Agile Model-Based Systems Engineering (aMBSE)

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"Dance like nobody is watching,
Sing like you're alone in the shower,
Engineer like you're a passenger hurtling though space in a speeding tube of death that you designed."

Law of Douglass # 135

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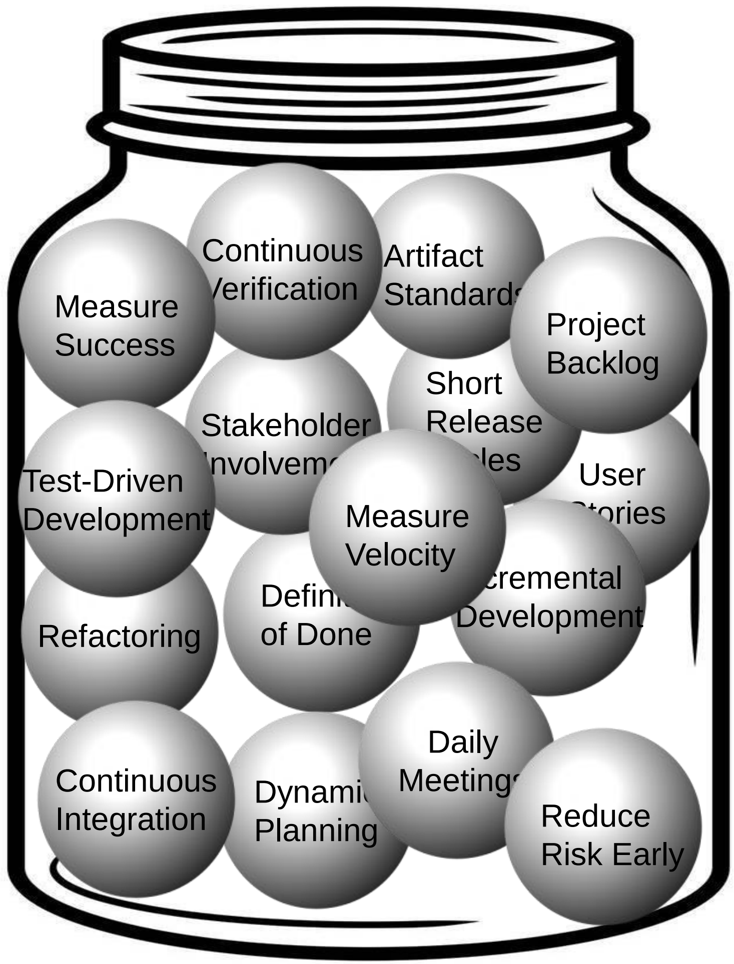
Agile Practices



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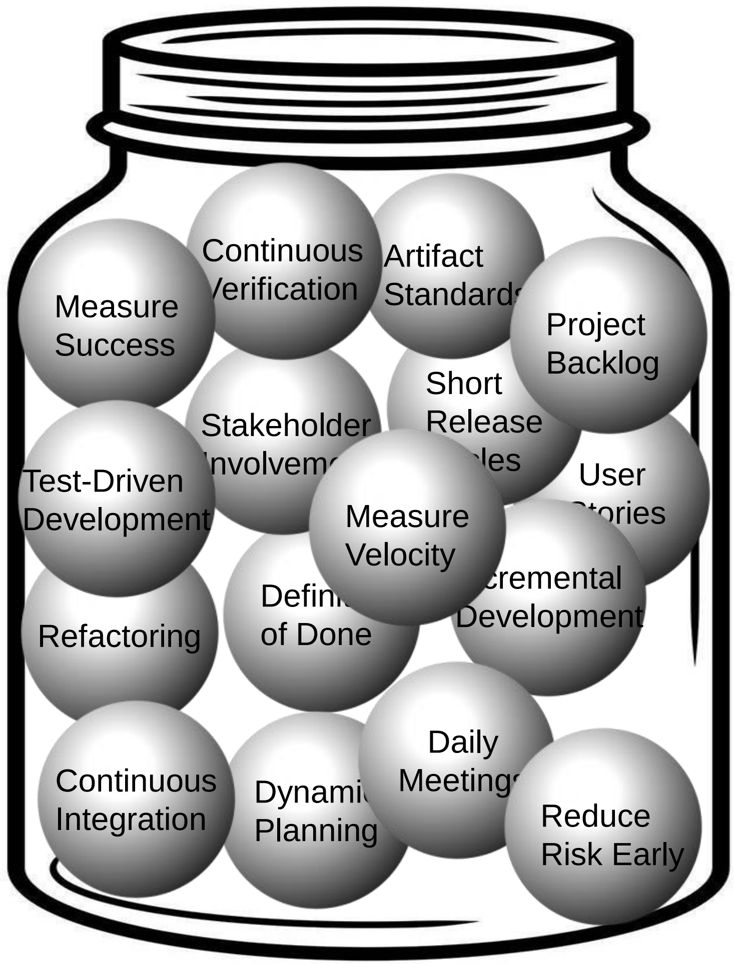
Agile Practices

Create and apply test cases as you develop the product, not after the fact



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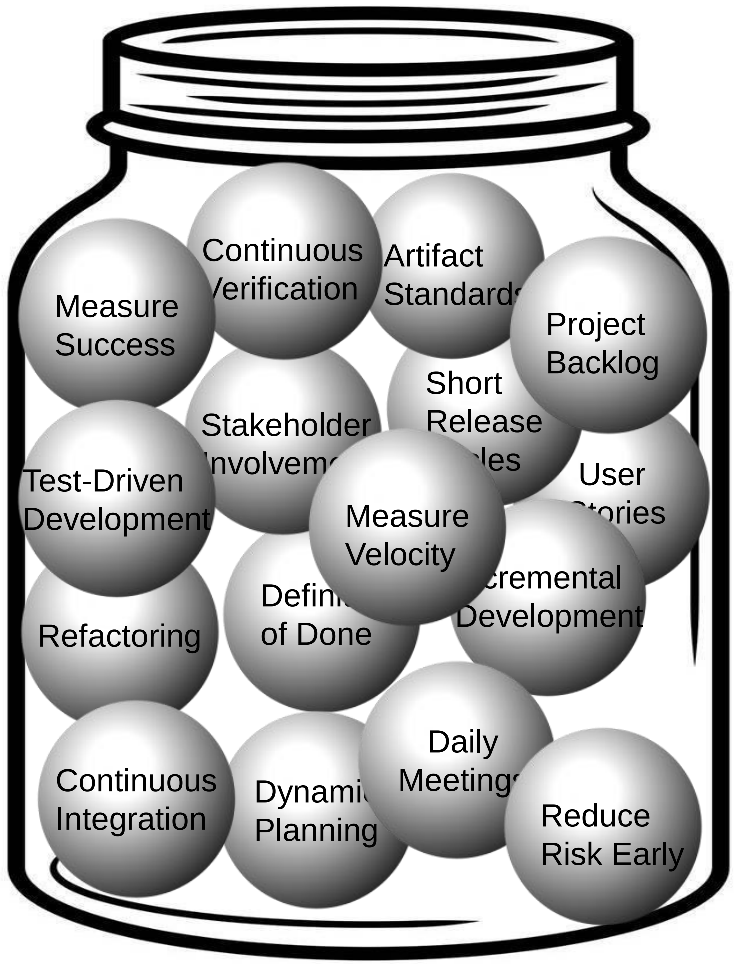

Continuously verify the correctness of your engineering data

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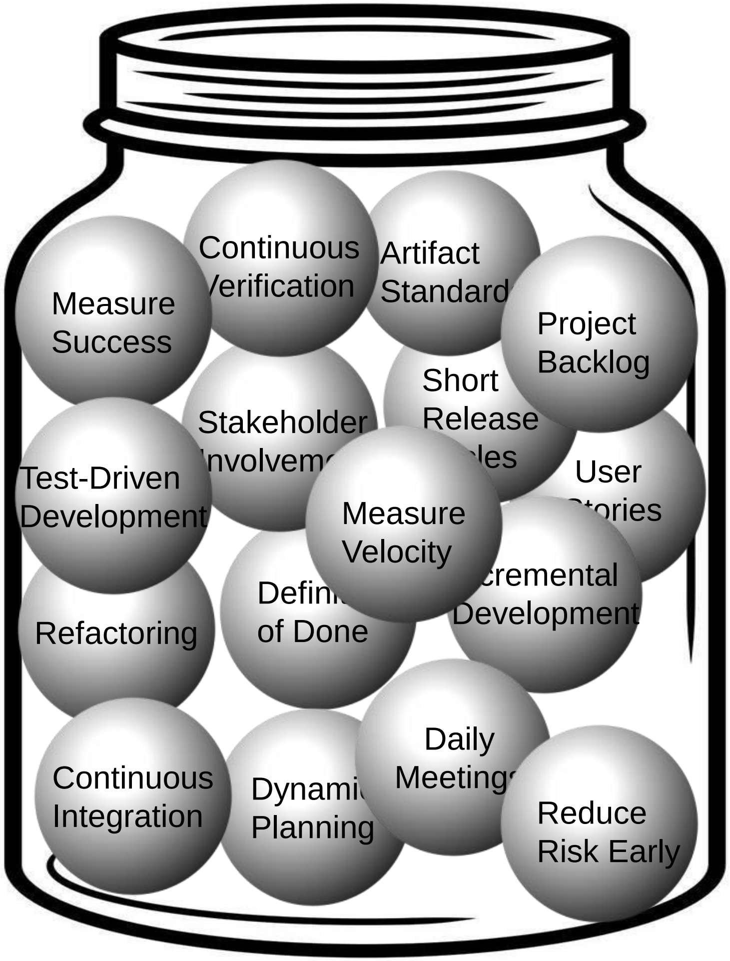

Ensure work products have the right form and content

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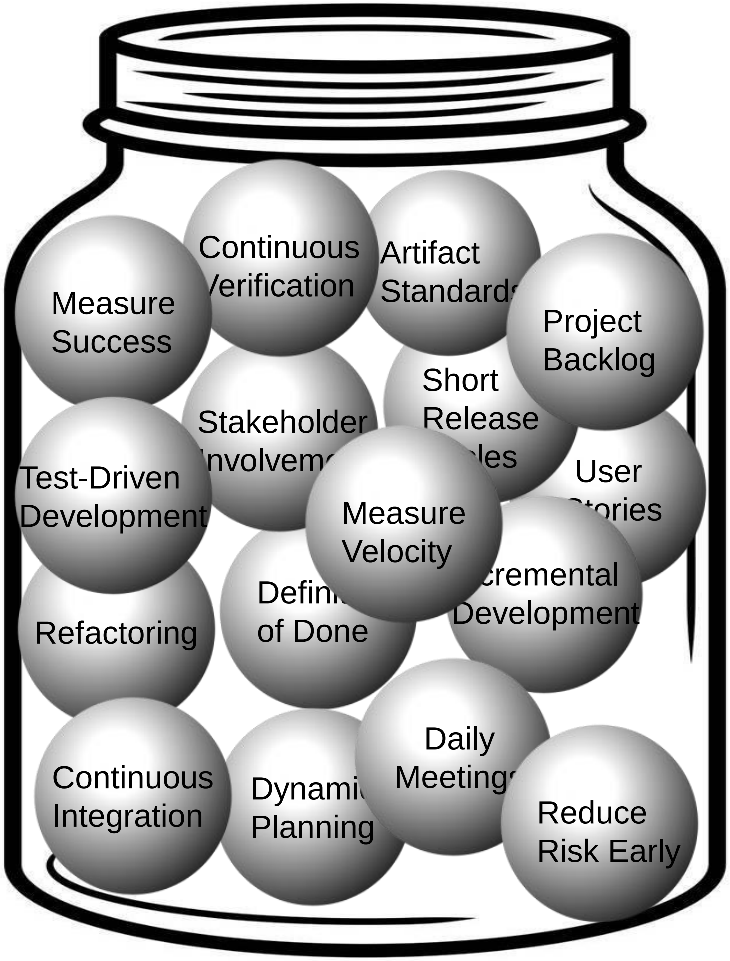
Continuously integrate work product components to ensure on-going consistency



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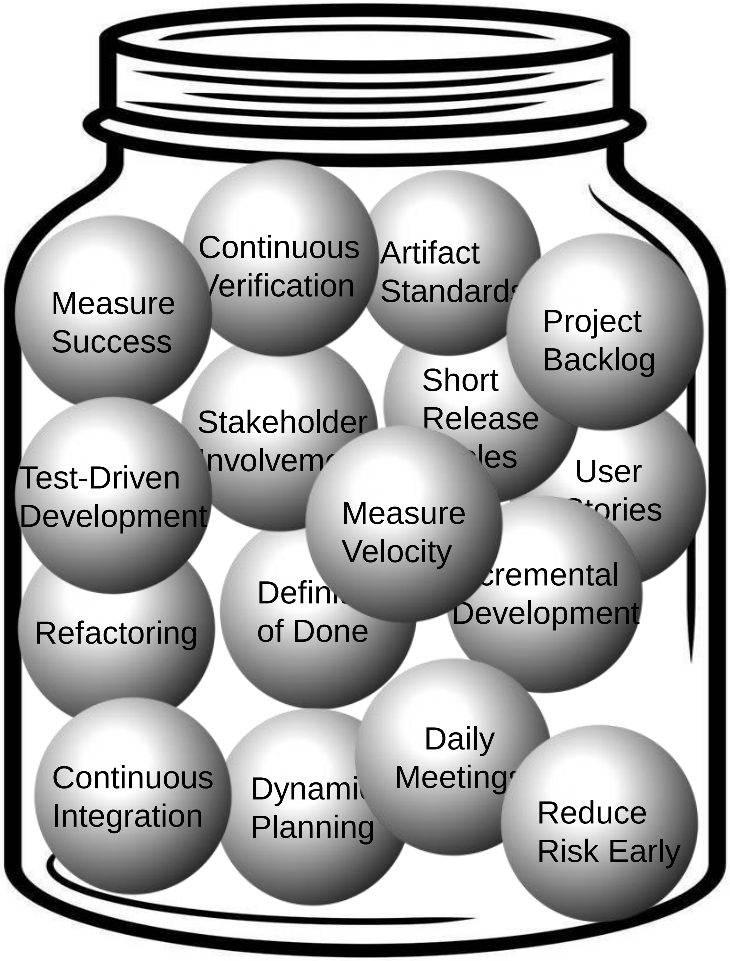

Measure progress against plan

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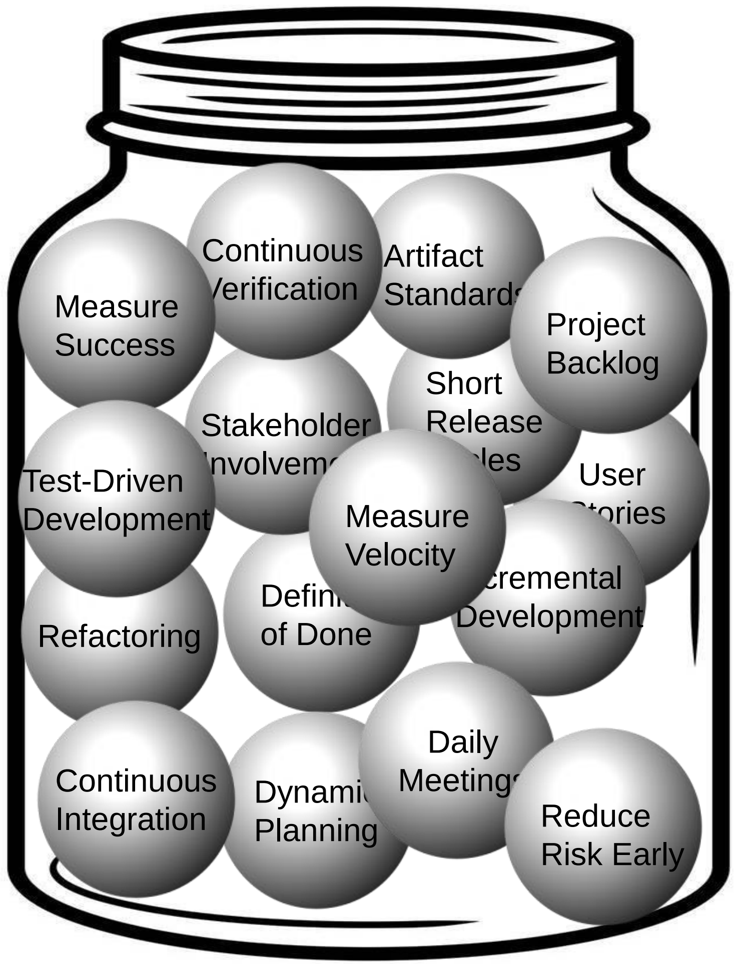

Constantly measure your progress against goals and objectives with metrics, such as

- Velocity
- Deviation from plan
- Burn down rate
- Remaining risk
- Defect rate
- Defects remaining
- Requirements churn
- Test coverage

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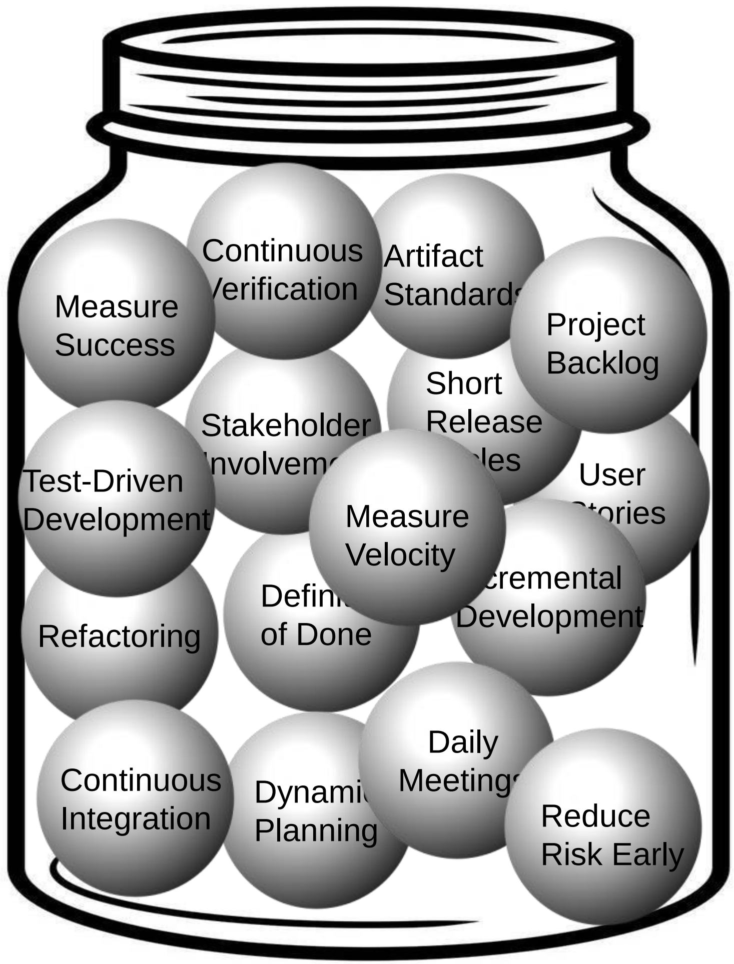
Plan to the best of your information, but plan to replan as you learn more about the product and project



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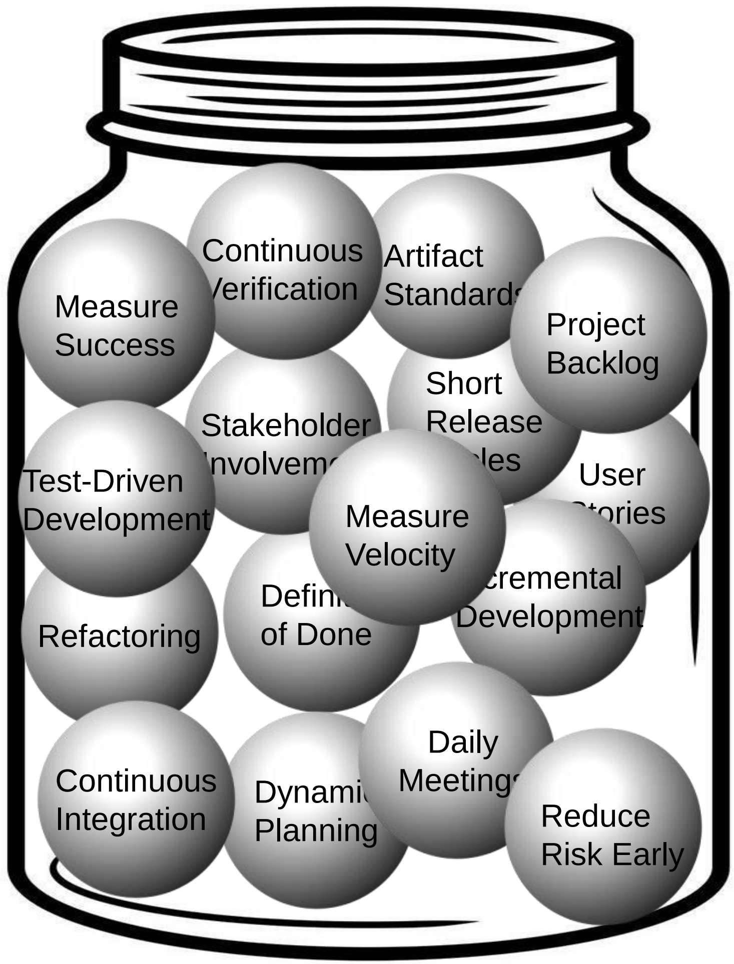

Develop the work products in small increments verifying their correctness as you go

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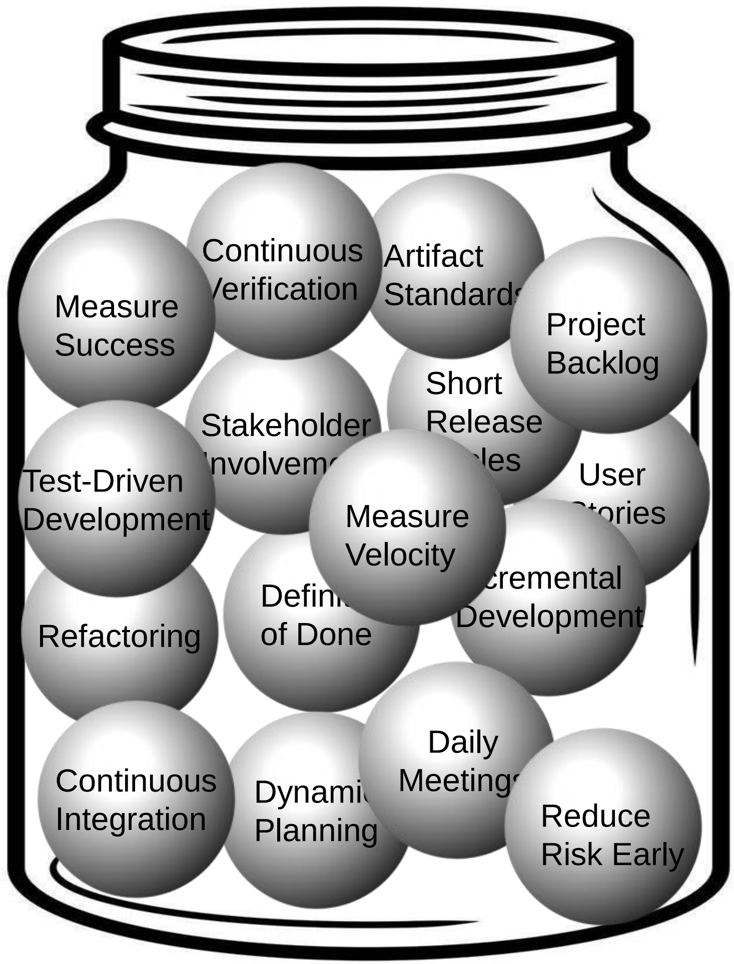

Increments should be small in degree of change and short in duration

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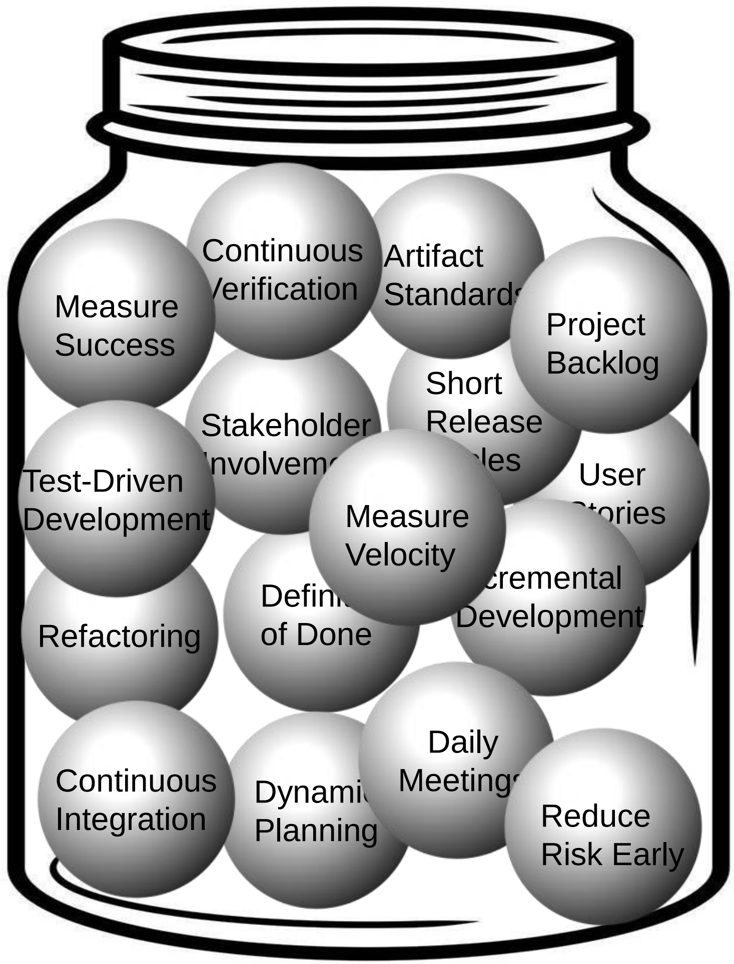

Be clear on what it means to have successfully and fully reached the objectives of the task or increment and verify that you have done so

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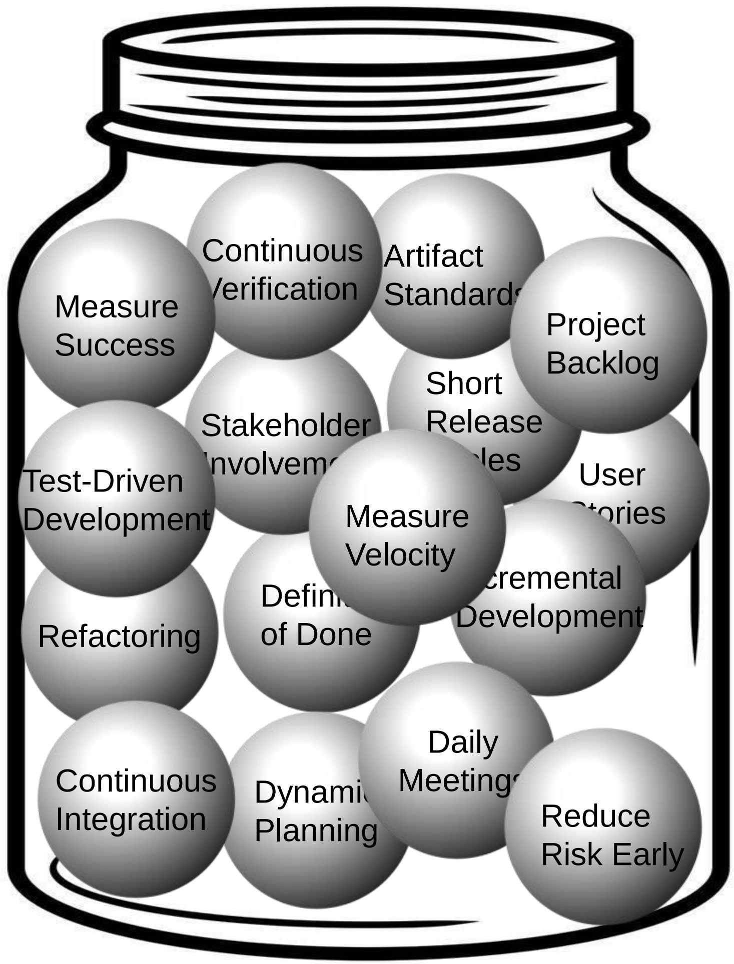

Identify risk to success, plan *spikes* to address them, and execute them within the increments

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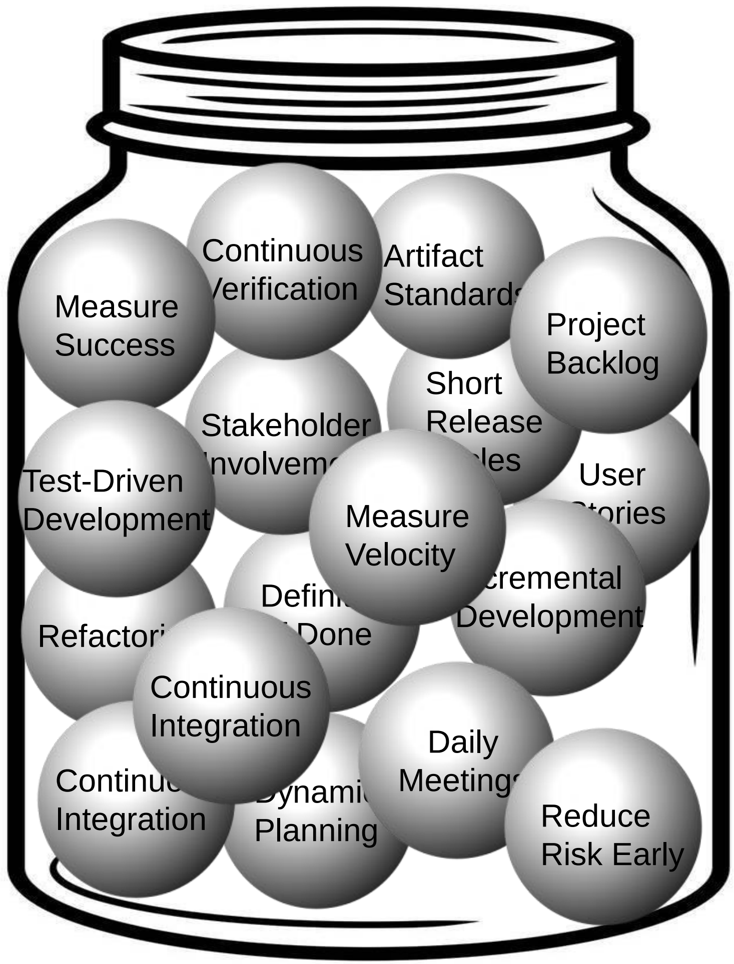
Incremental development is predicated on the idea that change is growth and refactoring is reorganization as more information becomes known



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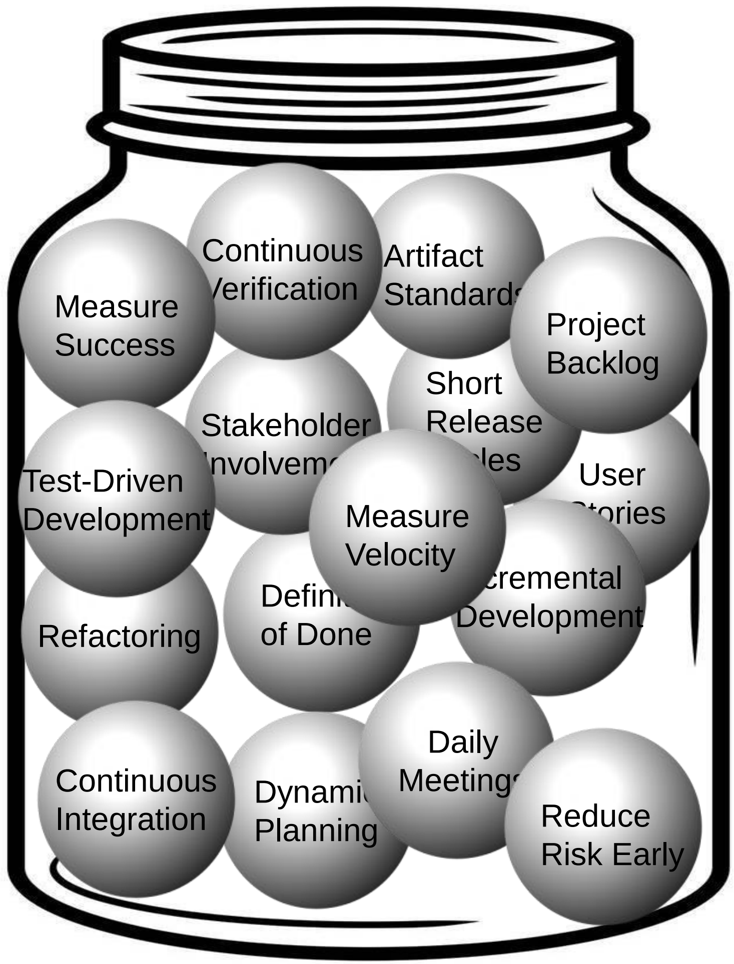
Incrementally validate the product with the stakeholder to ensure it meets their needs



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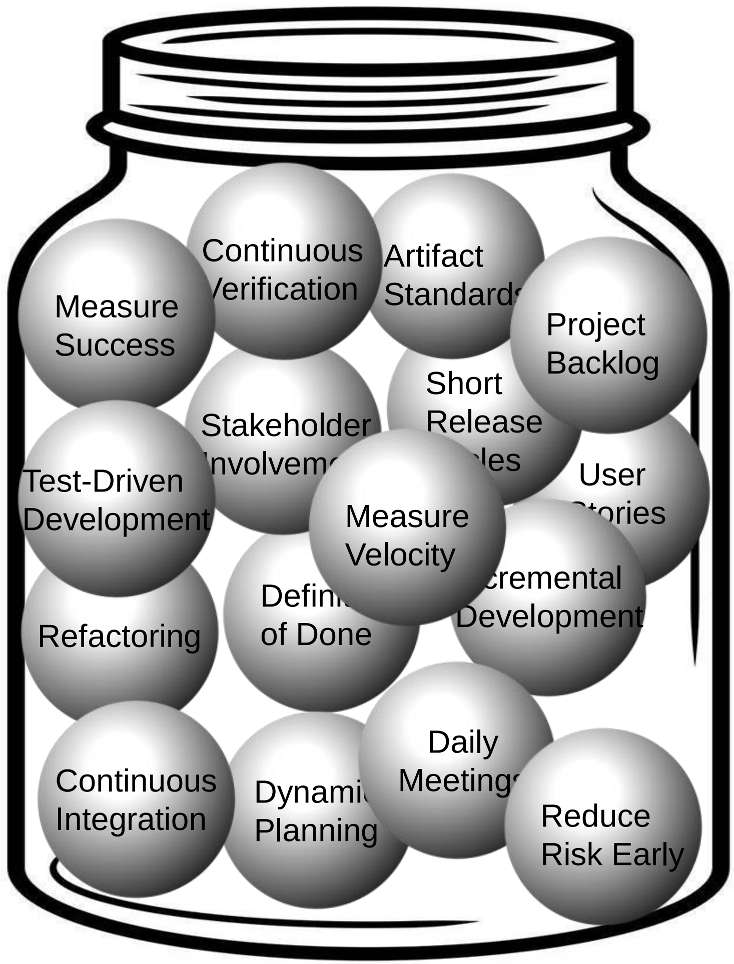

Maintain and burn down a prioritized list of things to do, including features to incorporate, design to include, and risks to reduce

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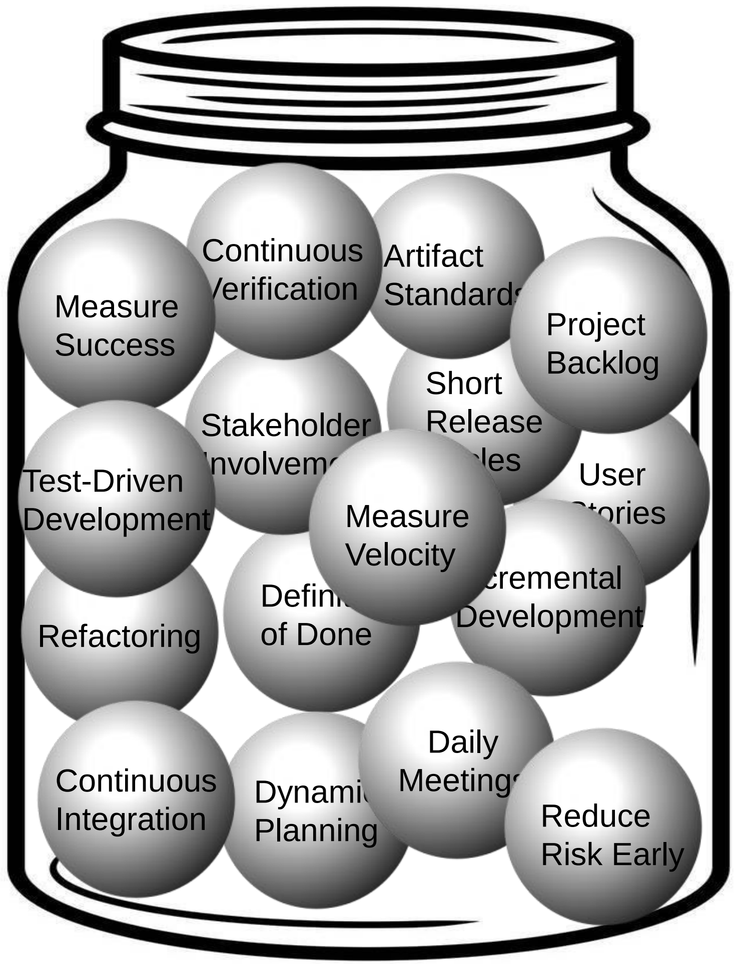

Use Cases or User Stories aid in the capture and analysis of requirements

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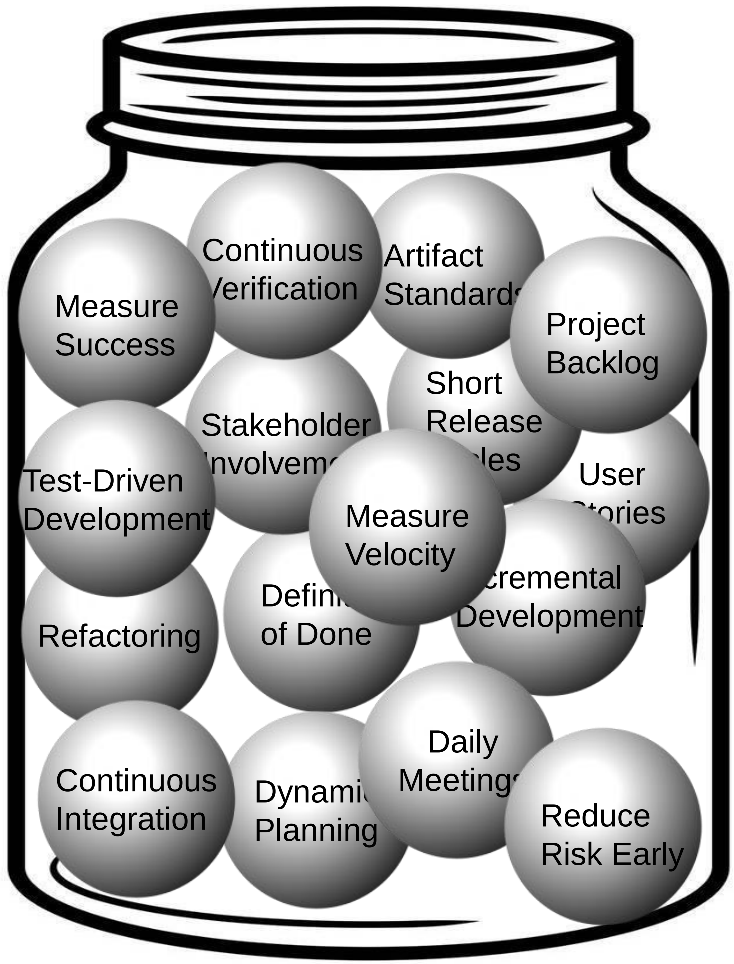

Each day, have a short meeting in which team members identify where they are and their “blockers”

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Common Systems Work Products

- Requirements
  - Stakeholder
  - System
  - Subsystem
  - Engineering Specific: Software, Electronics, Mechanical, Pneumatics, Hydraulic, …
- Architecture
  - Functional
  - Logical
  - Physical
  - Trade studies
- Interfaces
  - System – Actor
  - Subsystem – Subsystem
  - Interdisciplinary (e.g. software – electronics)
- Dependability analysis & specifications
  - Safety
  - Reliability
  - Security
- Trace matrices

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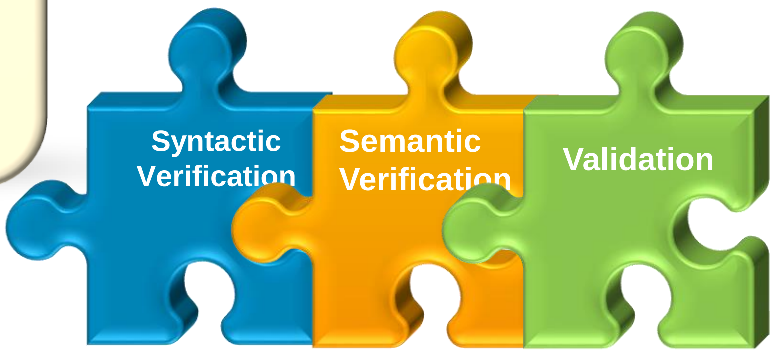
What do we mean by "verification & validation" of work products?

Semantic Verification

- "correct" (*compliance in meaning*)
  Performed by engineering personnel

Three basic techniques

- **Semantic review** (subject matter expert & peer) – most common, weakest means
- **Testing** – requires executability of work products, impossible to fully verify
- **Formal methods** – strongest but hard to do and subject to invariant violation



Syntactic Verification

– "well-formed" (*compliance in form*)
  Performed by quality assurance personnel

- **Audits** – work tasks are performed as per plan and guidelines
- **Syntactic review** – work products conform to standard for organization, structure and format

Validation

- "meets the stakeholder need"
  Performed by customer + engineering

Some common techniques

- **Review** – (subject matter expert & customer) – most common, weakest
- **Simulation** – show simulated input → outputs
- **Sandbox** – exploratory usage in constrained environment
- **Flight test** – demonstration of system capabilities
- **Deployment –** early usage of system of partial capability

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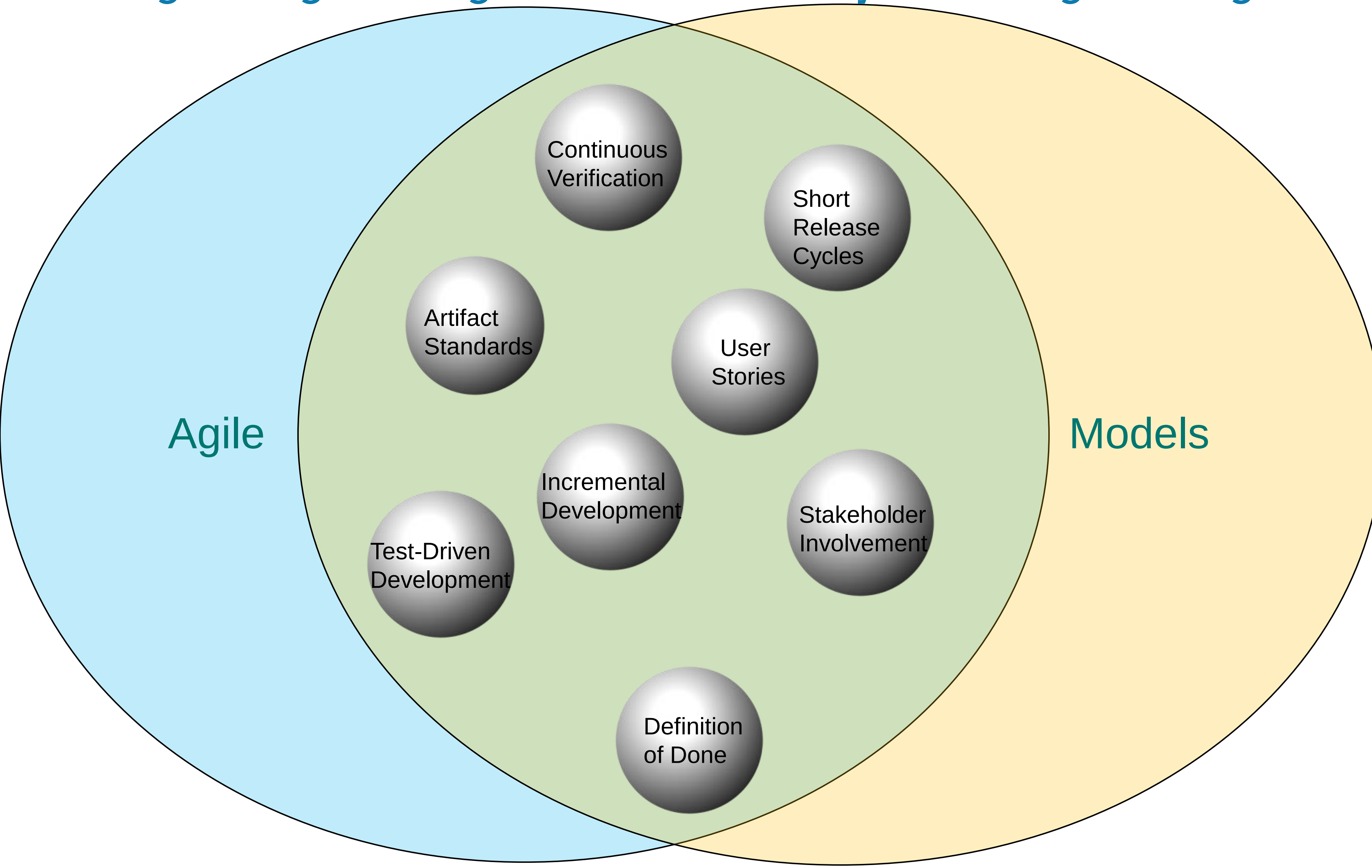
Putting the Agile in Agile Model-Based Systems Engineering



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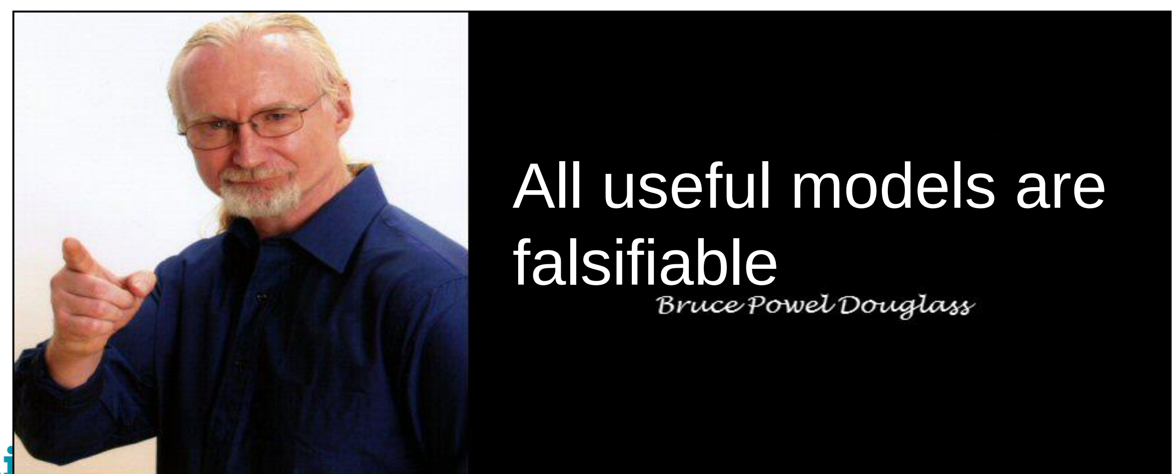
Modeling is Essential for Agile MBSE

- Models:
  - Answer questions
  - Faithfully, precisely, and completely address the purpose and scope of the model
  - Trace to both source and subsequent work products
  - Support autogeneration of subsequent work products, when applicable:
    - Architecture Notebook
    - Interface Specifications (e.g. ICD)
    - Trace matrices
    - Test plans and test cases
    - Project process work and objectives
  - Provide the ability to verify the correctness, accuracy, precision, and completeness of engineering data



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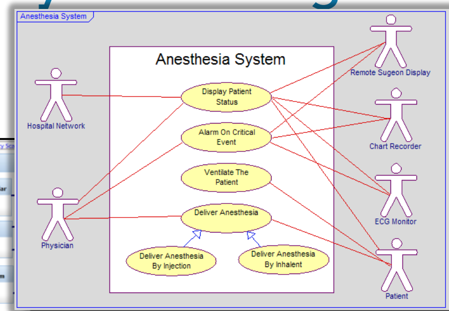
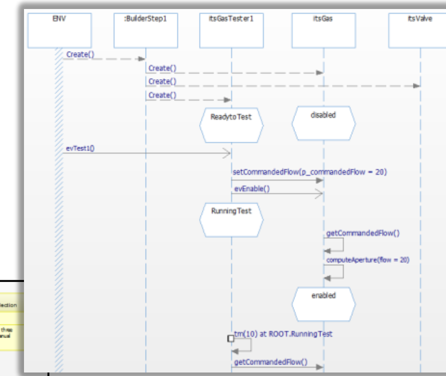
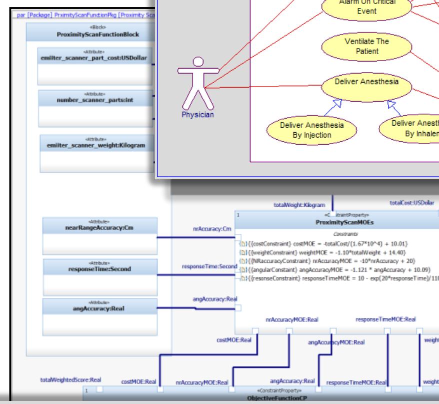
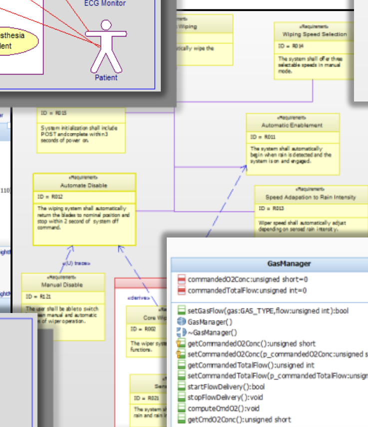
Common SysML Views for Systems Engineering

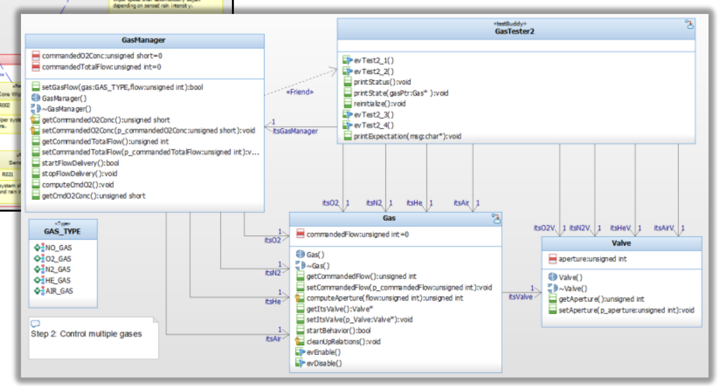
- Diagrams
  - Use case diagram
  - Requirements Diagram
  - Block Diagram
    - Block Definition Diagram
    - Internal Block Diagram
  - Activity Diagram
  - Sequence Diagram
  - State Diagram
  - Parametric Diagram
- Tables
  - Requirements Table
  - Allocation Table
  - Trace Table
- Matrices (traceability)
  - Requirements – Use Case Allocation Matrix
  - Requirements – Subsystem Allocation Matrix
  - Requirements – Requirements Trace Matrix
    - System → stakeholder
    - Subsystem → system

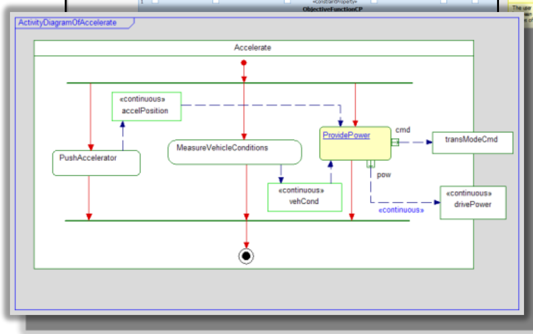


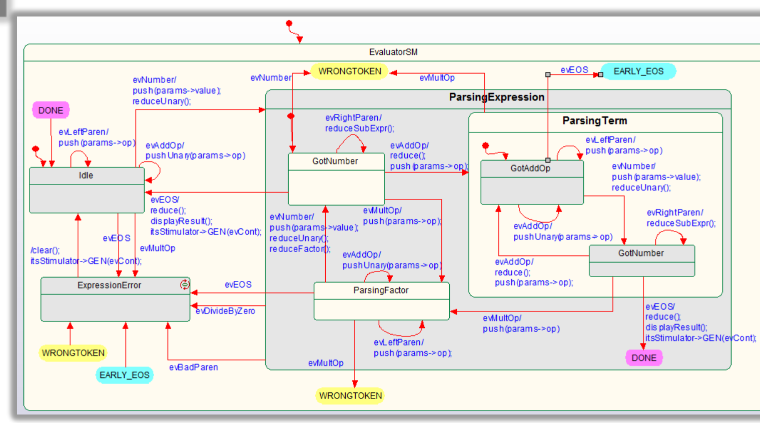








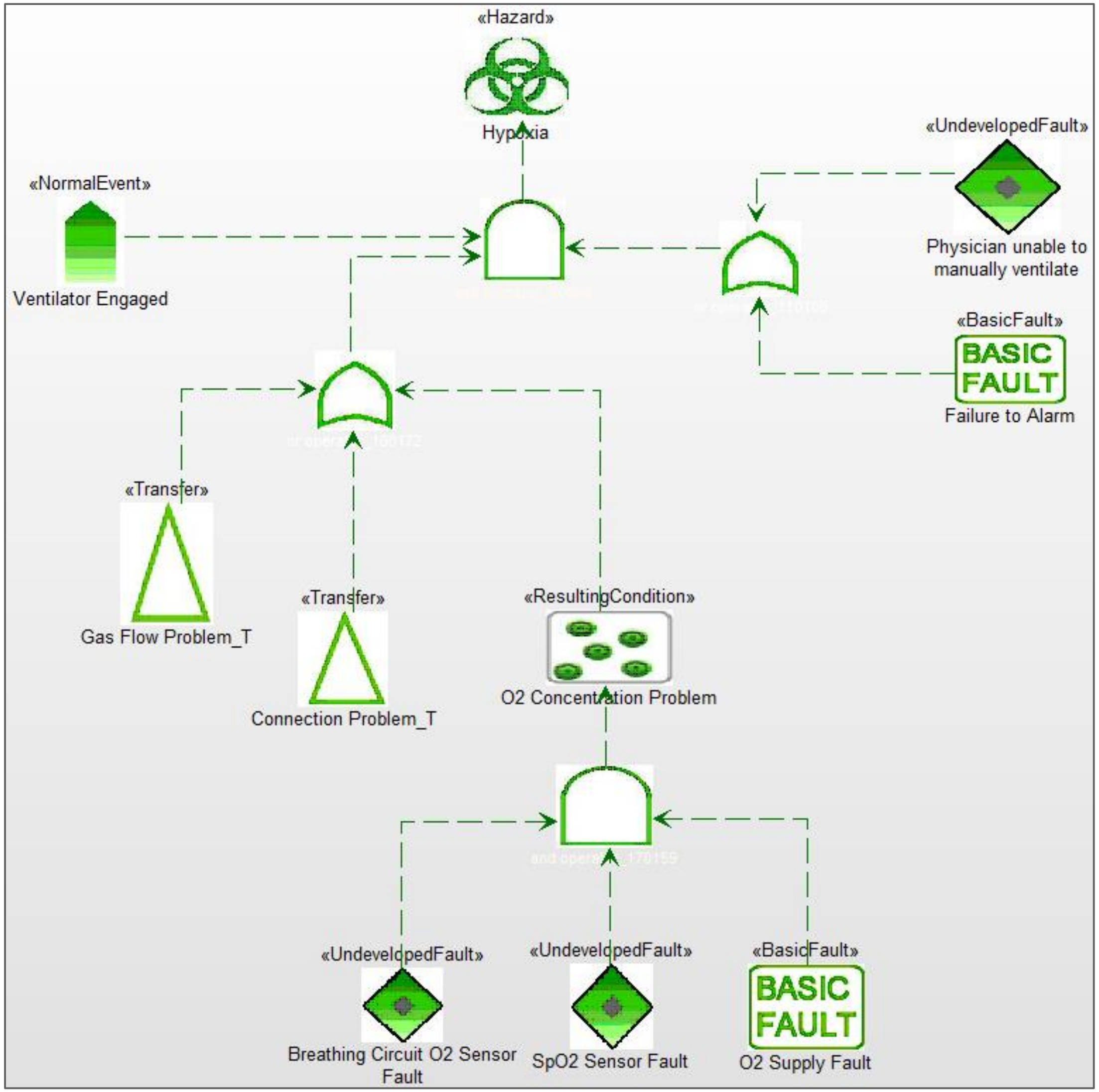




Integrated Safety and Reliability Analysis

- Fault Tree Analysis (FTA) connects *hazards* with logical combinations of events, conditions, errors, and faults
- Allows you to identify
  - Effects of combinations of conditions and events on safety
  - Safety measures
  - Safety requirements
  - Impacts of architectural, technological, and design choices on safety

UML Dependability Profile



http://merlinscave.info/Merlins_Cave/Models/Entries/2017/3/3_Dependability_Analysis_Profile.html

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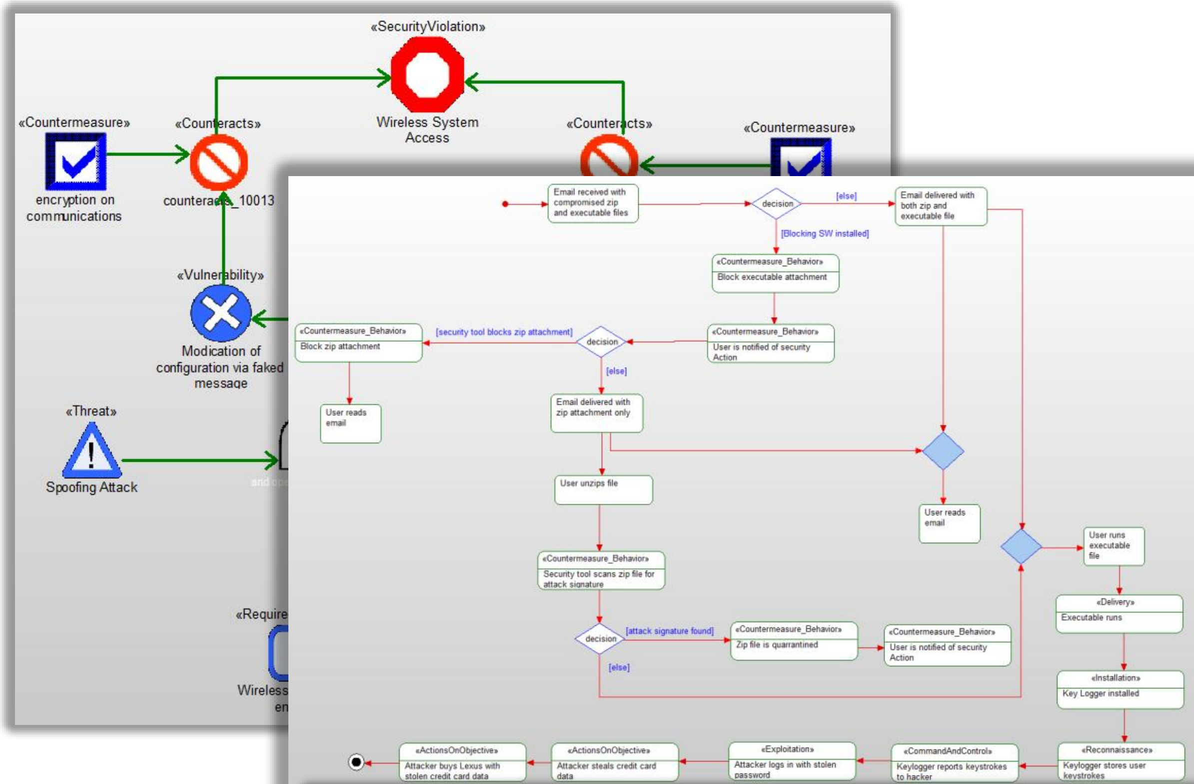
Model-Based Threat Analysis

- Security Analysis Diagram (SAD) is like a Fault Tree Analysis (FTA) but for security, rather than safety
  - It looks for the logical relation between assets, vulnerabilities, attacks, and security violations
  - Permits reasoning about security
    - What kind?
    - How much?
    - Risk assessments
    - Cost of security penetration
    - Adequacy of countermeasures
    - Who has access to assets



Threat Analysis Table

Asset value is the value of the asset to be protected (1=very low, 10=very high).

Likelihood is the probability of the attack (1=very low, 10=certain).

Reproducibility refers to how easy it is to reproduce the attack (for example, does it depend on timing or other circumstances?) (1=hard, 10 = very easy).

Exploitabilty refers to how easy it is to launch the attack (1=very easy, 10=very hard).

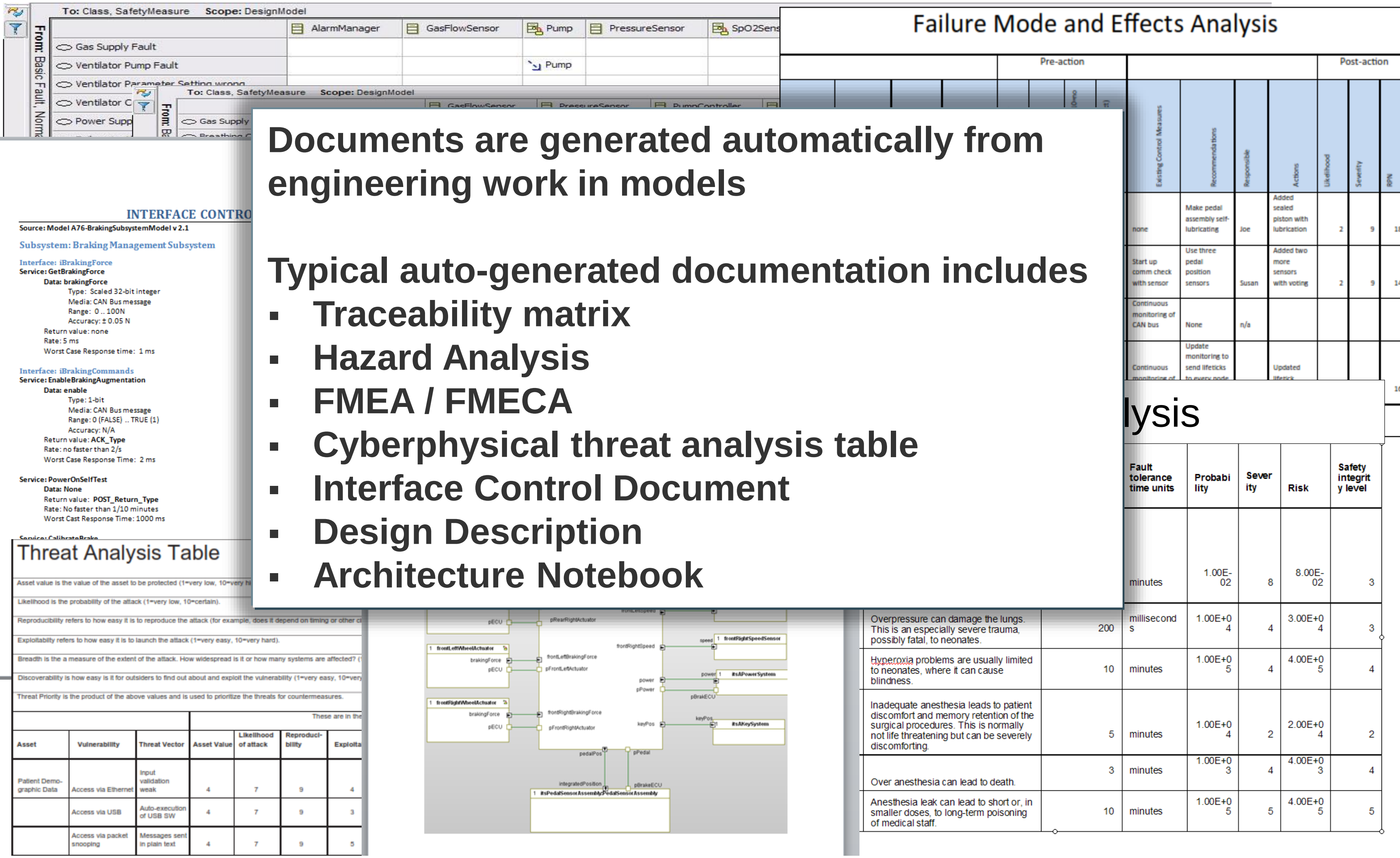
Breadth is the a measure of the extent of the attack. How widespread is it or how many systems are affected? (1=few, 10=very many).

Discoverability is how easy is it for outsiders to find out about and exploit the vulnerability (1=very easy, 10=very hard).

Threat Priority is the product of the above values and is used to prioritize the threats for countermeasures.

			These are in the range of 1 -10							
Asset	Vulnerability	Threat Vector	Asset Value	Likelihood of attack	Reproduci-bility	Exploitability	Breadth	Discover-ability	Threat Priority	Countermeasure
Patient Demo-graphic Data	Access via Ethernet	Input validation weak	4	7	9	4	1	9	9072	Internal encryption
	Access via USB	Auto-execution of USB SW	4	7	9	3	1	9	6804	Internal encryption
	Access via packet snooping	Messages sent in plain text	4	7	9	5	1	8	10080	Message encryption

Auto-generation of summary documentation from models



Documents are generated automatically from engineering work in models

Typical auto-generated documentation includes

- Traceability matrix
- Hazard Analysis
- FMEA / FMECA
- Cyberphysical threat analysis table
- Interface Control Document
- Design Description
- Architecture Notebook

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So What IS a Model then?

Modeling is the development of a semantically correct set of engineering data of relevant systems and their properties

Models have views (e.g. diagrams)

Diagrams show subsets of eng. data

Diagrams have singular purpose

Diagrams answer questions

Diagrams support specific reasoning

Models have scope

Models have purpose

Models have accuracy

Models have fidelity

Models are falsifiable

Models are verifiable

Models *are interconnected data!*

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Harmony Agile MBSE Delivery Process

Rational. Method Composer

Search this Site:

Team (IBM)

- Welcome to the Rational Harmony Agile Model-Based Systems Engineering
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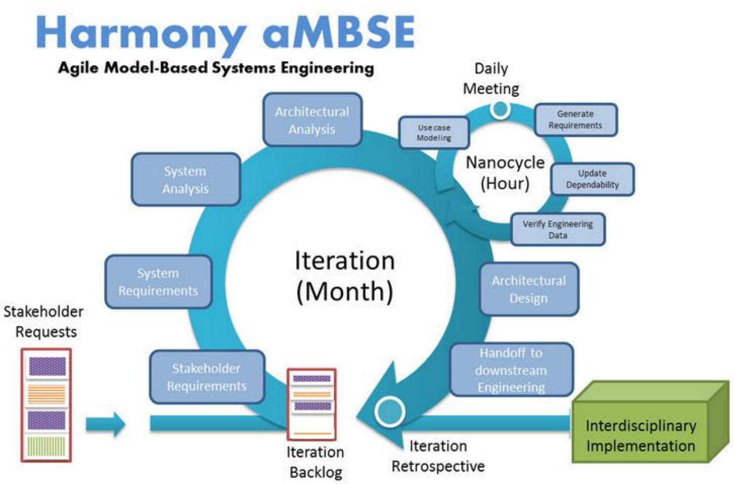
Welcome to the Rational Harmony Agile Model-Based Systems Engineering

Welcome to the Rational Harmony Agile Model-Based Systems Engineering

The Rational Harmony Agile Model-Based Systems Engineering (aMBSE) process is a delivery process for the development of systems engineering data and work product using both model-based systems techniques with UML and SysML but is at the same time agile and incorporates agile practices for improved quality and engineering efficiency.

Main Description



With the initial release of the UML in 1995, systems engineers had a standard language in which they could express requirements, architectures, designs, and other kinds of engineering data. However, there was widespread belief that the Unified Modeling Language (UML) itself was too "software oriented" for general use in systems engineering which led to the development and release of the Systems Modeling Language (SysML). UML and SysML provide a number of key advantages for the development of system engineering data:

- Precision of engineering data
- Data consistency across work products and engineering activities
- A common source for engineering truth
- Improved visualization and comprehension of engineering data
- Ease of integration of disparate engineering data
- Improved management and maintenance of engineering data

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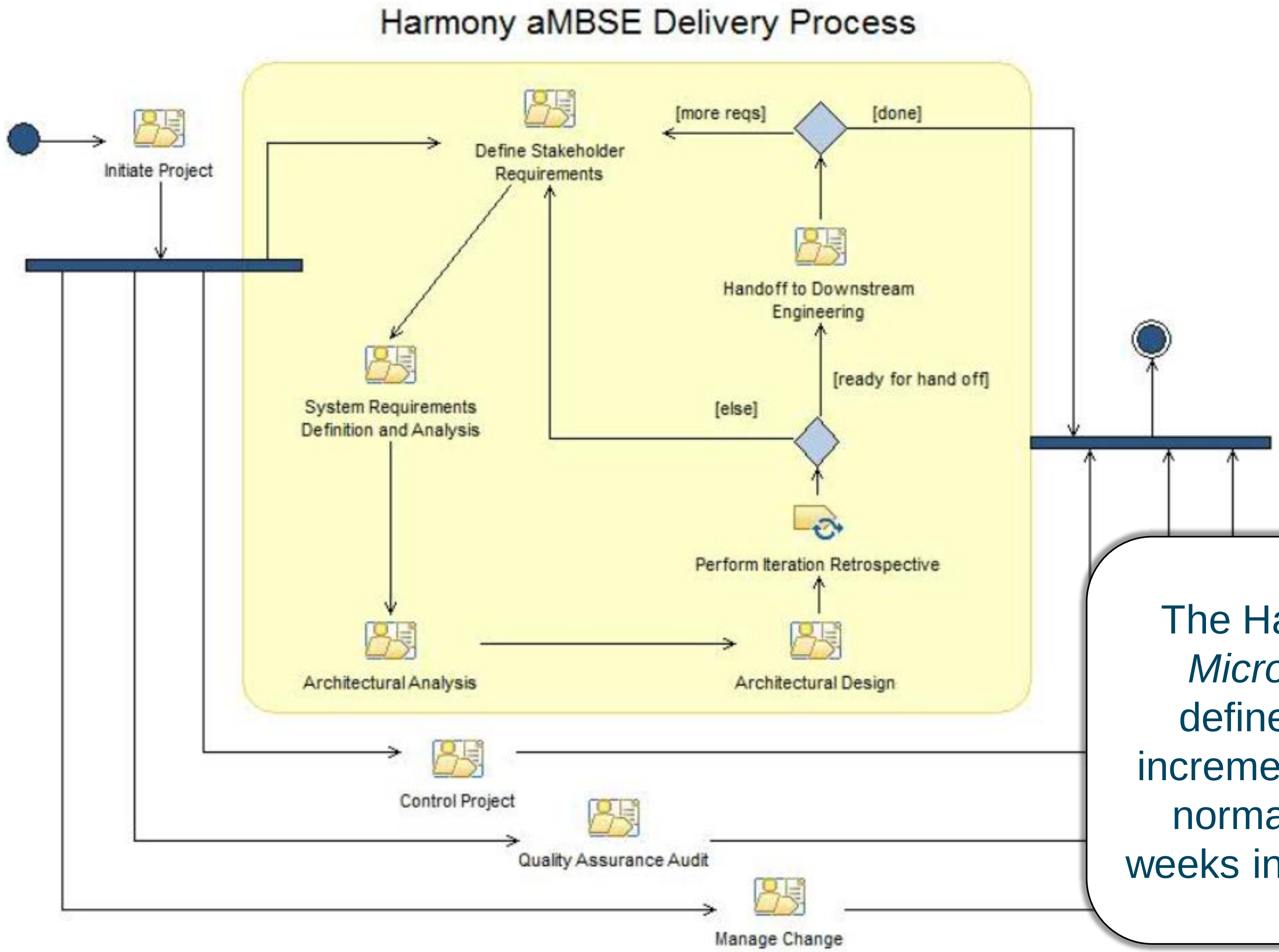
Harmony aMBSE Practices: Incremental Development



The Harmony *Microcycle* defines one increment cycle, normally 1-4 weeks in duration

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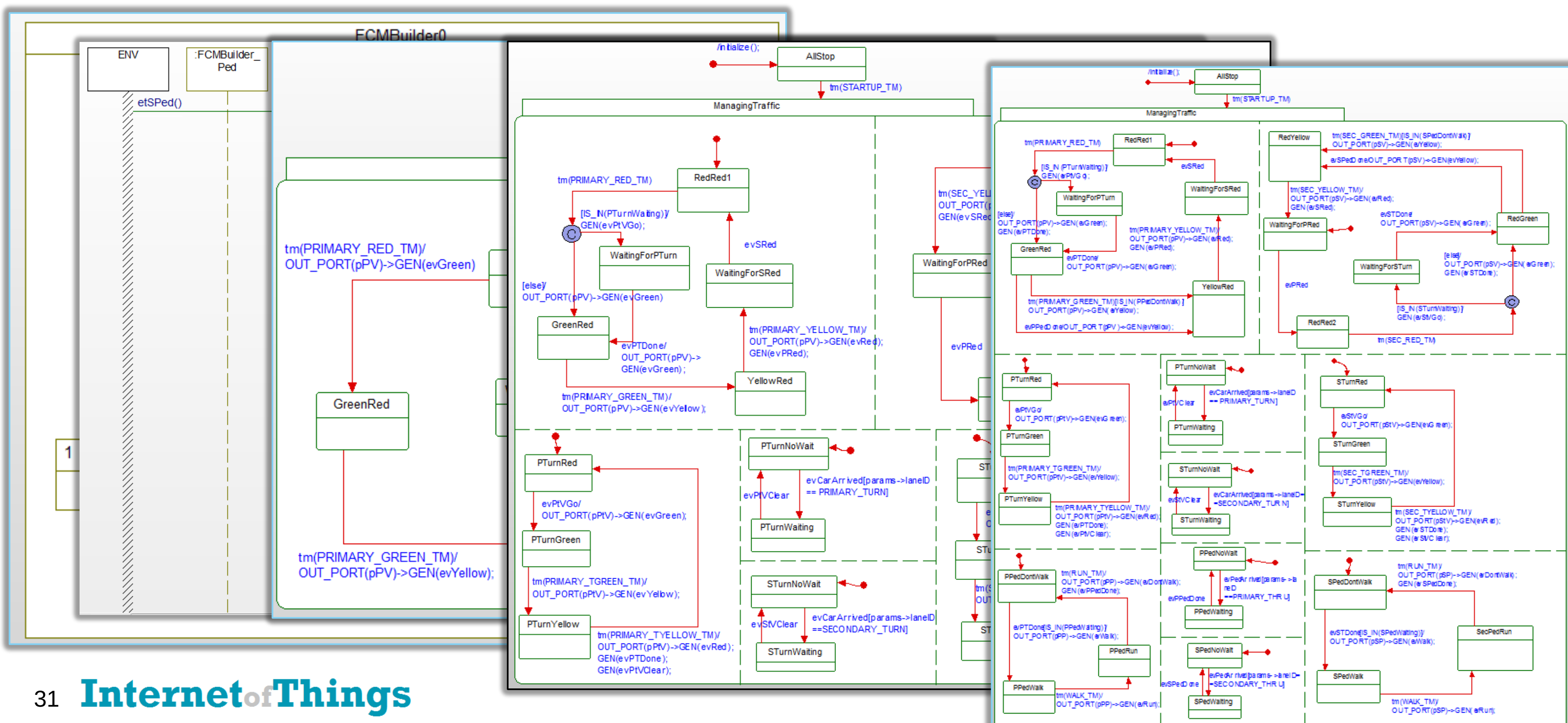
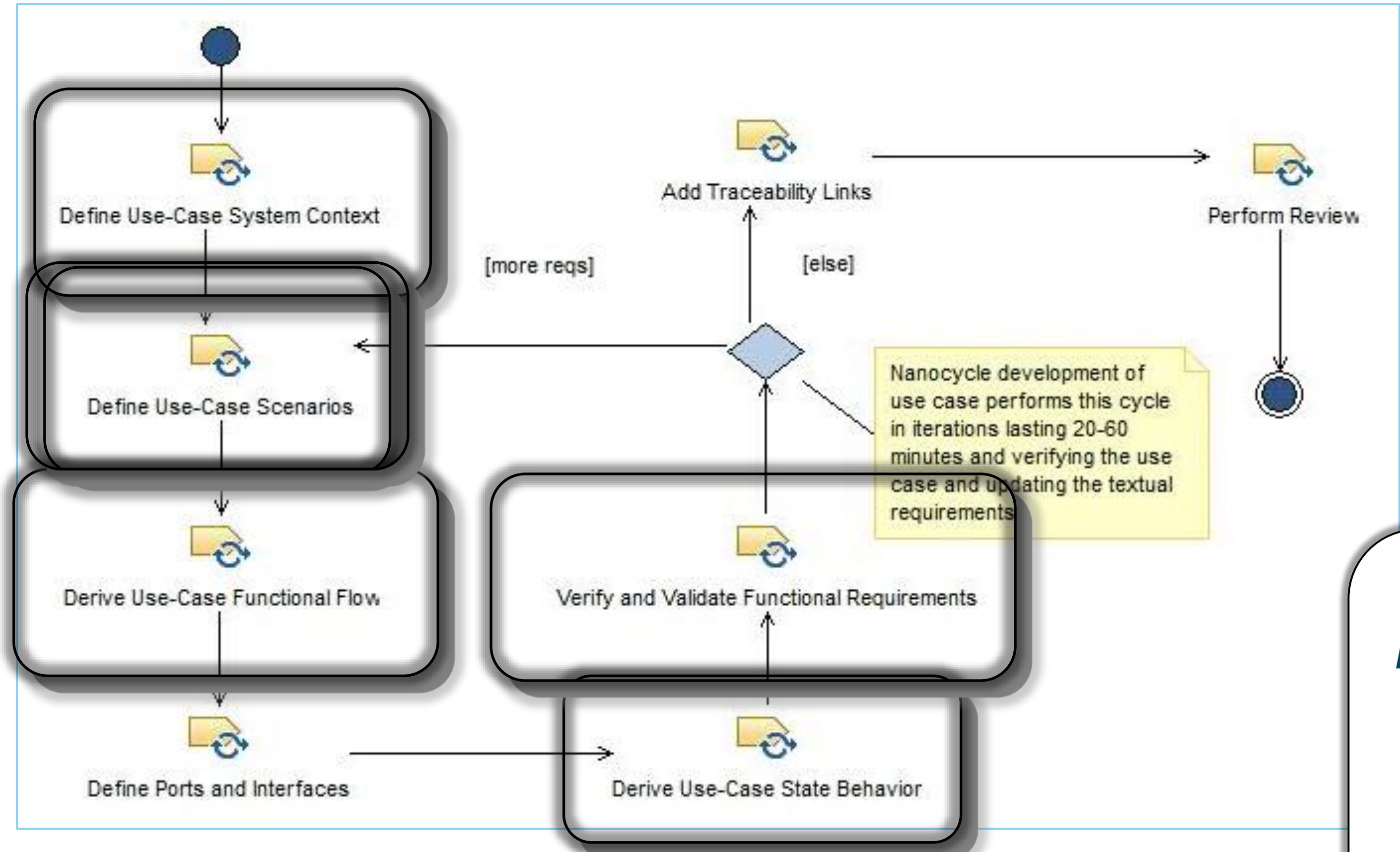
Test-Driven Development for MBSE Work Products

- The principle behind TDD is to develop and apply test cases as you develop a system to demonstrate that it is correct
  - This is done in parallel with the system development and not ex post facto
  - This is about defect avoidance not so much defect identification and repair
- TDD applies to the development of complex system use case, architecture and design models



Scenario Driven Use Case Construction / Validation



The Harmony *Nanocycle* defines a short work product development cycle, 20-60 minutes in duration

Making it Agile

Loop
- **Loop**
  - **Conceptualize requirement aspect**
  - **Incrementally augment model**
  - **Verify**
- **Repeat until all requirements added**

Repeat for all use cases

< 1 hr

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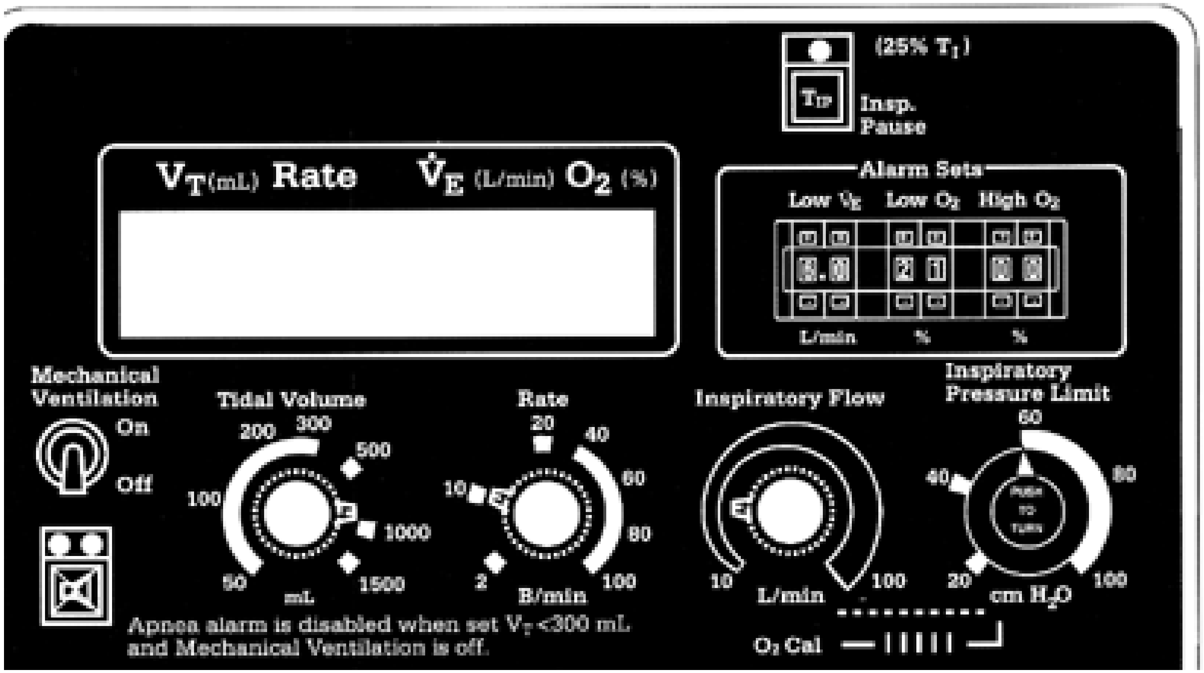
Exploring Requirements – Then vs Now



- The system shall set V_t in the range of 50 to 1500 ml
- The user shall push in the knob to confirm the V_t before the value becomes active
- While monitoring, the system will display measured V_t output
- Respiration Rate shall be set in the range of 2 – 100 b/m
- The user shall push in the Rate knob to confirm the Rate value before it becomes active
- Neonate mode shall support V_t from 50 to 500 ml
- …

- Questions
  - What happens if the user turns the V_t knob *and then turns the Rate knob before pushing in to confirm?*
  - How to I abort a V_t change once started?
  - What happens if the user tries to set the V_t to 1500 and the system is configured for neonates?

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The Traditional Option

- Search through the (hundreds to thousands of) requirements to find the one that answers the question
- Once you've determined that it isn't in the spec, go back to the stakeholder(s) and ask then what you should do
- Or make up something that seems reasonable

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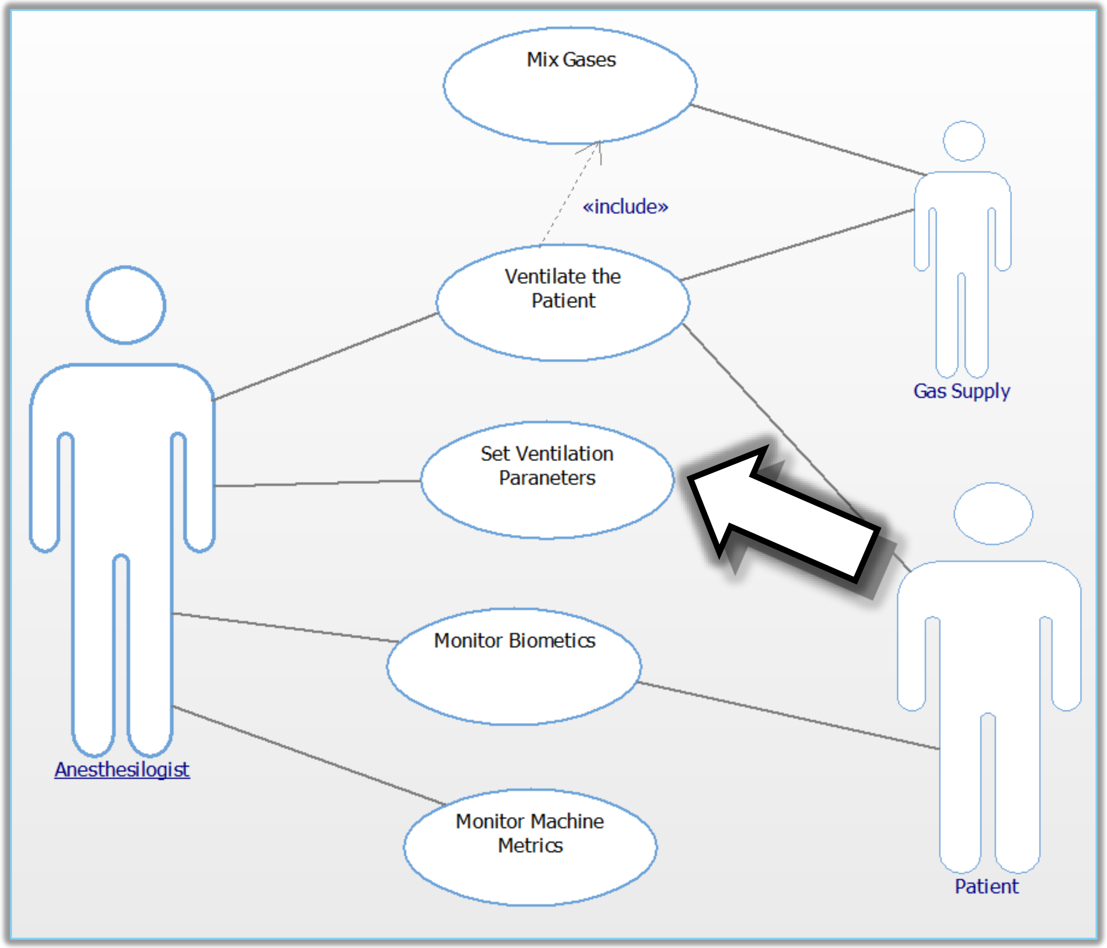
Executable Requirements Models

Benefits

- Ability to explore and evaluate requirements
- Improve ability to identify requirement defects:
    - Missing requirements
    - Incomplete requirements
    - Conflicting requirements
- Provides facilities to do “what about this …?” analysis
- Reliably results in *better requirements*



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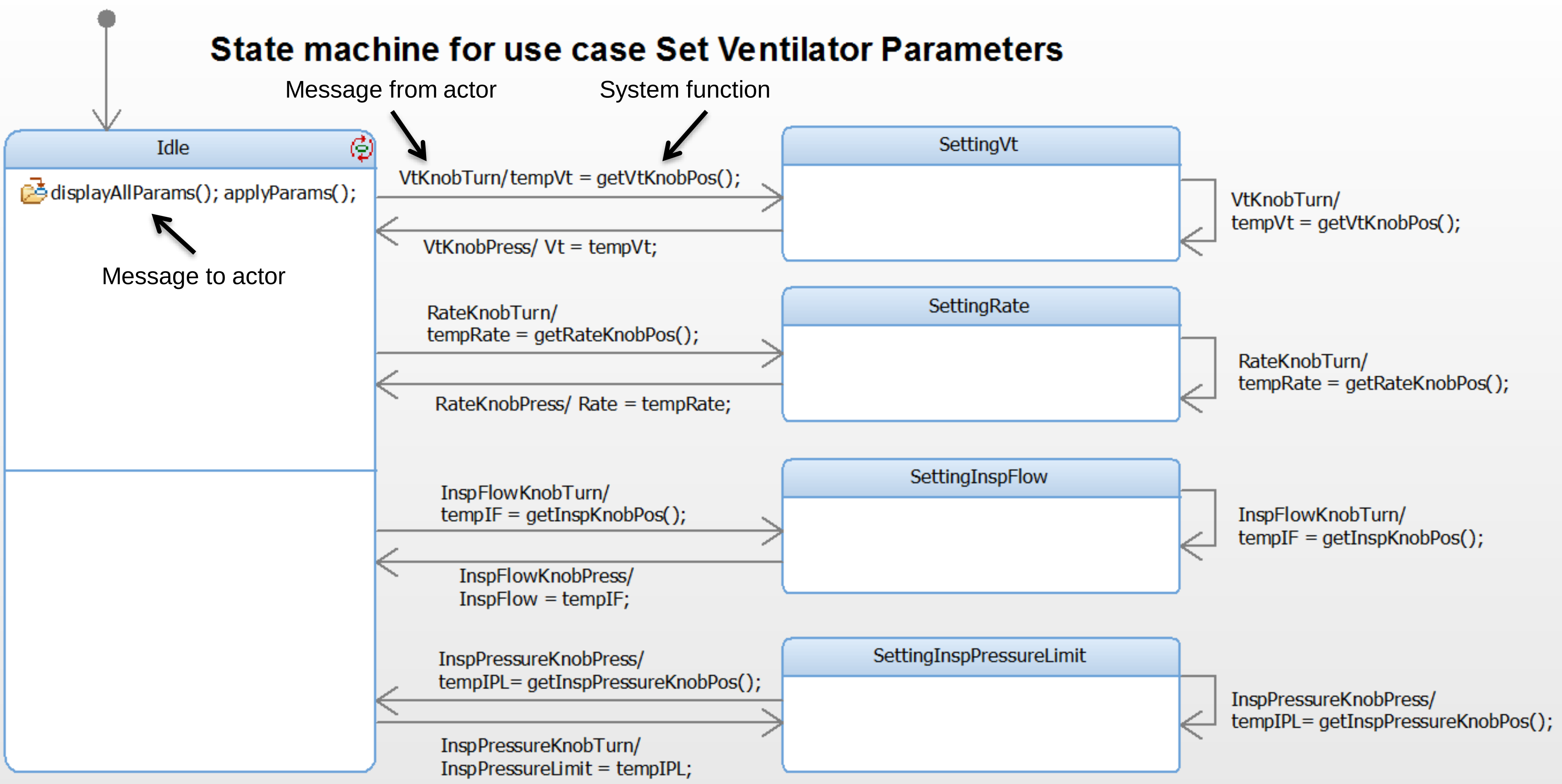
The Modeling Option



Note that this state machine is a precise specification of **requirements**, and not design

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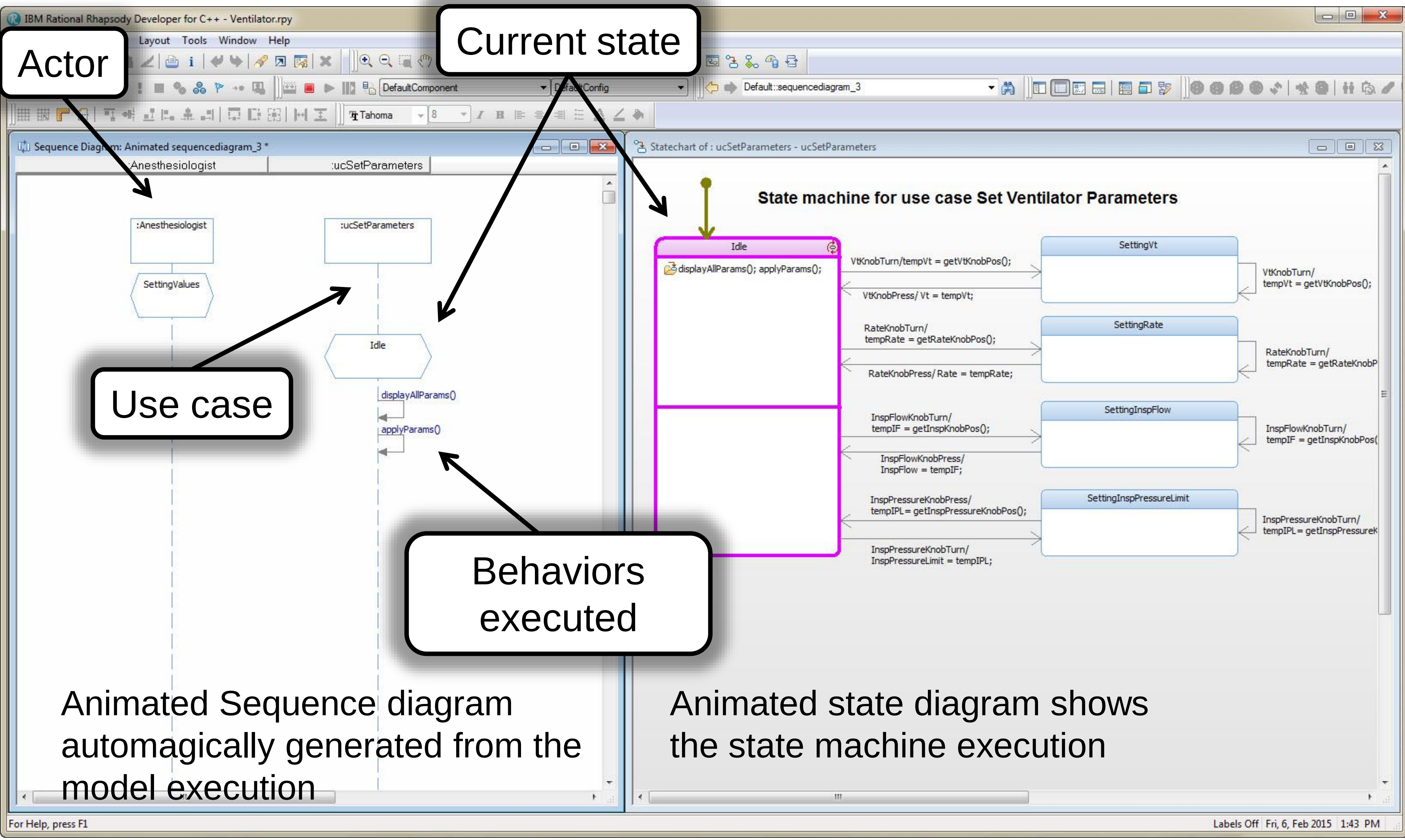
Running the Requirements Model



Animated Sequence diagram automagically generated from the model execution

Animated state diagram shows the state machine execution

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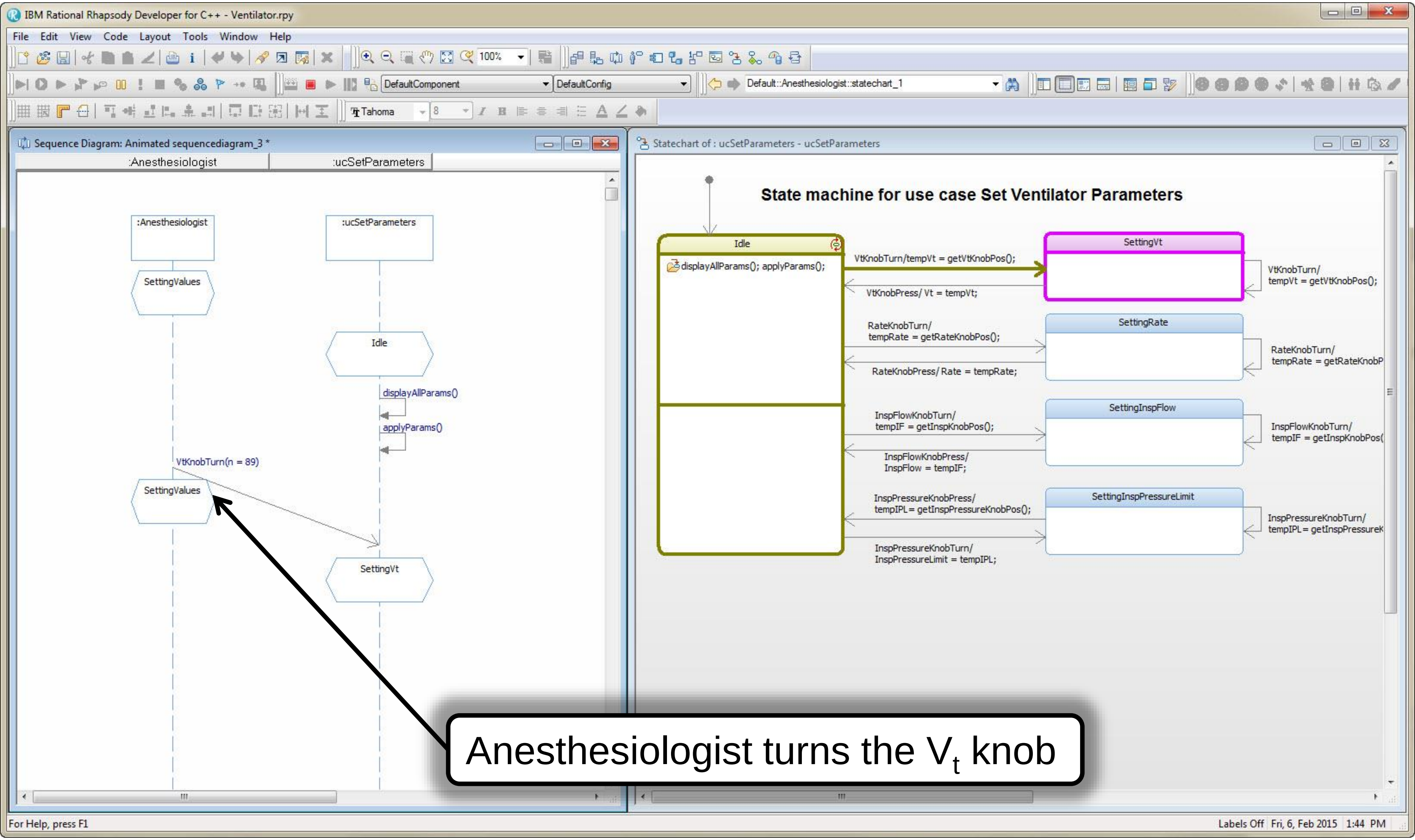
Running the Requirements Model



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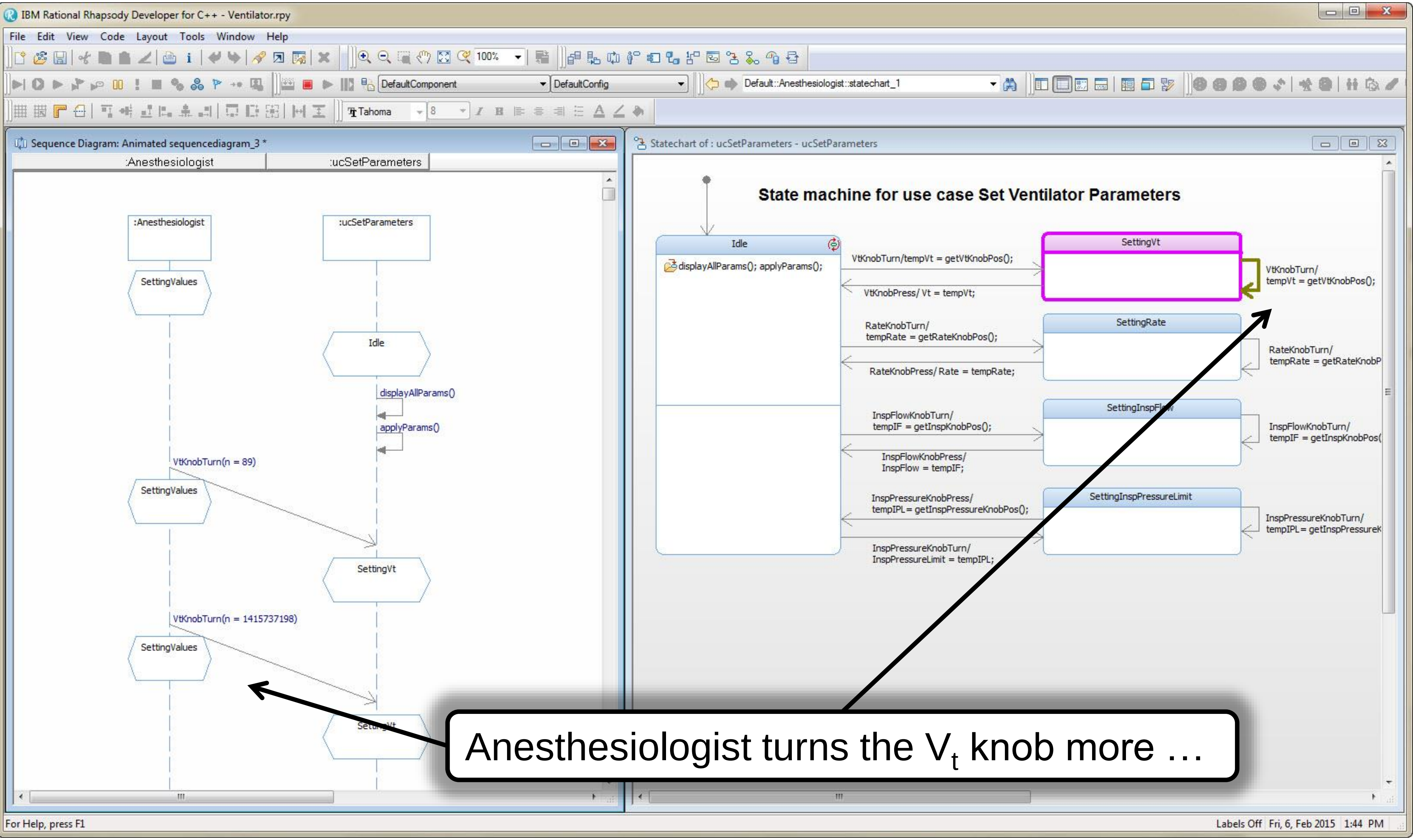
Running the Requirements Model



Anesthesiologist turns the V_t knob more …

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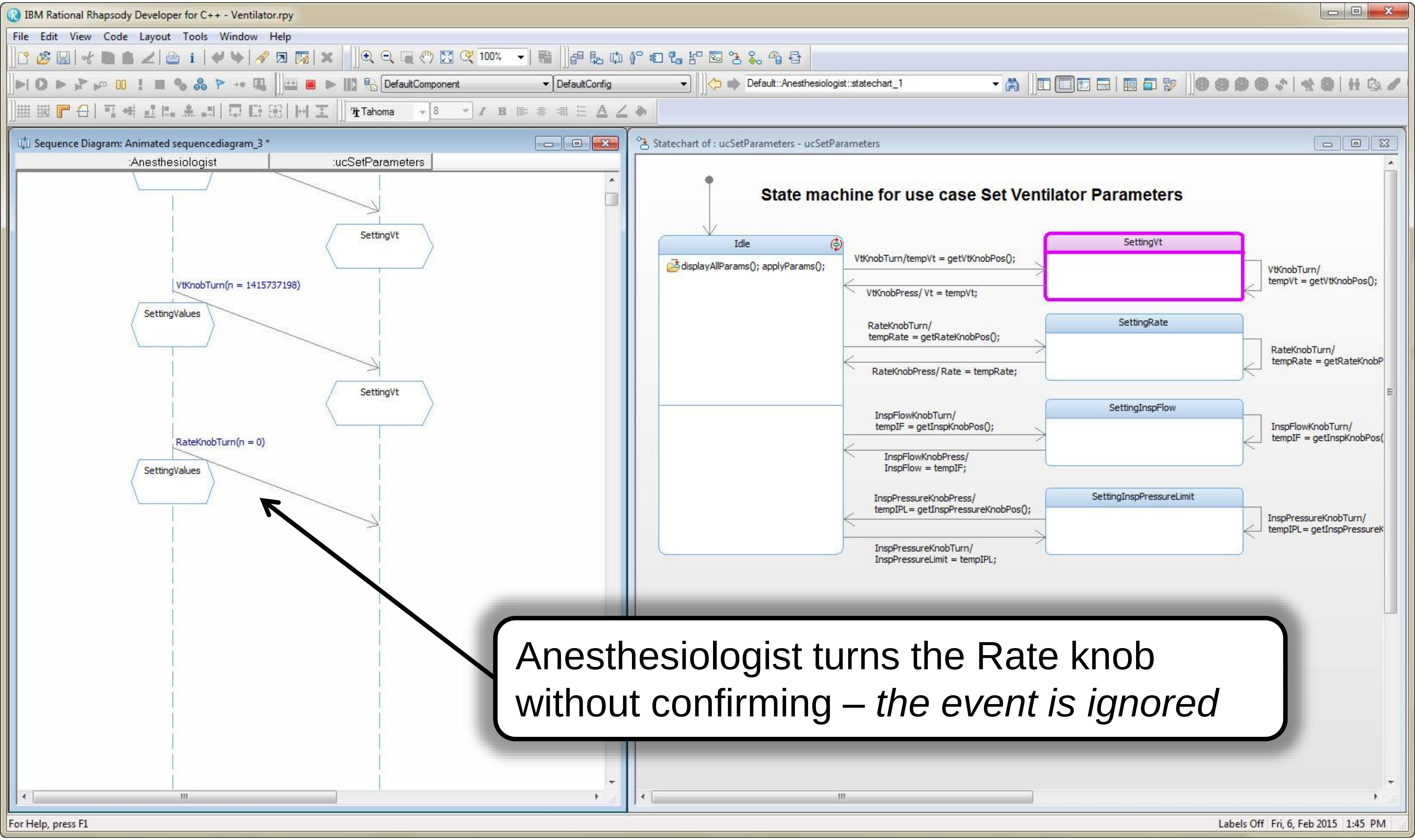
Running the Requirements Model



Anesthesiologist turns the Rate knob without confirming – *the event is ignored*

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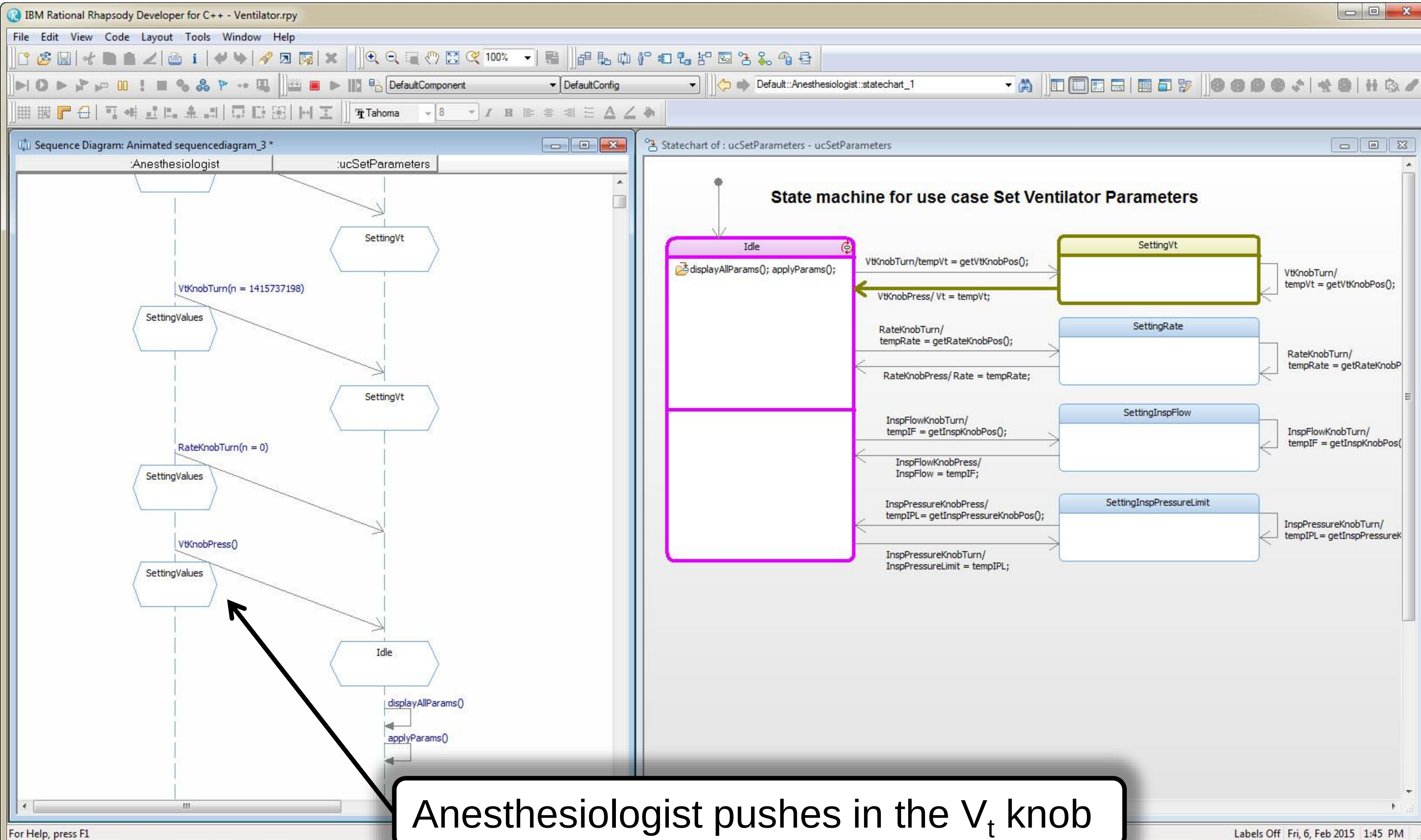
Running the Requirements Model



Anesthesiologist pushes in the V_t knob

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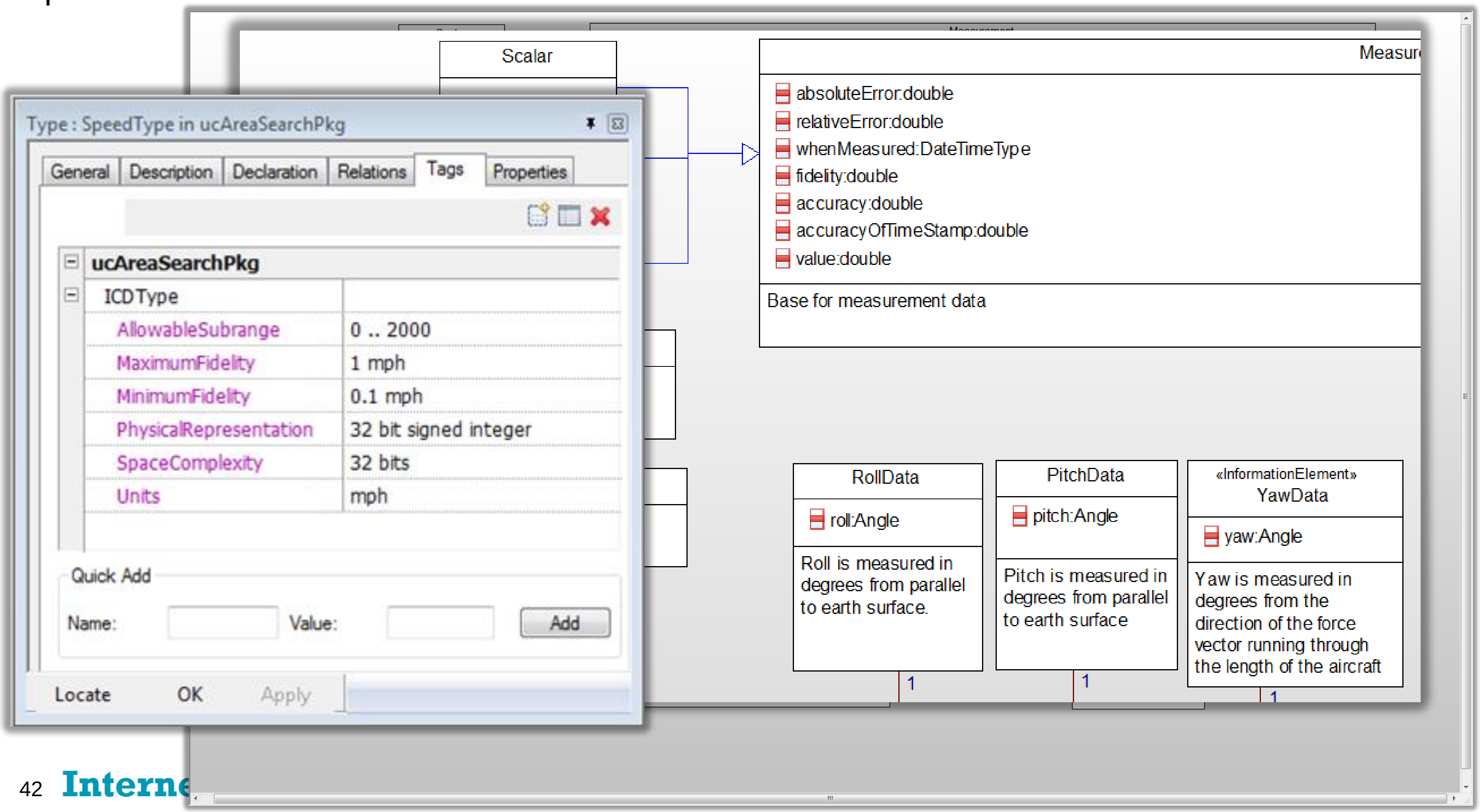
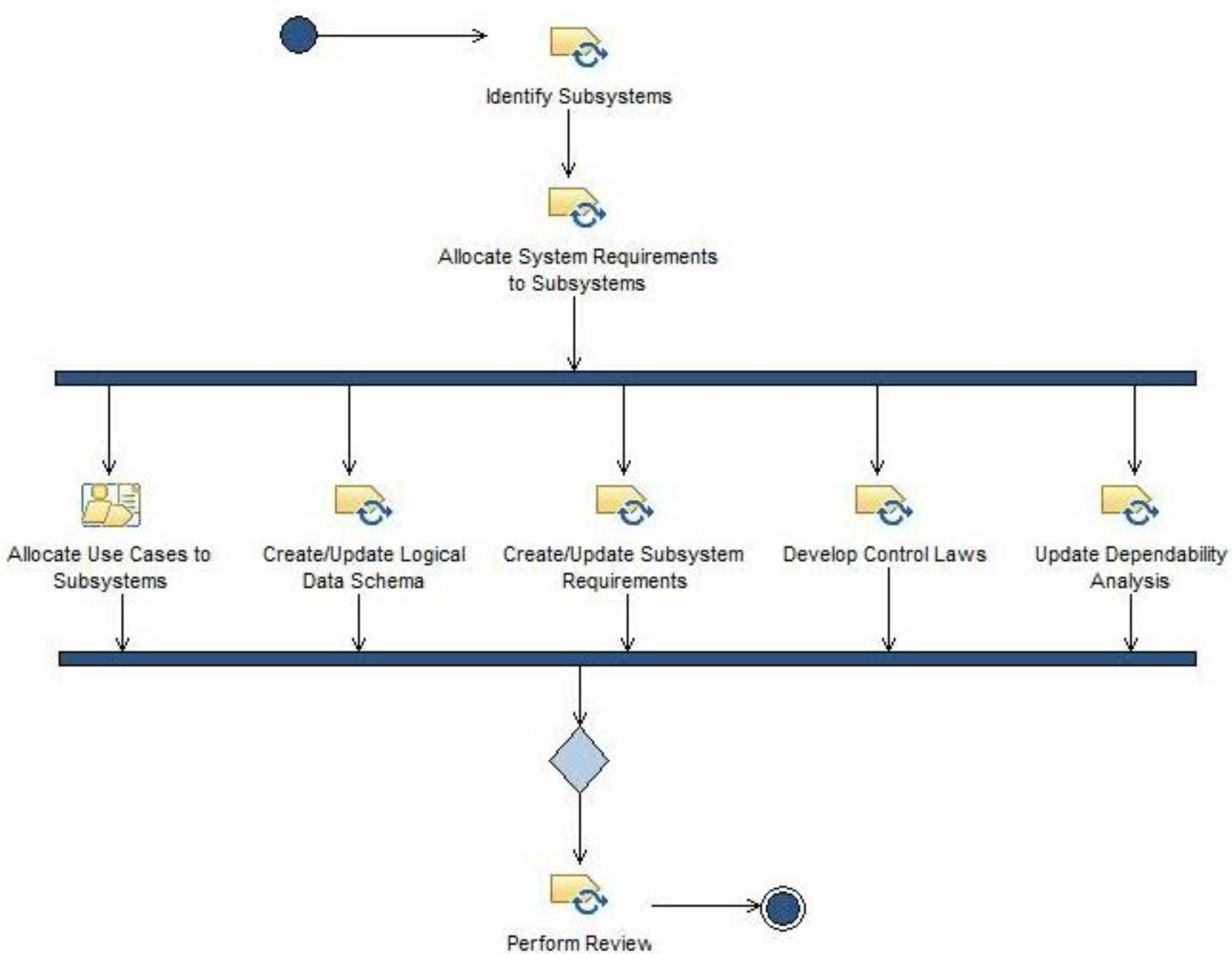
Logical Data and Flow Schema Modeling

- A logical data schema identifies the logical properties of important data elements and types and the relations among such data elements and their metadata
- Although the name is “data schema” it includes physical, materiel, and energy flows specification as well



Specifying System Architecture



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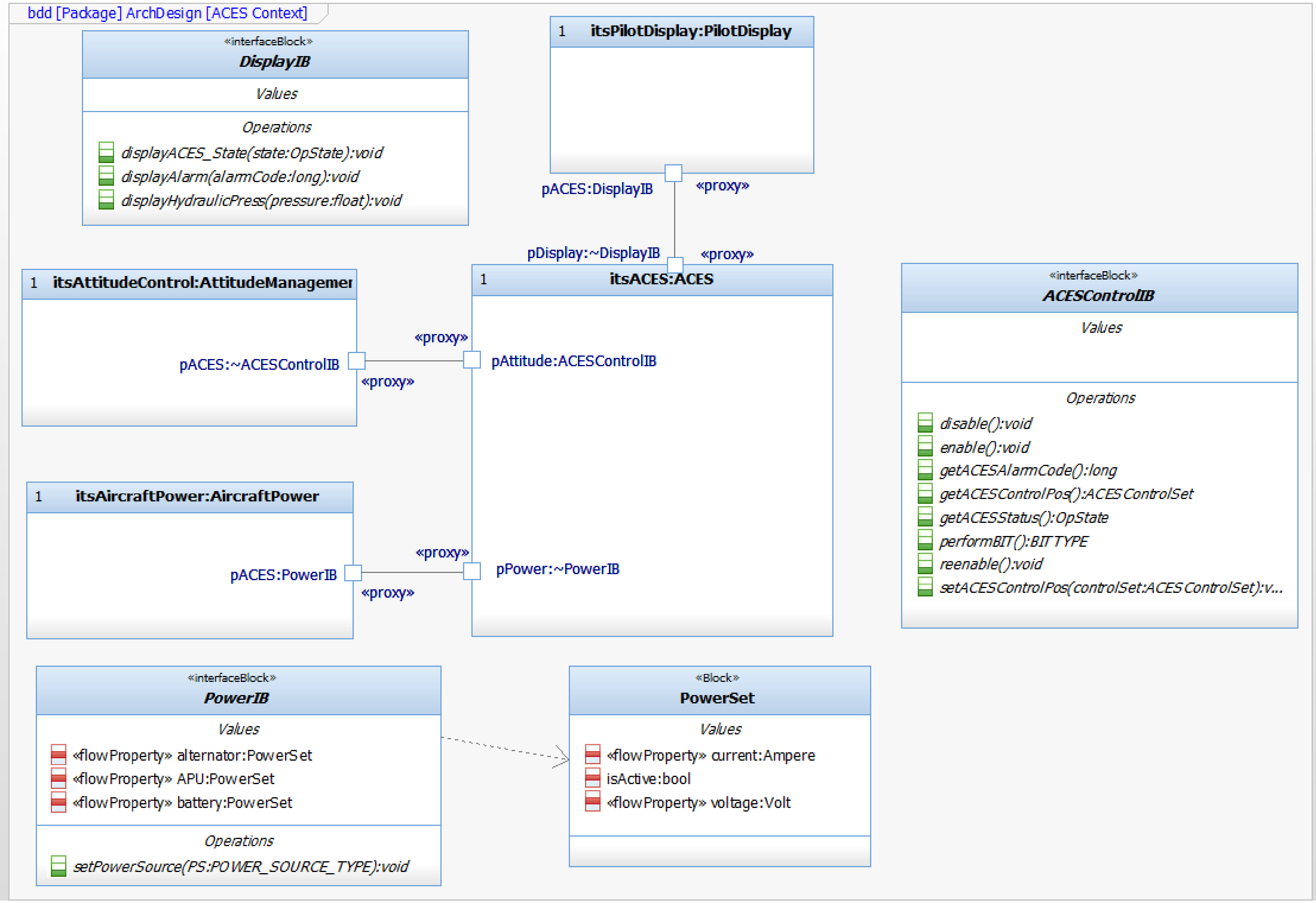
Architecture: System Context



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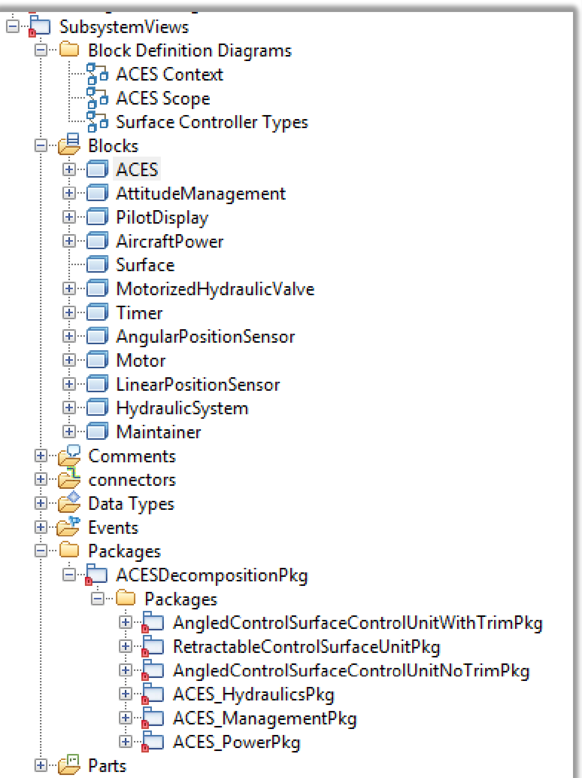
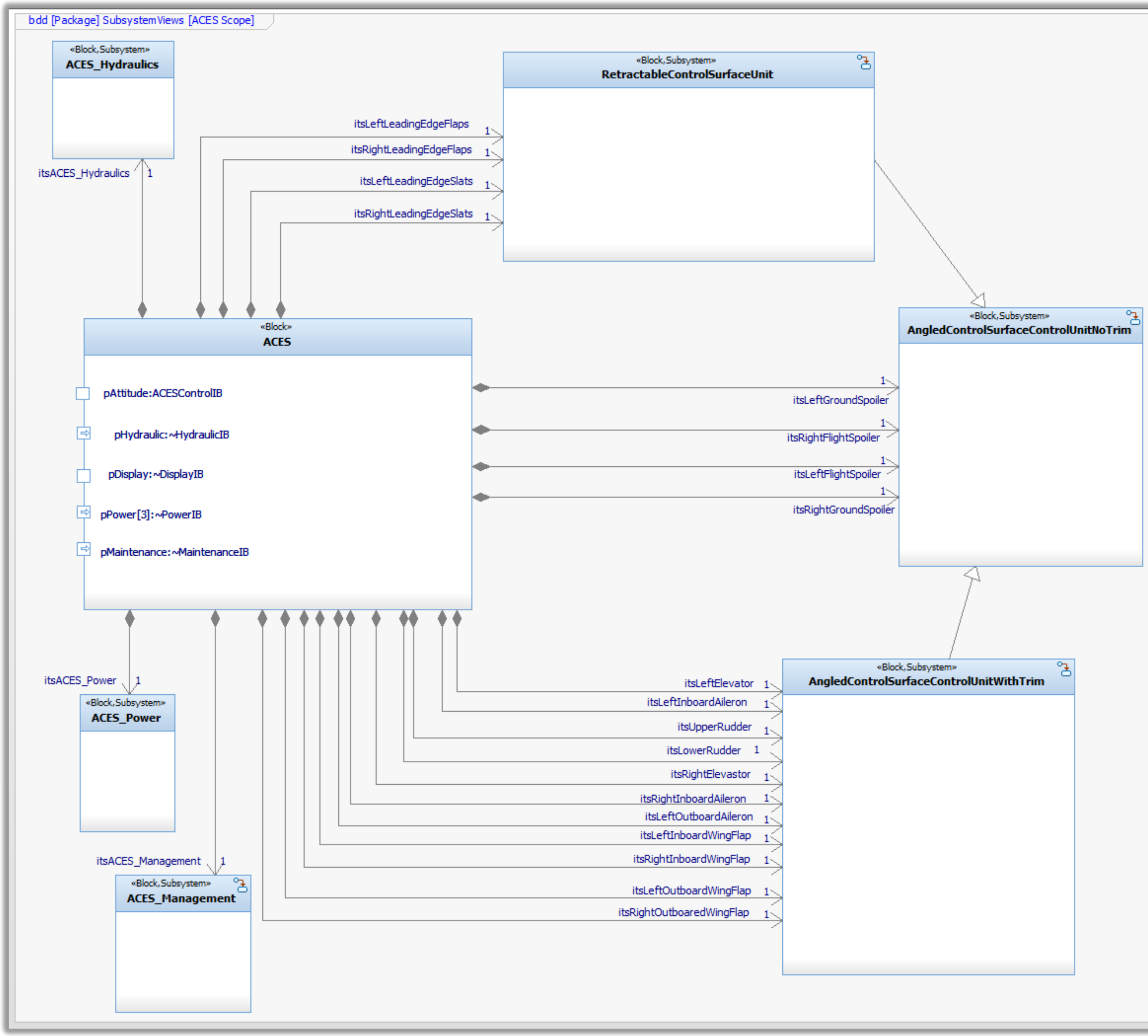
Architecture Structure 2





Showing the physical messaging details for an ICD*

- ICD tables can be constructed automatically from model data. Here we see columns:
  - Message name
  - Message content field
  - Content field type
  - Content field metadata value, such as
    - Range
    - Format
    - Accuracy
    - Fidelity
    - Timing
    - …

Name in cls	Name in Attr	Classifier in Attr	Name in tags	Value in tags
CBP_HydraulicStatus	status	HydraulicStatus		
CBP_Move	position	double	Numer_Of_Bytes	4
CBP_Move	surfaceID	SurfaceIDType		
CBP_Move	position	double	Format	4-byte IEEE floating point format
CBP_Move	position	double	Usage	Commanded position
CBP_MoveDone	surfaceID	SurfaceIDType	Numer_Of_Bytes	1
CBP_MoveDone	timeUsed	Interval_In_MS	Usage	Duration of movement time in ms
CBP_MoveDone	timeUsed	Interval_In_MS	Starting_Byte_Number	5
CBP_MoveDone	posAchieved	double	Format	4-byte IEEE floating point format
CBP_MoveDone	posAchieved	double	Numer_Of_Bytes	4
CBP_MoveDone	posAchieved	double	Usage	The measured position achieved in movement
CBP_MoveDone	posAchieved	double	Starting_Byte_Number	1
CBP_MoveDone	posAchieved	double	Endianism	Big
CBP_MoveDone	timeUsed	Interval_In_MS	Numer_Of_Bytes	4
CBP_MoveDone	surfaceID	SurfaceIDType	Endianism	Big
CBP_MoveDone	surfaceID	SurfaceIDType	Starting_Byte_Number	0
CBP_MoveDone	surfaceID	SurfaceIDType	Usage	ID of the referenced control surface
CBP_MoveDone	timeUsed	Interval_In_MS	Endianism	Big
CBP_PowerSource	powerSource	POWERSOURCE_TYPE		
CBP_PowerStatus	status	PowerStatus		
CBP_ReportError	when	TimeDate_Type		
CBP_ReportError	errorType	ERROR_TYPE		
CBP_ReportError	surfaceID	SurfaceIDType		
CBP_RequestConfiguration	surfaceID	SurfaceIDType		
CBP_RequestSWStatus	surfaceID	SurfaceIDType		
CBP_State	stateID	SystemOperationalState	Endianism	Big
CBP_SurfaceConfiguration	lowPos	double	Starting_Byte_Number	0
CBP_SurfaceConfiguration	lowPos	double	Usage	spec for low movement range end point. Starting_Byte is relative to start of contents.
CBP_SurfaceConfiguration	lowPos	double	Endianism	Big
CBP_SurfaceConfiguration	lowTrimPos	double	Starting_Byte_Number	8
CBP_SurfaceConfiguration	lowTrimPos	double	Usage	Spec for low end of Trim range. Number of BYtes is relative to start of contents.
CBP_SurfaceConfiguration	lowTrimPos	double	Format	4-byte IEEE floating point format
CBP_SurfaceConfiguration	lowTrimPos	double	Endianism	Big
CBP_SurfaceConfiguration	lowTrimPos	double	Numer_Of_Bytes	4
CBP_SurfaceConfiguration	highPos	double	Numer_Of_Bytes	4
CBP_SurfaceConfiguration	surfaceID	SurfaceIDType	Endianism	Big
CBP_SurfaceConfiguration	surfaceID	SurfaceIDType	Numer_Of_Bytes	1
CBP_SurfaceConfiguration	surfaceID	SurfaceIDType	Starting_Byte_Number	22
CBP_SurfaceConfiguration	surfaceID	SurfaceIDType	Usage	Id of the surface this configuration refers to. Number of BYtes is relative to start of contents.
CBP_SurfaceConfiguration	highExtPos	double	Starting_Byte_Number	20
CBP_SurfaceConfiguration	highExtPos	double	Numer_Of_Bytes	4
CBP_SurfaceConfiguration	lowPos	double	Format	4-byte IEEE floating point format
CBP_SurfaceConfiguration	highExtPos	double	Usage	Spec for high end of extension range. Number of BYtes is relative to start of contents.
CBP_SurfaceConfiguration	highExtPos	double	Endianism	Big
CBP_SurfaceConfiguration	highExtPos	double	Format	4-byte IEEE floating point format
CBP_SurfaceConfiguration	lowPos	double	Numer_Of_Bytes	4
CBP_SurfaceConfiguration	lowExtPos	double	Starting_Byte_Number	16
CBP_SurfaceConfiguration	lowExtPos	double	Format	4-byte IEEE floating point format
CBP_SurfaceConfiguration	lowExtPos	double	Usage	Spec for low end of extension range. Number of BYtes is relative to start of contents.
CBP_SurfaceConfiguration	lowExtPos	double	Numer_Of_Bytes	4
CBP_SurfaceConfiguration	lowExtPos	double	Endianism	Big
CBP_SurfaceConfiguration	highTrimPos	double	Endianism	Big
CBP_SurfaceConfiguration	highTrimPos	double	Usage	Spec for high end of trim range. Number of BYtes is relative to start of contents.
CBP_SurfaceConfiguration	highTrimPos	double	Format	4-byte IEEE floating point format
CBP_SurfaceConfiguration	highTrimPos	double	Numer_Of_Bytes	4

* Interface Control Document

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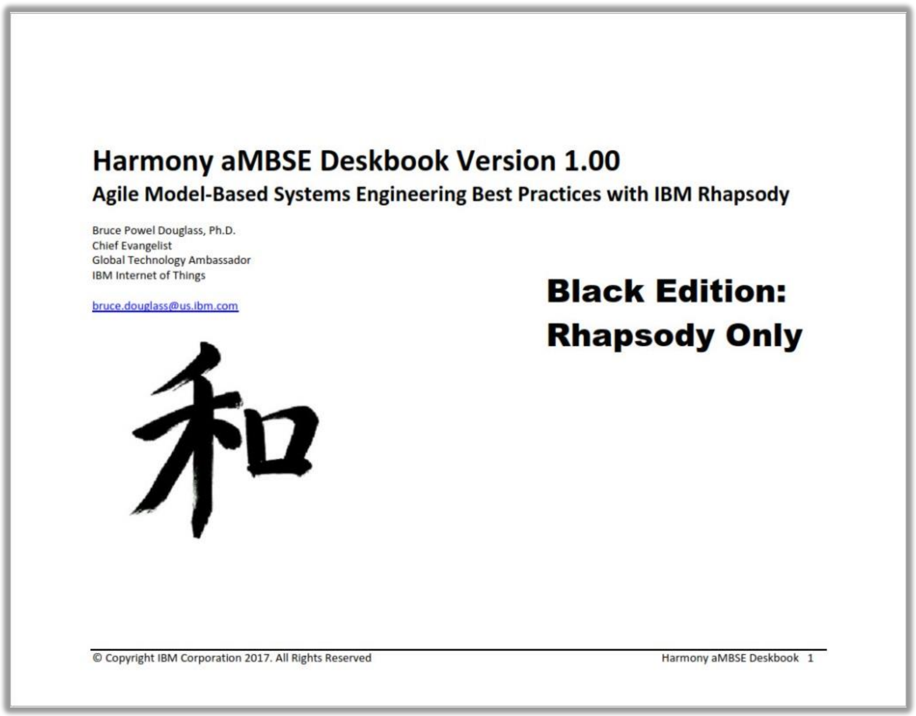

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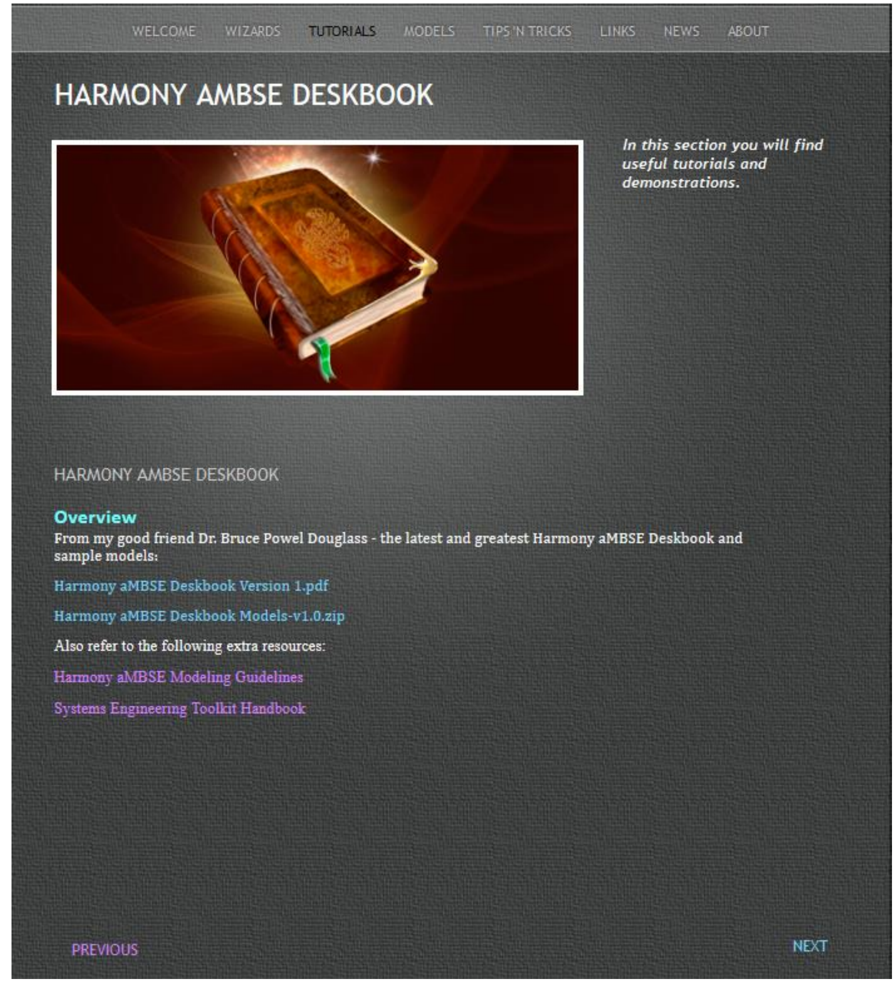

merlinscave.info/Merlins_Cave/Tutorials/Entries/2017/9/13_Harmony_aMBSE_Deskbook.html

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Other Free Stuff

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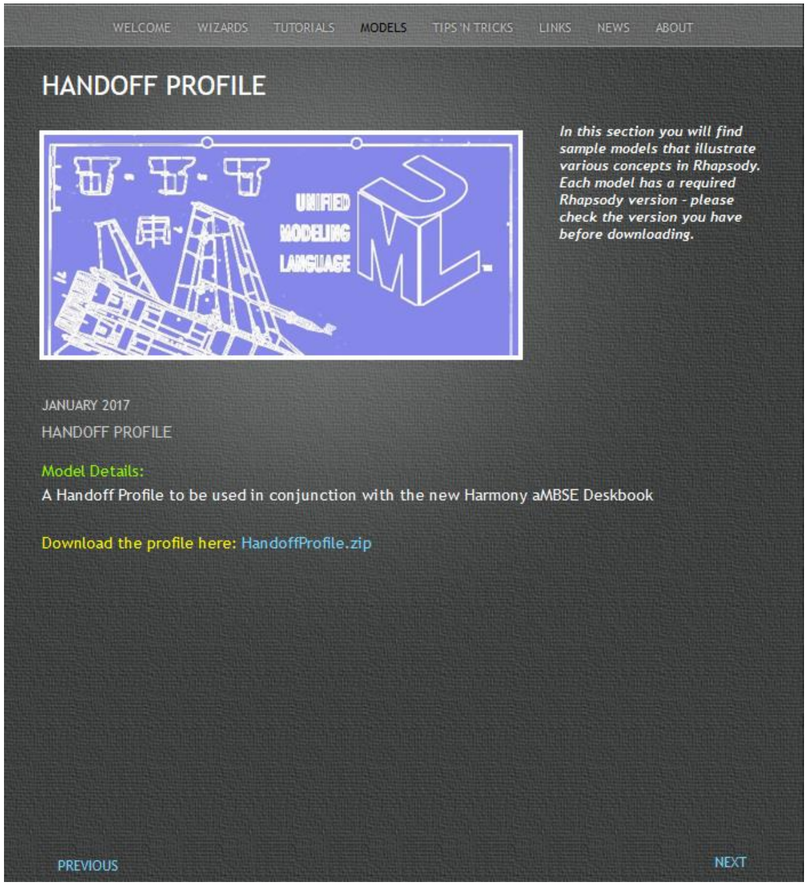

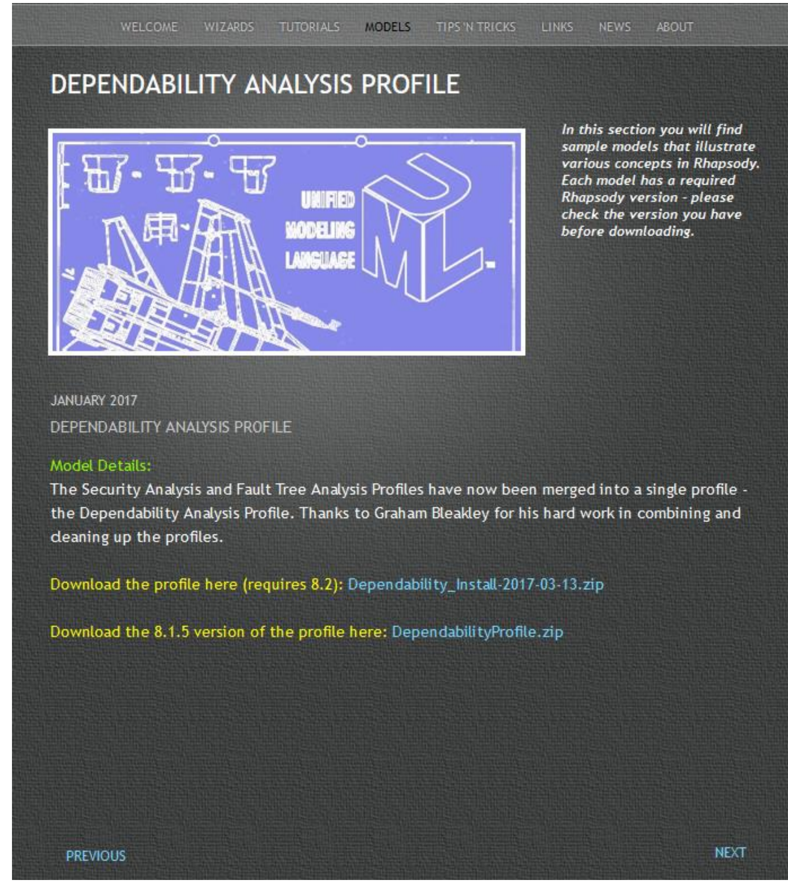

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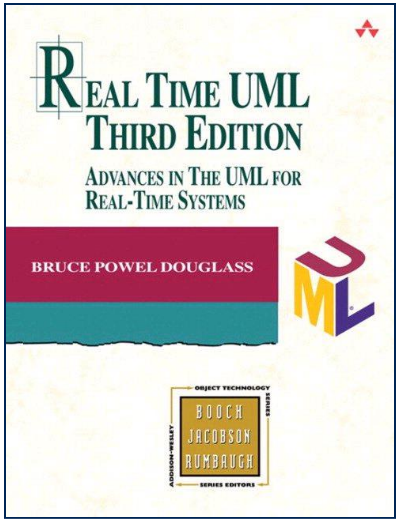
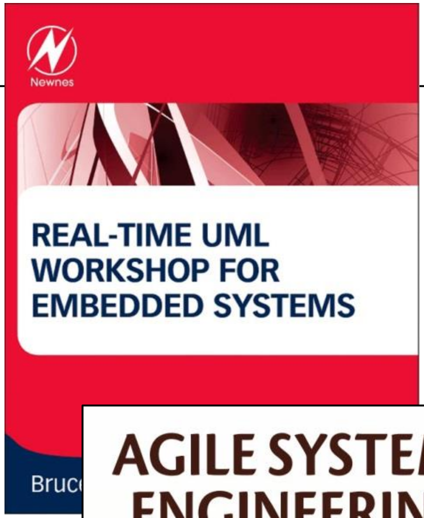
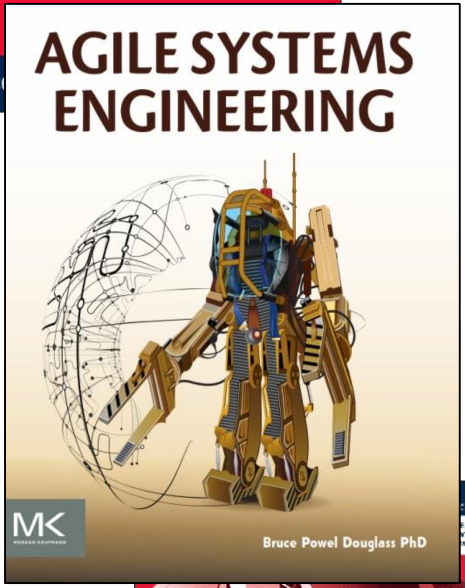
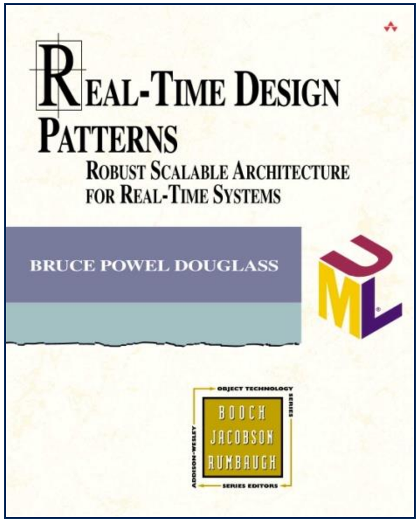
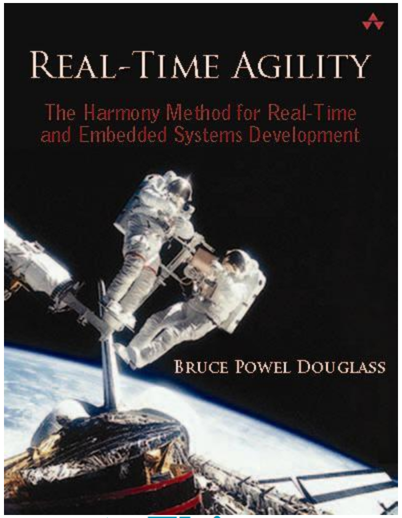
References

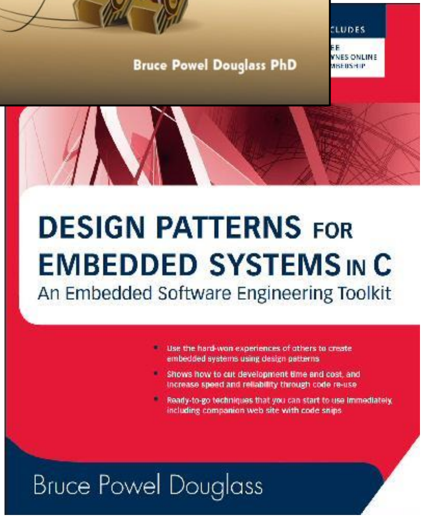


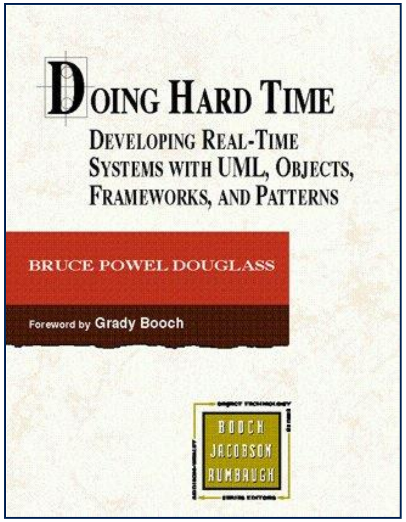












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