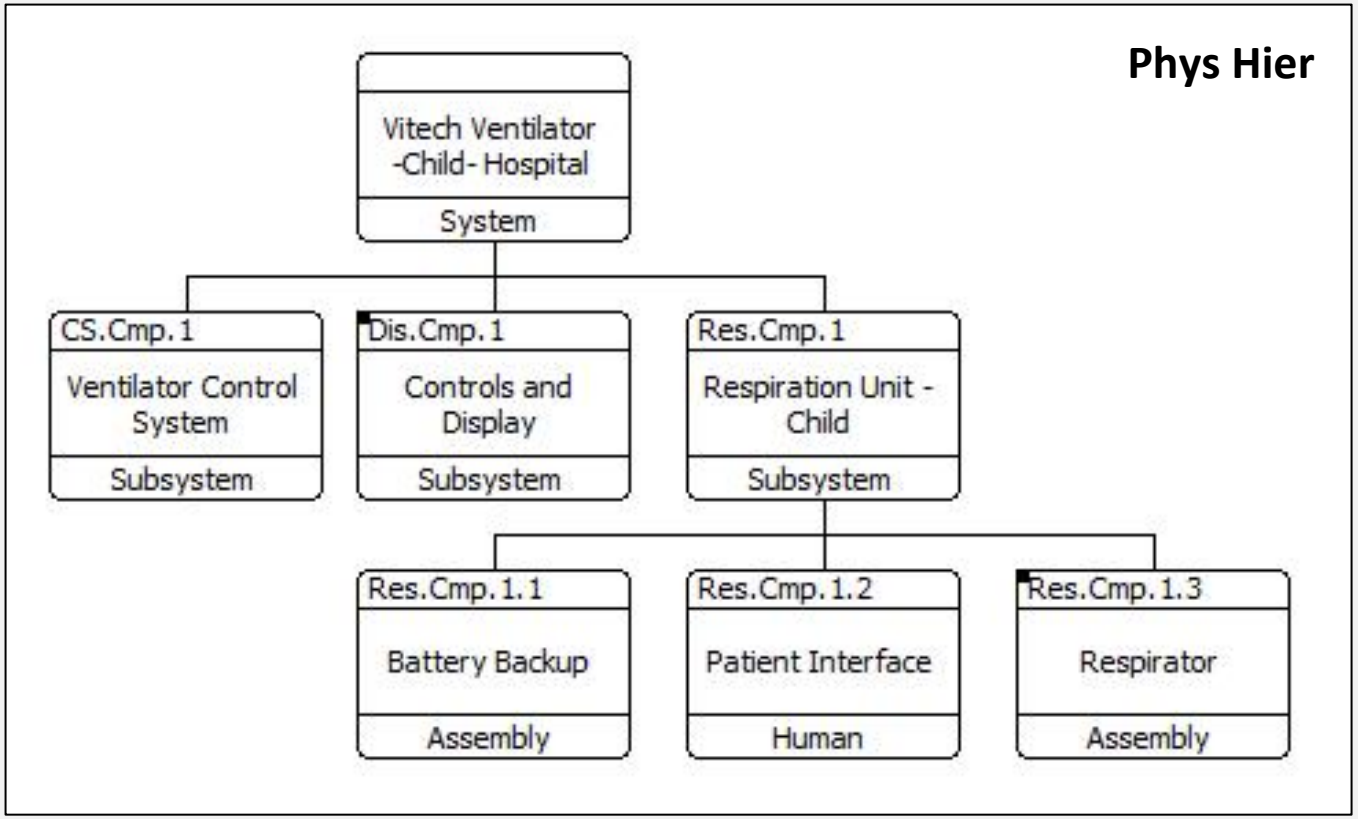
Example system

- Ventilator system
  - Breathing apparatus providing breath to patients who cannot breath on their own.
- The primary subsystems in the design are:

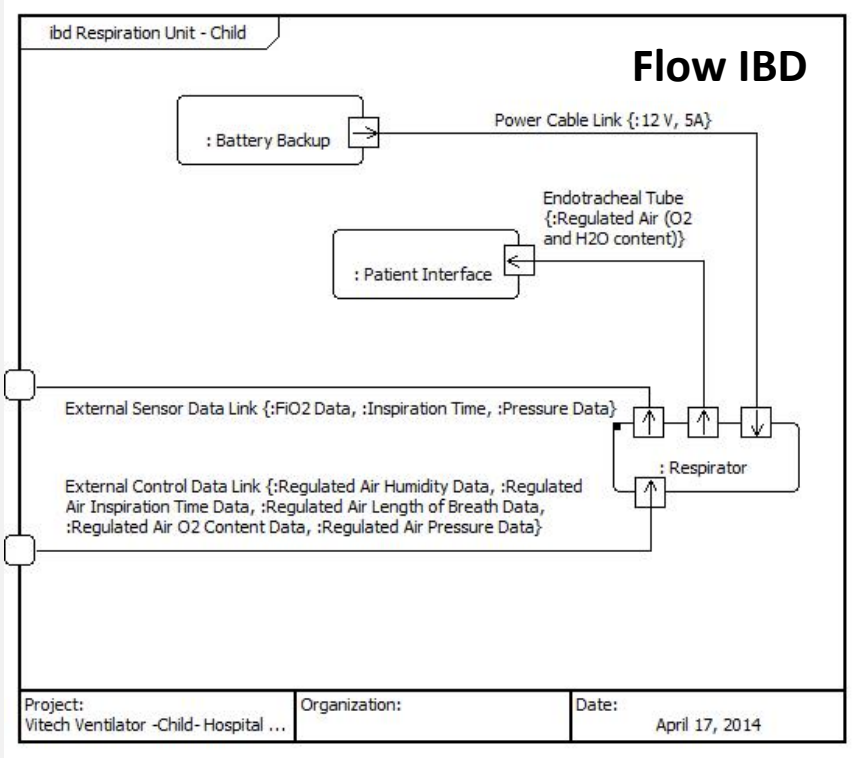


Hierarchical Architecture

- Within the *Respiration Unit*:



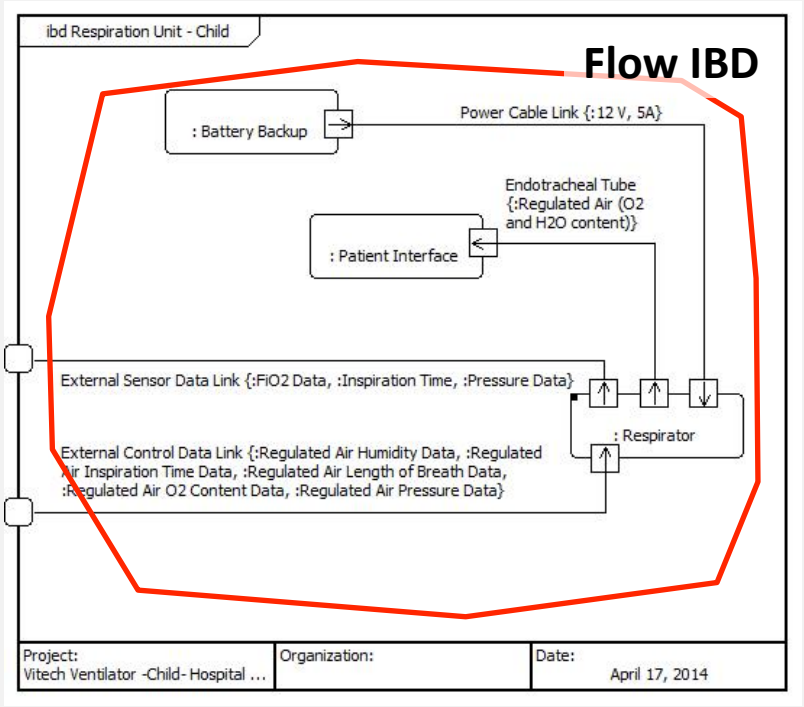
Viewing Physical/Message Interfaces



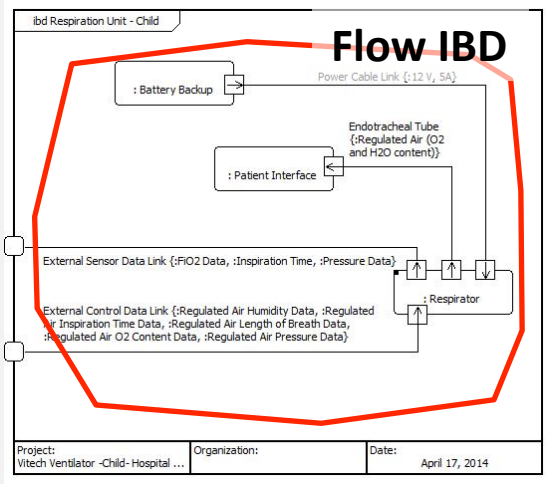
- The company may have different product variants:
  - Children, adults, seniors
  - Hospital, mobile

Drawing the Architectural Boundary

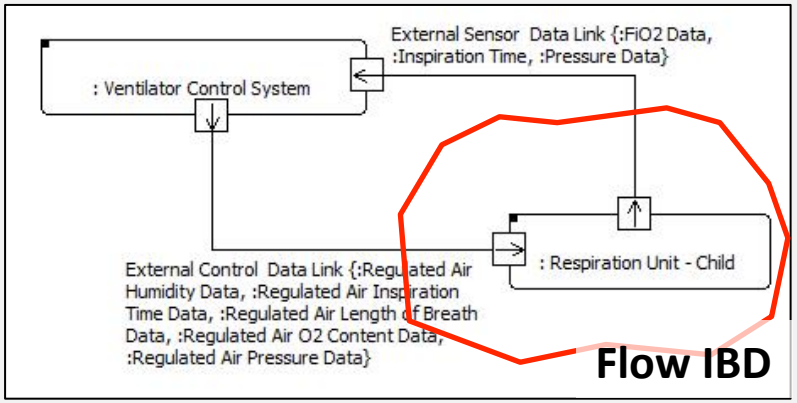
- Encompasses MBRE's architecture
- Defines MBRE's interfaces

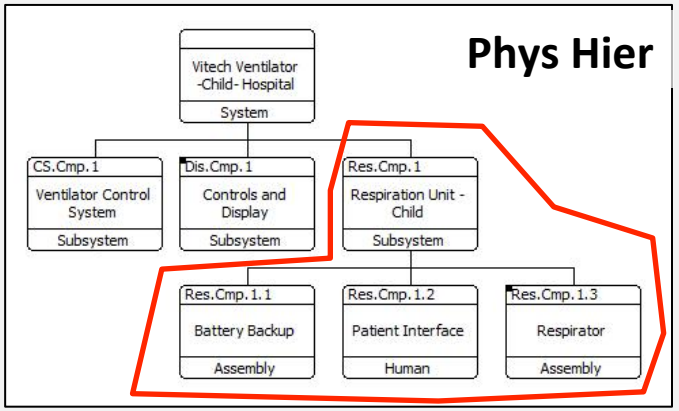


Viewing the Boundary in Context



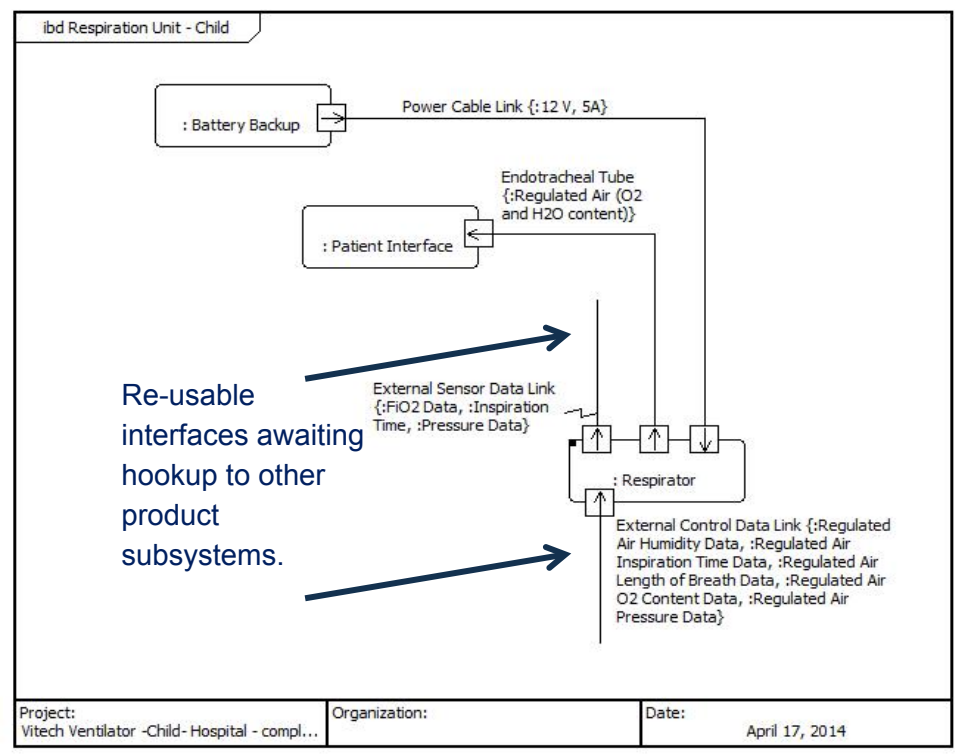
- Next higher assembly:





Beginning the Creation of the MBRE

- Dangling interfaces act as stubs
- Ready for connection by future Engineers on new products, projects and variants



Impacts of MBSE on MBRE

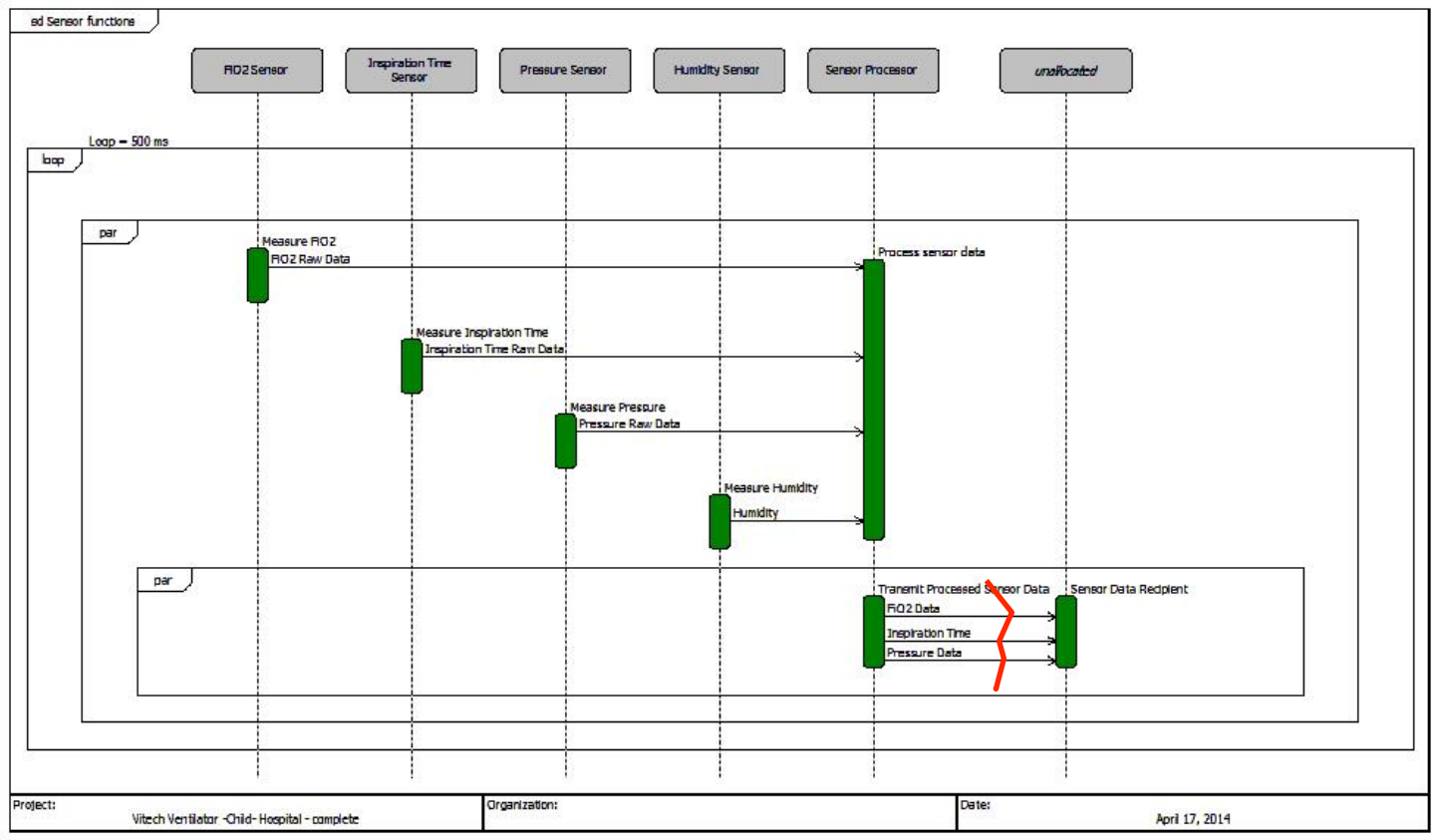
- MBSE can query/report on the dangling interfaces
- MBSE can generate the data dictionary
- MBSE can incorporate other architecture information critical for re-use:
  - Relationships to other SE artifacts (Rqmts, Tests, behavior, etc)
  - Cost
  - Rationale
  - POCs

Re-Usable Behavior
Defining the Boundary

The MBRE will perform functions

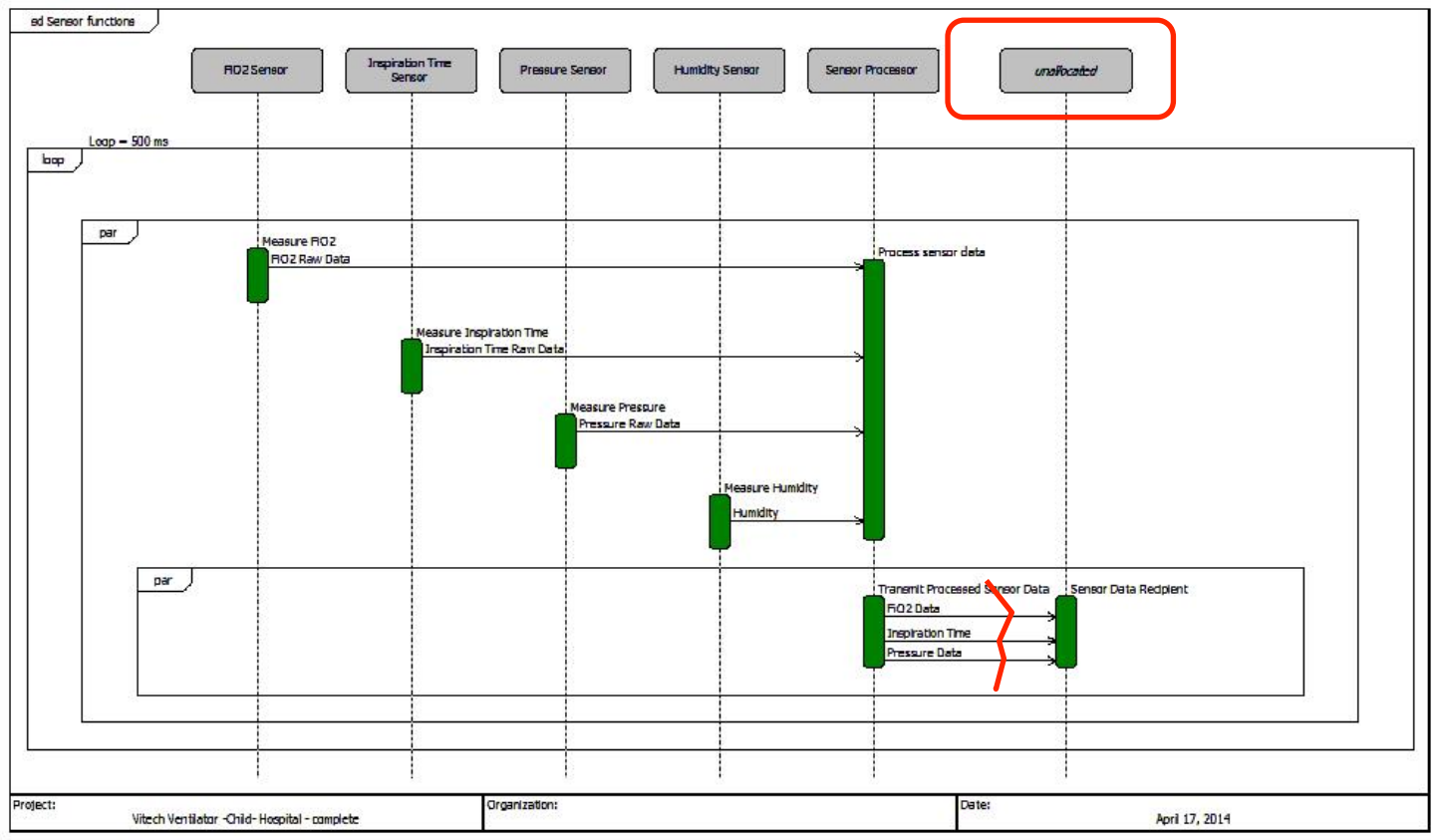
A system design without behavior is not a system design

Behavioral Boundary



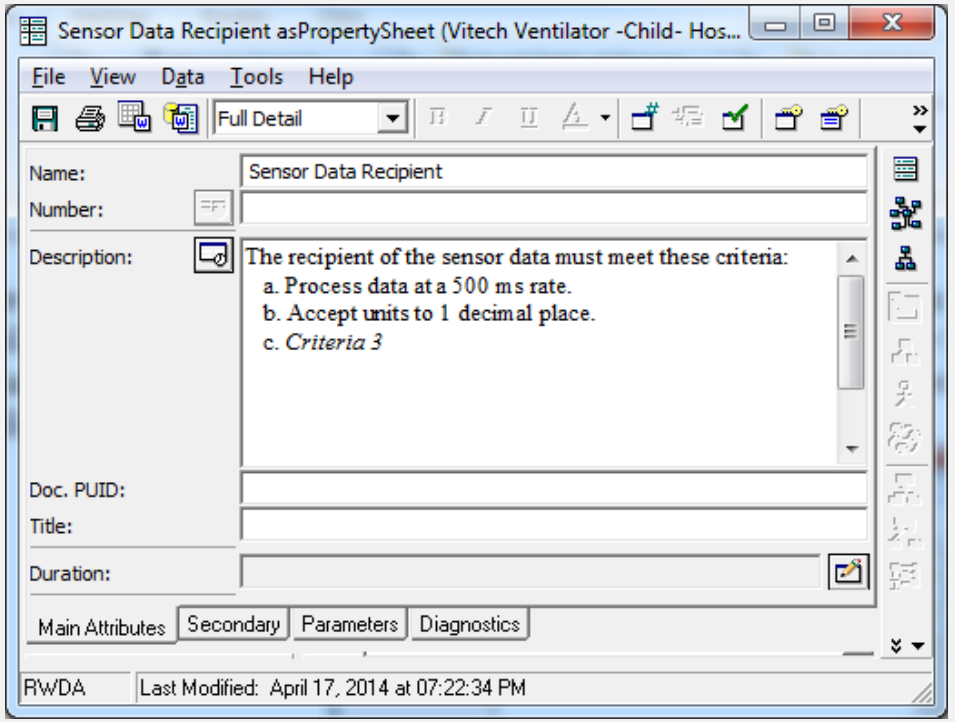
Behavioral Boundary

- ½ of Interface is “Un Allocated”



"Use Instructions", A critical aspect of the MBRE

- An MBRE must include usage instructions to enable future engineers to understand *how* to use the element.
- Represents some of the original thinking behind the element.
- Captured as documentation directly on the interfacing items.



Re-Usable Requirements
Two levels of detail

Why does the MBRE exist?

What needs does it satisfy?

MBRE Level

- Capture the requirements satisfied by the MBRE
  - Requirements constraining/defining architecture
  - Requirements which form basis for behavior
- Traceability
  - Trace to common requirements
  - Trace to regulatory as well as system requirements
- Used as a framework for verification methods

Requirement Name	Requirement Description	Implemented by Component
VV Control System - Rqmt-63	The VV Respirator shall provide respiration of the patient. The following parameters shall be provided to control respiration: FiO2 Pressure Inspiration time	Component Res.Cmp.1 Respiration Unit
VV Control System - Rqmt-64	The VV Respirator shall incorporate battery backup to ensure operation for 2 hours during a power outage.	Component Res.Cmp.1 Respiration Unit

System Level

- Traceability encompasses traceability to the MBRE from at least one-level higher
- Facilitates understanding the *intent* of the MBRE
- Used as a framework for system-level integration and testing validation methods

Re-Usable Verification and Validation

A guide to integration

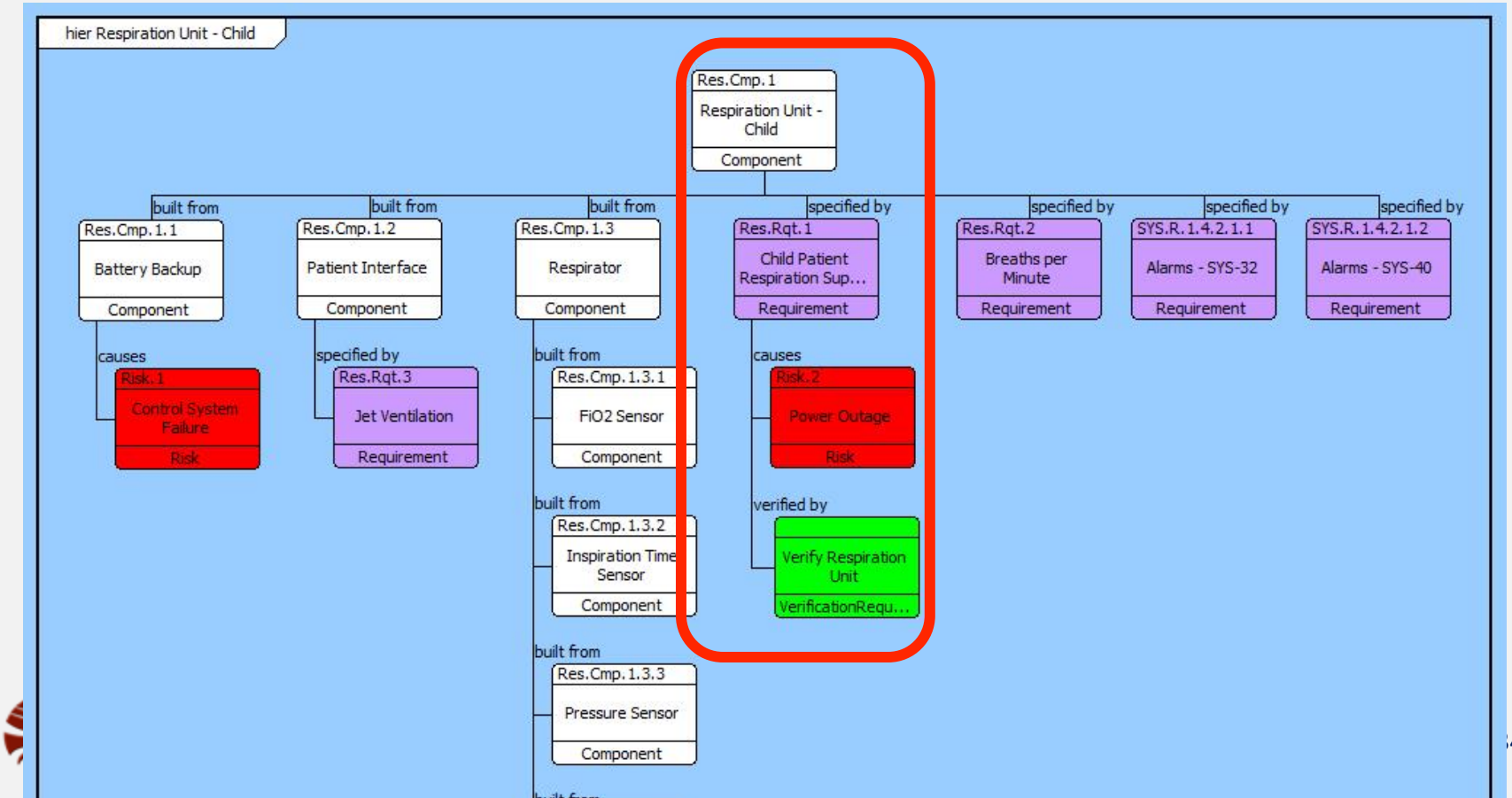
V & V at two levels

- Verification methods are captured and related to the *design* requirements ensure the MBRE operates as designed.
  - Most re-usable elements will be modified or varied
  - Provides recipient design team with baseline methods necessary to quickly develop a comprehensive verification event to test any changes they've made to the MBRE for their product variant.

- Validation methods should be provided for use at the *system* level
  - Support future design teams support in integration testing when incorporating the MBRE in new product variants.
  - As with the behavior model, instructions should be included along with the modelled procedures explaining to future design engineers which factors they should consider when designing a new product variant incorporating the MBRE.

Example of Traceability incorporated in MBRE

- Traceability thread to V&V Methods
- *Note: Behavior not shown here for simplicity*



Parameterized Data

Incorporating parametric brackets for future tailoring the MBRE

Use of Parameters

- Parameters will impact all four areas of the MBRE design
  - Architecture
  - Behavior
  - Requirements
  - Verification and Validation
- Use of parametric diagrams supports calculation
- MBRE relates parametric data across all facets of the element definition
  - Common Parameterized Reliability Requirement: "With the exception of Toner Replacement, the Printer shall operate without requiring maintenance, to include clearing paper jams and aligning printheads, for **{PARAMETER}** pages at **{PARAMETER}** pages printed per day over the course of the **{PARAMETER (WARRANTY PERIOD)}** months."

INCOSE International Council on Systems Engineering

Other Systems Engineering Considerations

The SE's job is not yet done…

- Systems engineers are also responsible for:
  - Risk
  - Product safety
  - Reliability
  - Manufacturability
  - Design-to-unit-production-cost

- Each of these areas can be incorporated into the MBRE model
  - Reduce or eliminate these costs on future programs.

Pulling it all together

Applying our new MBREs

Pulling it all together

- Formalizing the MBREs

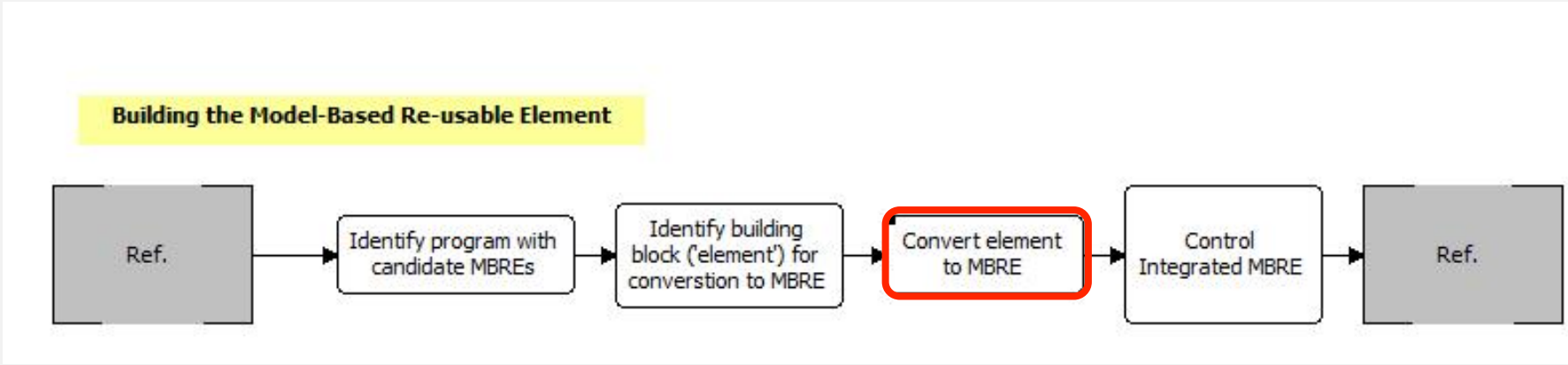
- Using our MBREs

Formalizing the MBREs

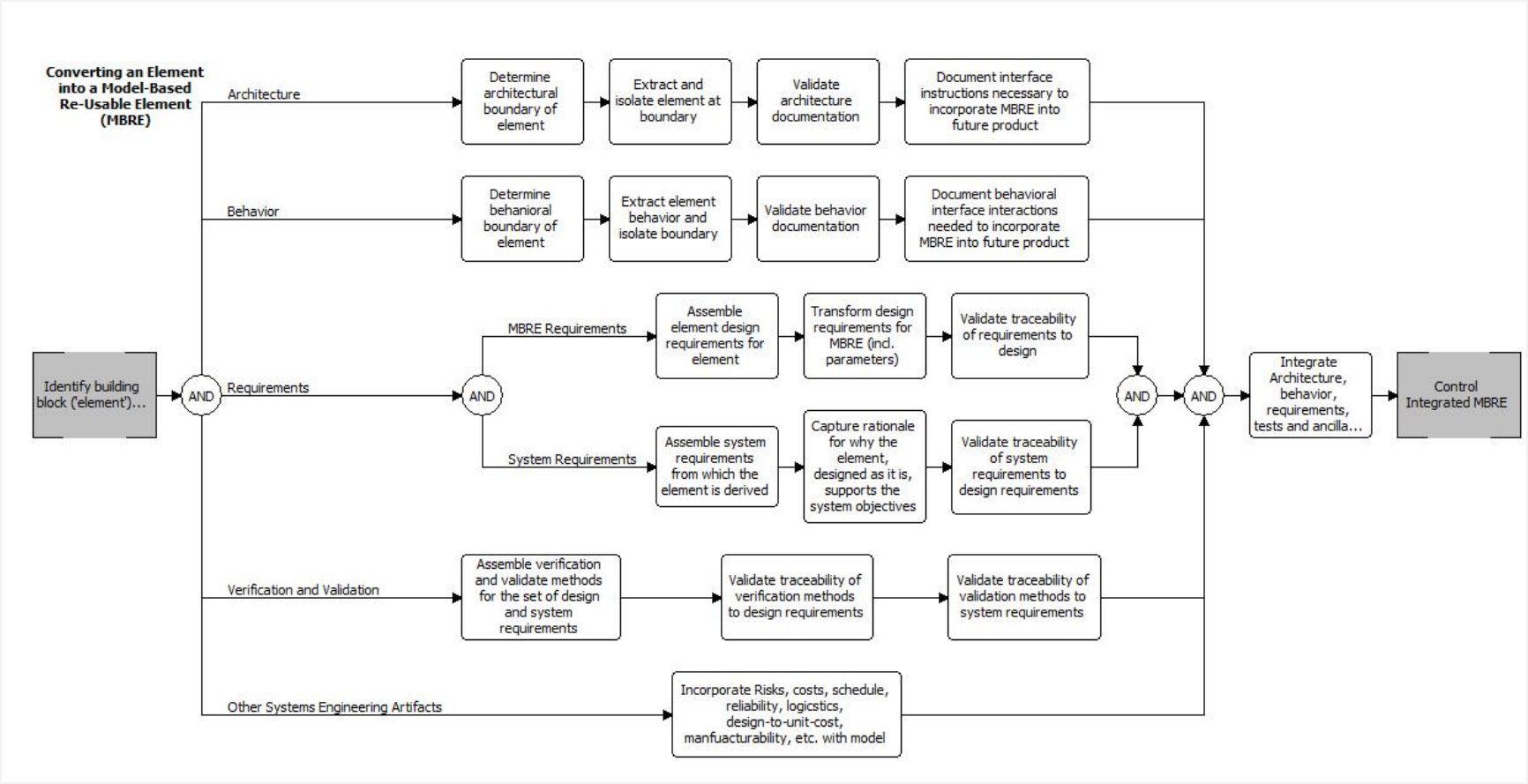
- Building MBREs is not a "side-bar" task of a tasked project team
- Investment is necessary to define the MBRE
  - Define Boundary
  - Develop "usage instructions"
  - Validate the MBRE definition
  - Release MBRE

Defining the MBRE

- Primary steps to convert a candidate into an MBRE
- Task can be quickly completed if design engineers are accessible

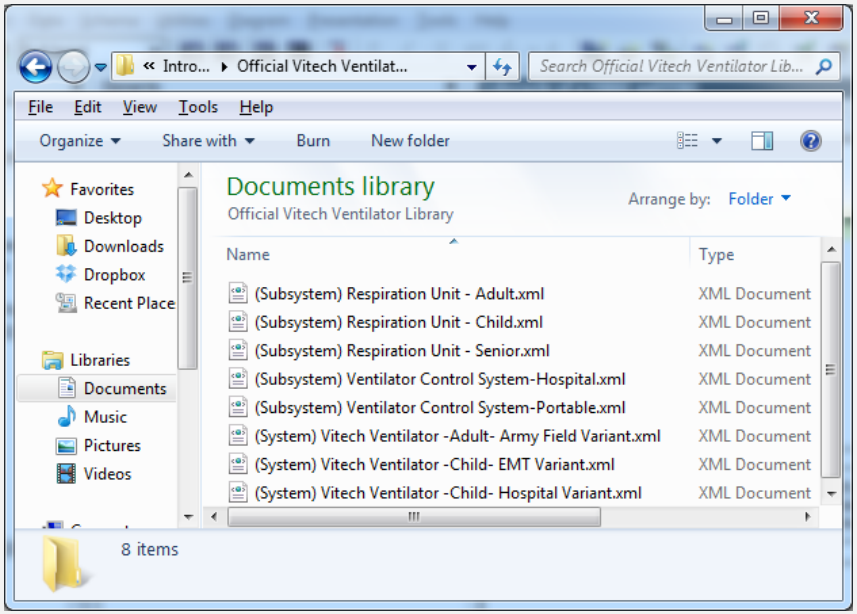


Details of "Convert Element to MBRE"



Releasing the MBRE

- Two options:
  - PDM
  - MBSE
- Each offers benefits
  - PDM:
    - Released with other artifacts (Code, VHDL, CAD)
  - MBSE
    - Directly integrate with future designs



Using the MBRE in future designs
New steps in development

- New Steps During Development
- First, Assemble system features or requirements
  - In conjunction with an assessment of available re-usable elements
  - This concerted effort helps provide quick cost-value tradeoffs early in the system conceptual phase.
-
- Second, Leverage common system requirements retrieved from the re-use library when specifying system
  - Quality increases dramatically
-
- Third, Import or relate to the re-usable elements in the model as the system is designed
  - The future engineers using the MBRE may have never met the engineers who created that MBRE model.
  - Different experiences or locations.
  - Uses complete model with instructions on how to use the element in a new system
  - Transfer knowledge, reduce development time without sacrificing quality.
  - Uses MBSE to accomplish this step.
  - The model should facilitate the traceability between the MBRE and the other system components.
  - The model should provide easy means to hook up interfaces, relate requirements to design and diagnose the design for errors and omissions.
  - The “assembly instructions” captured in the MBRE model are critical in this step.
-
- Finally, Tailor the MBRE.
  - It is appropriate for a re-usable element to require modifications to work within the new product variant.
  - Valuable to annotate these changes to alert detailed design engineers to the tailoring they will be required to make to the component.
  - MBSE helps greatly here: should report changes made to the baselined MBRE

INCOSE International Council on Systems Engineering

Using the MBRE in future designs
New steps in development

- First, Assemble system features or requirements
  - In conjunction with an assessment of available re-usable elements
  - This concerted effort helps provide quick cost-value tradeoffs early in the system conceptual phase
- Second, Leverage common system requirements retrieved from the re-use library when specifying system
  - Quality increases dramatically

INCOSE International Council on Systems Engineering

Using the MBRE in future designs
New steps in development

- Third, Import or relate to the re-usable elements in the model as the system is designed
  - The future engineers using the MBRE may have never met the engineers who created that MBRE model.
  - Different experiences or locations.
  - Uses complete model with instructions on how to use the element in a new system
  - Transfer knowledge, reduce development time without sacrificing quality.

Uses MBSE to accomplish this step.

The model should facilitate the traceability between the MBRE and

Using the MBRE in future designs
New steps in development

- Third, Import or relate to the re-usable elements in the model as the system is designed
  - The future engineers using the MBRE may have never met the engineers who created that MBRE model.
  - Different experiences or locations.
  - Uses complete model with instructions on how to use the element in a new system
  - Transfer knowledge, reduce development time without sacrificing quality.

  - Uses MBSE to accomplish this step.
  - The model should facilitate the traceability between the MBRE and the other system components.
  - The model should provide easy means to hook up interfaces, relate requirements to design and diagnose the design for errors and omissions.
  - The "assembly instructions" captured in the MBRE model are critical in this step.

INCOSE International Council on Systems Engineering

Using the MBRE in future designs
New steps in development

- Finally, Tailor the MBRE.
  - It is appropriate for a re-usable element to require modifications to work within the new product variant.
  - Valuable to annotate these changes to alert detailed design engineers to the tailoring they will be required to make to the component.
  - MBSE helps greatly here: should report changes made to the baselined MBRE

Return on Investment Calculations

- Extracted from Author's previous presentation
- Common Requirements Measurement

- **Execuspec Inc.'s has found a minimum of 30 minutes of engineering development time on any given requirement (usually much more).**
- ***Assumptions: Rate of $60 / hour, 1/3 Rqmts are Parameterized, 15 Min to modify parameters.***
- **Project would save $30,000 by having re-usable requirements available:**
  - **Savings = 1000 Rqmts x 0.5 Hrs/Rqmt x $60/Hr = $30,000**
- **Project would expend $6,995 checking the database and updating Parameters:**
  - **UseCost = Time to review 1000 pre-written Rqmts x $/Hr + Time to update Params x $/Hr**
  - **UseCost = ((1000 Rqmts/30 Rqmts/Hr) x $60/Hr) + (0.25 Hrs x 333 Rqmts x $60/Hr) = $6,995**
- **Productivity Gain = ($30,000 - $6,995) / ($30,000) = 328%**

- $3.28 project savings for every $1.00 invested

INCOSE International Council on Systems Engineering

More recent ROI Calculations

- Factors assessed included:
  - Cost of adapting subsystem for re-use library
  - Cost of validating the re-use model
  - Cost of incorporating a re-usable subsystem into a new product variant
  - Cost savings per subsystem using a CORE Re-Use Library
- **Design Re-Use…**

  …reduces specification and implementation time and cost for those subsystems by 71.5%.

  $3.50 project savings for every $1 invested in building an MBSE re-use library

Conclusion

- Concerts *individual knowledge* into *corporate knowledge*
- Systems level re-use includes *all* aspects of system definition
  - Architecture – Behavior – Requirements – V&V
- Viewed from the *component* and *system* levels
- Includes *usage instructions* to guide future engineers
- MBREs are *enabled by* MBSE
  - Maintains Traceability
  - Actively supports design integration
- Not a side-bar activity
  - *Well worth the investment*

INCOSE International Council on Systems Engineering

Conclusion

- Concerts *individual knowledge* into *corporate knowledge*

Systems level re-use includes *all* aspects of system

Architecture → Behavior → Requirements → V&V

component *system*

usage instructions

enabled by

Maintains Traceability

Actively supports design integration

Well worth the investment

Conclusion

- Concerts *individual knowledge* into *corporate knowledge*
- Systems level re-use includes *all* aspects of system definition
  - Architecture
  - Behavior
  - Requirements
  - V&V

component *system*

usage instructions

enabled by

Maintains Traceability

Actively supports design integration

Well worth the investment

INCOSE International Council on Systems Engineering

Conclusion

- Concerts *individual knowledge* into *corporate knowledge*
- Systems level re-use includes *all* aspects of system definition
  - Architecture – Behavior – Requirements – V&V
- Viewed from the *component* and *system* levels

usage instructions

enabled by

Maintains Traceability

Actively supports design integration

Well worth the investment

INCOSE International Council on Systems Engineering

Conclusion

- Concerts *individual knowledge* into *corporate knowledge*
- Systems level re-use includes *all* aspects of system definition
  - Architecture – Behavior – Requirements – V&V
- Viewed from the *component* and *system* levels
- Includes *usage instructions* to guide future engineers

enabled by

Maintains Traceability

Actively supports design integration

Well worth the investment

INCOSE International Council on Systems Engineering

Conclusion

- Concerts *individual knowledge* into *corporate knowledge*
- Systems level re-use includes *all* aspects of system definition
  - Architecture – Behavior – Requirements – V&V
- Viewed from the *component* and *system* levels
- Includes *usage instructions* to guide future engineers
- MBREs are *enabled by* MBSE
  - Maintains Traceability
  - Actively supports design integration

Well worth the investment

INCOSE International Council on Systems Engineering

Conclusion

- Concerts *individual knowledge* into *corporate knowledge*
- Systems level re-use includes *all* aspects of system definition
  - Architecture – Behavior – Requirements – V&V
- Viewed from the *component* and *system* levels
- Includes *usage instructions* to guide future engineers
- MBREs are *enabled by* MBSE
  - Maintains Traceability
  - Actively supports design integration
- Not a side-bar activity
  - *Well worth the investment*

INCOSE International Council on Systems Engineering

Re-Use Libraries: Leveraging MBSE to greatly increase engineering productivity

Warren B. Smith
wsmith@vitechcorp.com
wsmith@wrayn.com
(480) 560-2655 (cell)

http://www.is2014proceedings.com/download.php?id=paper_92