Spring 2013

Adopting Model-Based System Engineering Tools

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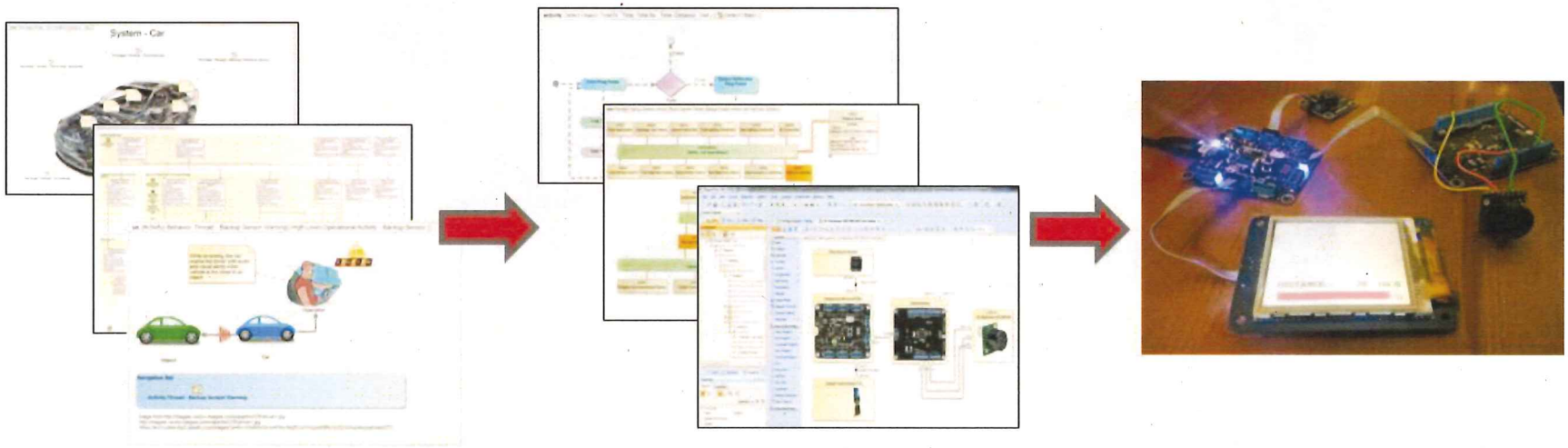
ADOPTING MODEL-BASED SYSTEM ENGINEERING TOOLS



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SELP695

SPRING 2013

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PROJECT GOALS

- **Identify the benefits and limitations of two categories of Model-Based System Engineering (MBSE) modeling tools**

Entry-Level MBSE Tools

Image derived from: webpages.scu.edu, microsoft.com, openoffice.org, libreoffice.org

Professional MBSE Tools

Image derived from: static.ddmcdn.com, atego.com, nomagic.com, ibm.com, sparxsystems.com

- **Conduct a benefit-to-cost analysis of both MBSE tool types**
- **Determine if professional MBSE tools is worth the increased cost and effort required to adopt**

BACKGROUND AND MOTIVATION FOR THE PROJECT

- **Currently attempting to implement MBSE in a early phased program with significant resistant to adopting MBSE tools:**
  - General cultural resistance to change
  - Security and Information Technology (IT) department approvals for new software tools
  - Cost & schedule constraints
- **An entry-level MBSE tool (Visio) is currently being used because Professional MBSE tools are not available nor approved in the closed area**
  - Is an Entry-Level MBSE tool good enough?
  - Is a Professional MBSE tool worth the cost and trouble of acquiring all the organizational approvals?

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AGENDA

- Introduction to Model Based System Engineering (MBSE)
- Project Study Approach and Results
- Supporting Lean Principles with MBSE Tools
- Ethical Considerations and Importance of the Study
- Summary and Recommendations

INTRODUCTION TO MODEL BASED SYSTEM ENGINEERING (MBSE)

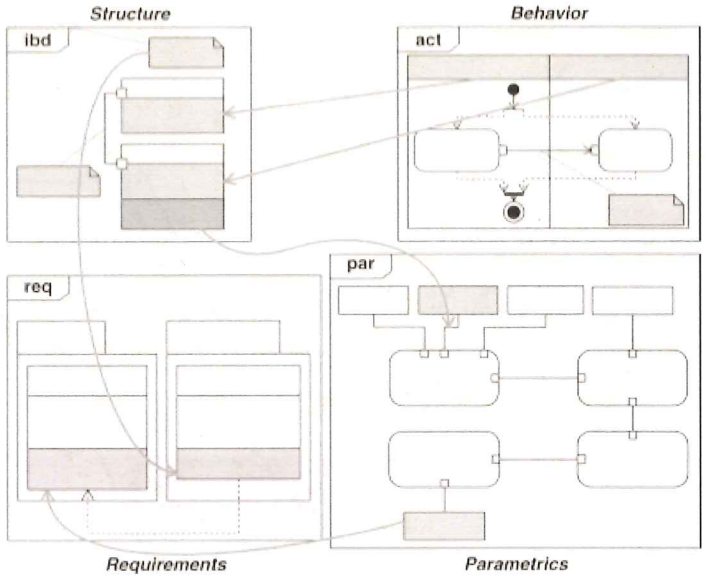

Image Source: A Practical Guide to SysML

SYSTEMS ENGINEERING PROCESS

- **Systems Engineering** is an interdisciplinary approach and means to enable the realization of successful systems. It focuses on defining customer **needs** and required **functionality** early in the development cycle, documenting **requirements**, then proceeding with design **synthesis** and system **validation** while considering the complete problem [Source: INCOSE]

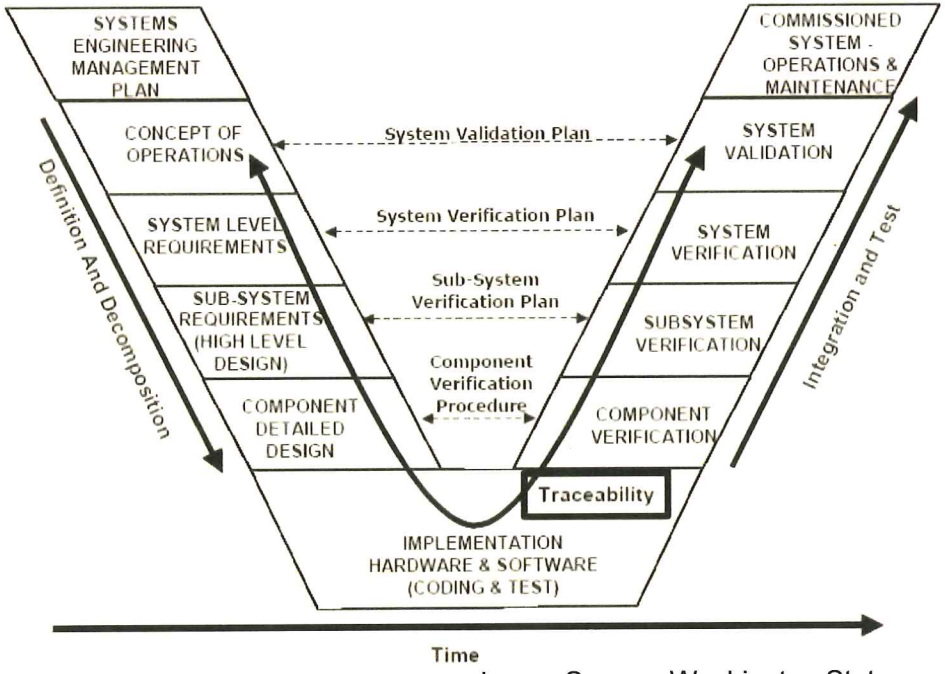

Image Source: Washington State Department of Transportation

DOCUMENT BASED SYSTEMS ENGINEERING

- **"The generation of textual specifications and design documents, in hard-copy or electronic format, that are then exchanged between customers, users, developers, and testers. The Systems Engineer emphasis is placed on controlling the documentation and ensuring the documents are valid, complete, and consistent, and that the developed system complies with the documentation." [A Practical Guide to SysML, Sanford Friedenthal]**

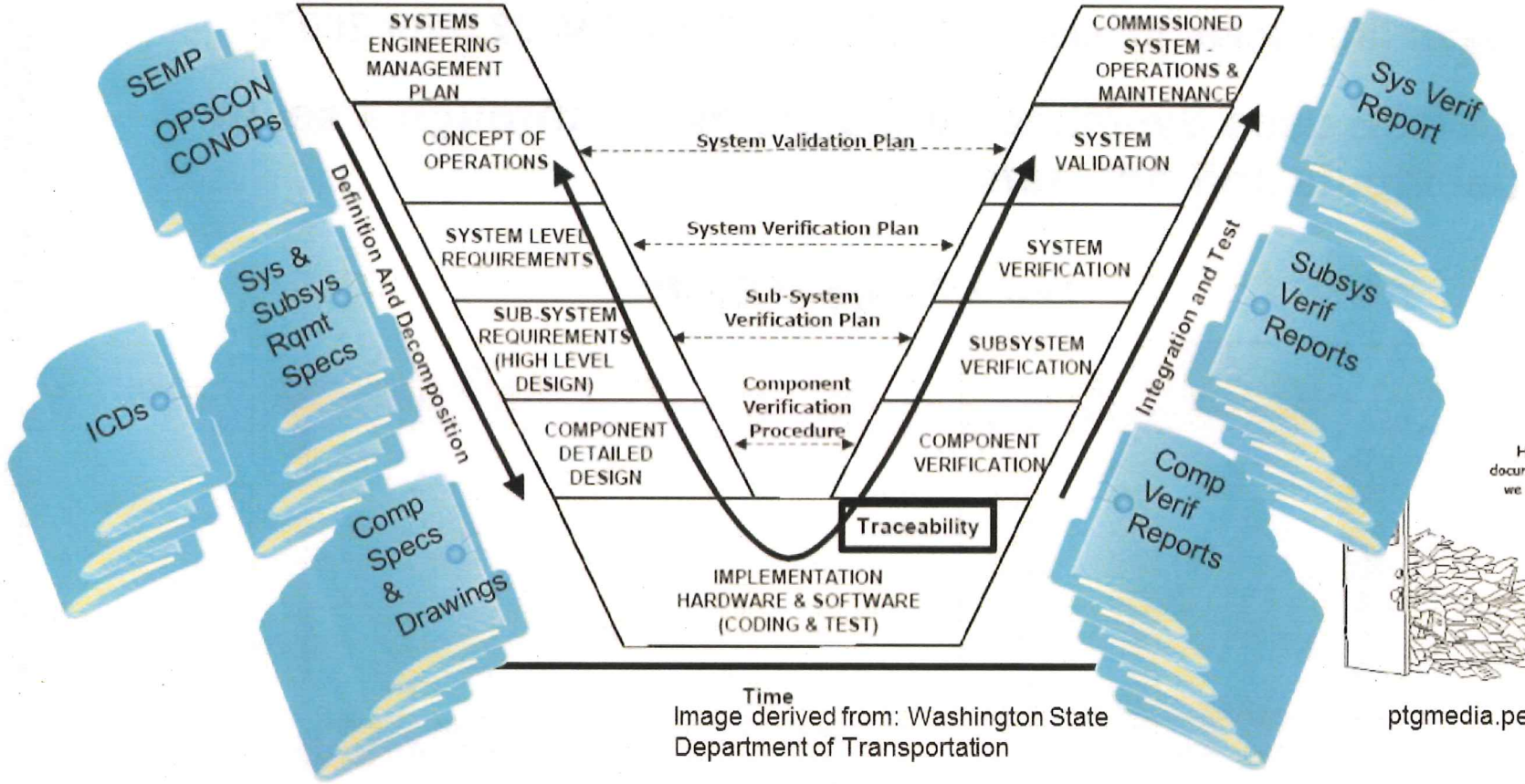

Image derived from: Washington State Department of Transportation

Image Source: ptgmedia.pearsoncmg.com

MODEL-BASED SYSTEM ENGINEERING

- "Model-based system 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 the development and later life cycles phases [INCOSE-TP-2004-004-02 Sept 2007]"
- The MBSE uses SysML to define the model through a set of visual inputs and rule-sets

The 4 Pillars of SysML

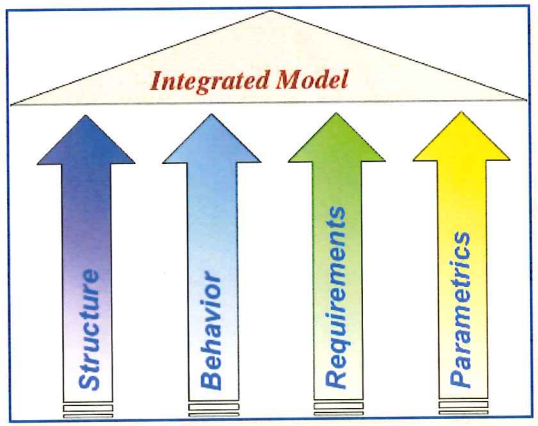

Image Source: Mandi-Alvidrez

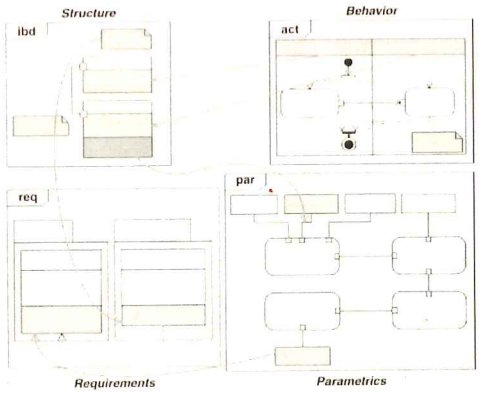

Image Source: A Practical Guide to SysML

MAPPING THE MODEL TO THE SYSTEM ENGINEERING PROCESS

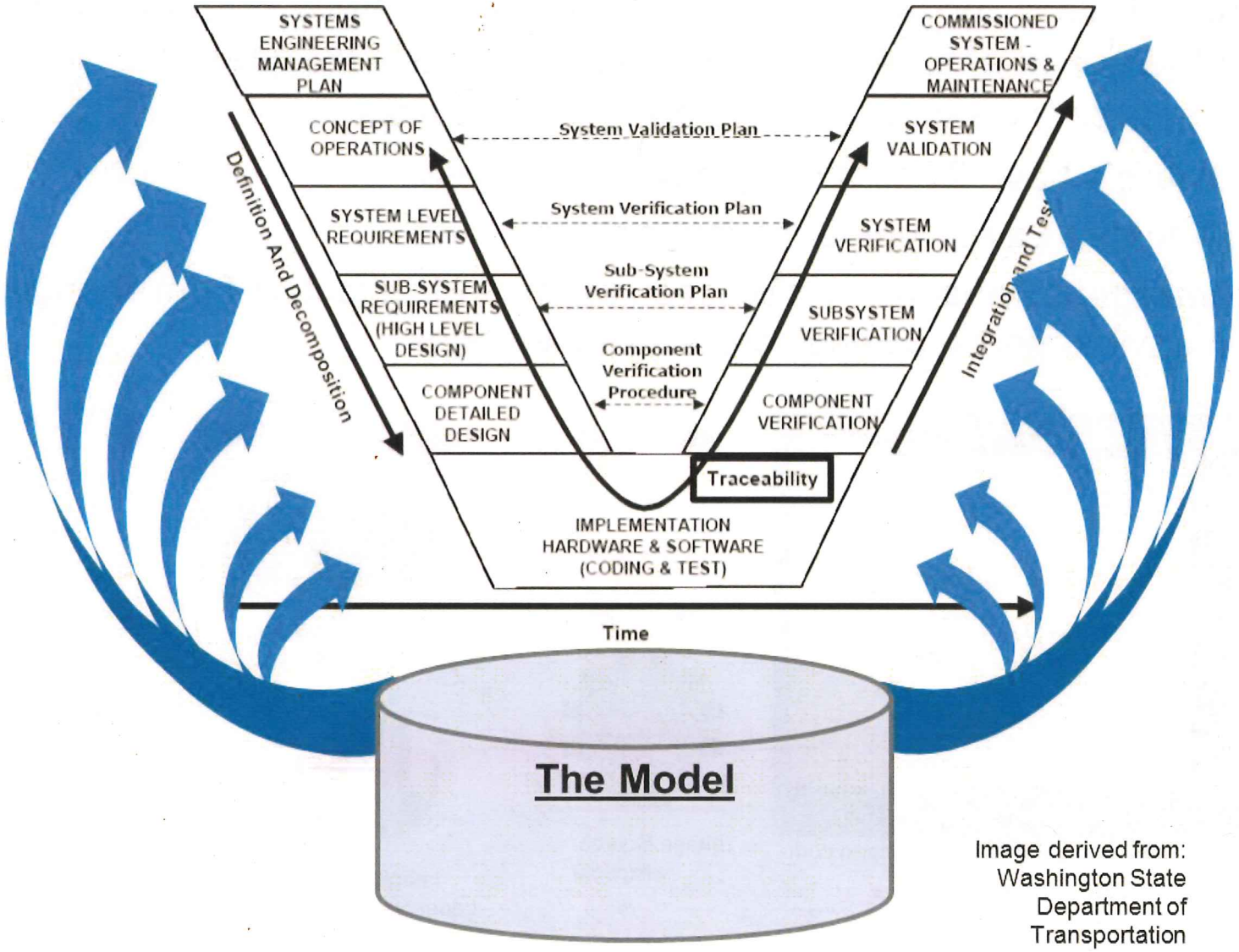

Image derived from: Washington State Department of Transportation

WHY THE CHANGE?

- Document-based System Engineering just is not agile enough to keep up with the surge of today's computing power, the number of communication nodes, and a rapidly evolving world
  - **Moore's Law:** 2x computing power every year
  - **Metcalf's Law:** Number of nodes = $n(n-1)/2$
  - **Emergent Behavior:** Unforeseen asymmetrical factors from changes in environments, competitors, and adversaries

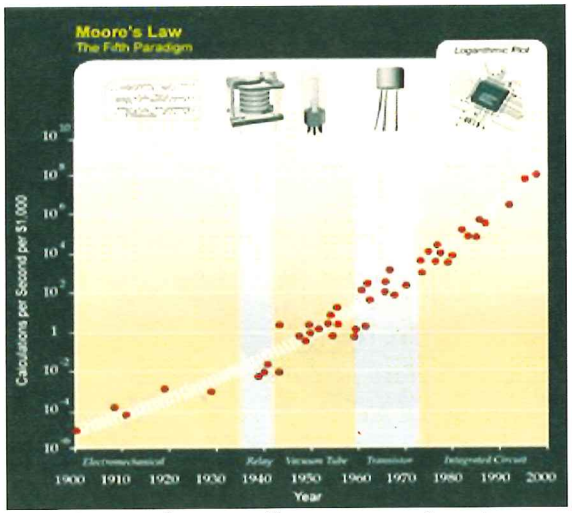

Image Source: threemovesahead.com

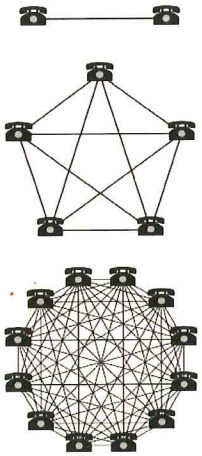
Image Source: wikipedia


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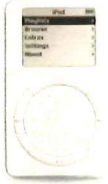
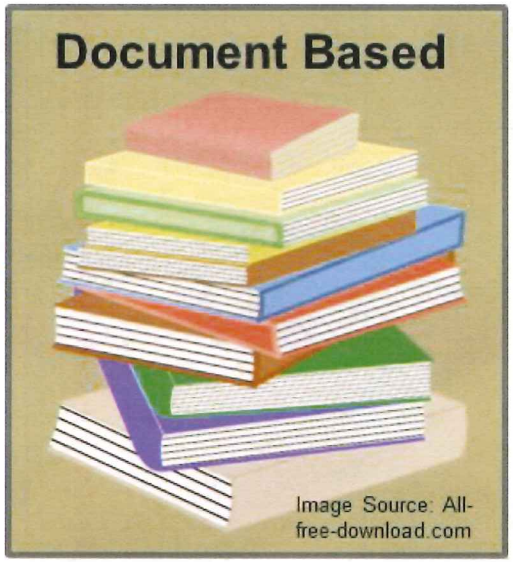


Image Source: ww.buymytronics.com

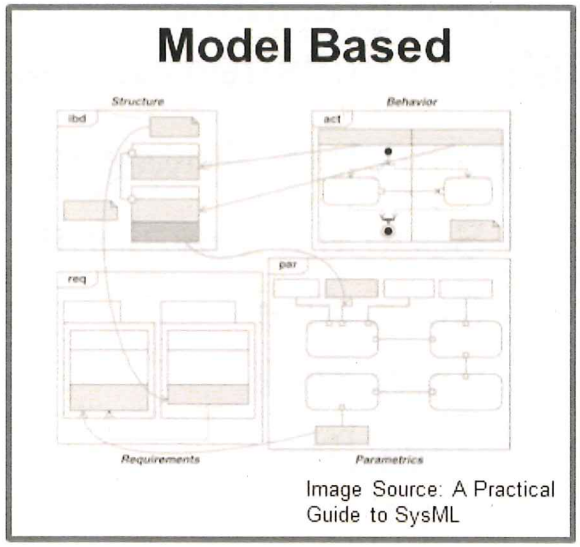
THE SHIFT IN APPROACHES TO SYSTEM ENGINEERING

Traditional

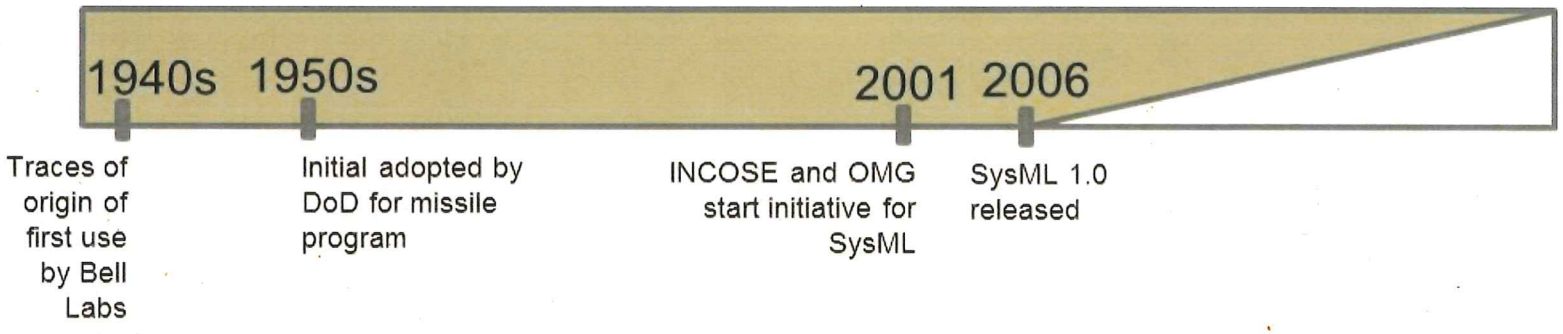


System captured by aggregation of multiple standalone documents

New



System captured in an integrated model with software tools



ENTRY-LEVEL MBSE TOOL

- **Free-form graphical editors that use SysML stencils/templates**
  - MS office(Visio, Powerpoint)
  - Open Source Equivalents
    - Openoffice
    - LibreOffice
- **Characteristics**
  - Low software cost
  - Low technical learning curve
  - Lacking in more advance MBSE features

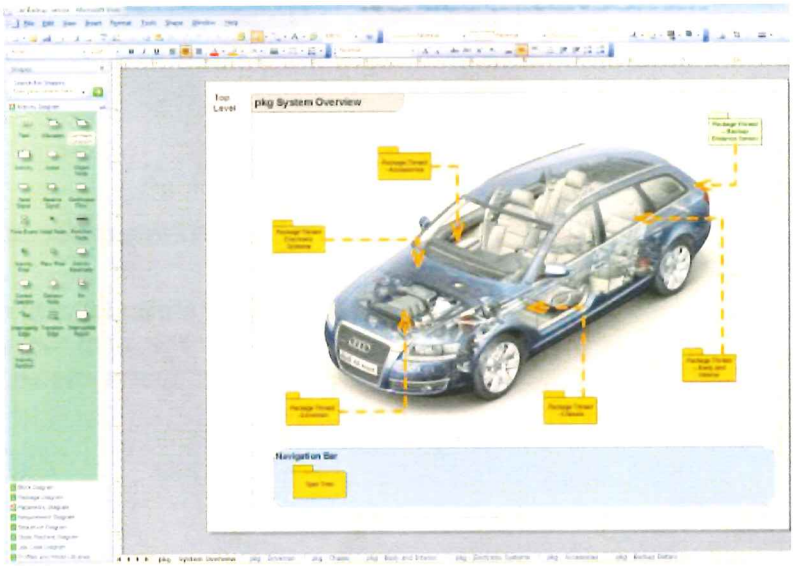
Image derived from: webpages.scu.edu, microsoft.com, openoffice.org, libreoffice.org

PROFESSIONAL MBSE TOOLS

- **Modeling tools that contain formal structure and rule validation to SysML**
  - MagicDraw
  - Sparx Enterprise Architect
  - Artisan Studio
  - IBM Rational Rhapsody
- **Characteristics**
  - Higher cost for software
    - On the order of thousands of dollars per user with annual license
  - Higher learning curve
  - Full rich set of MBSE features

Image derived from: static.ddmcdn.com, atego.com, nomagic.com, ibm.com, sparxsystems.com

STUDY APPROACH AND RESULTS



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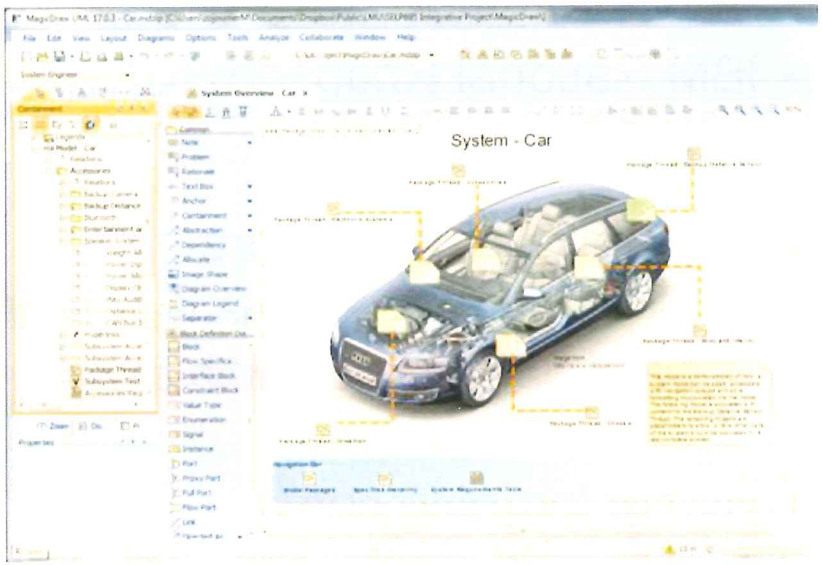

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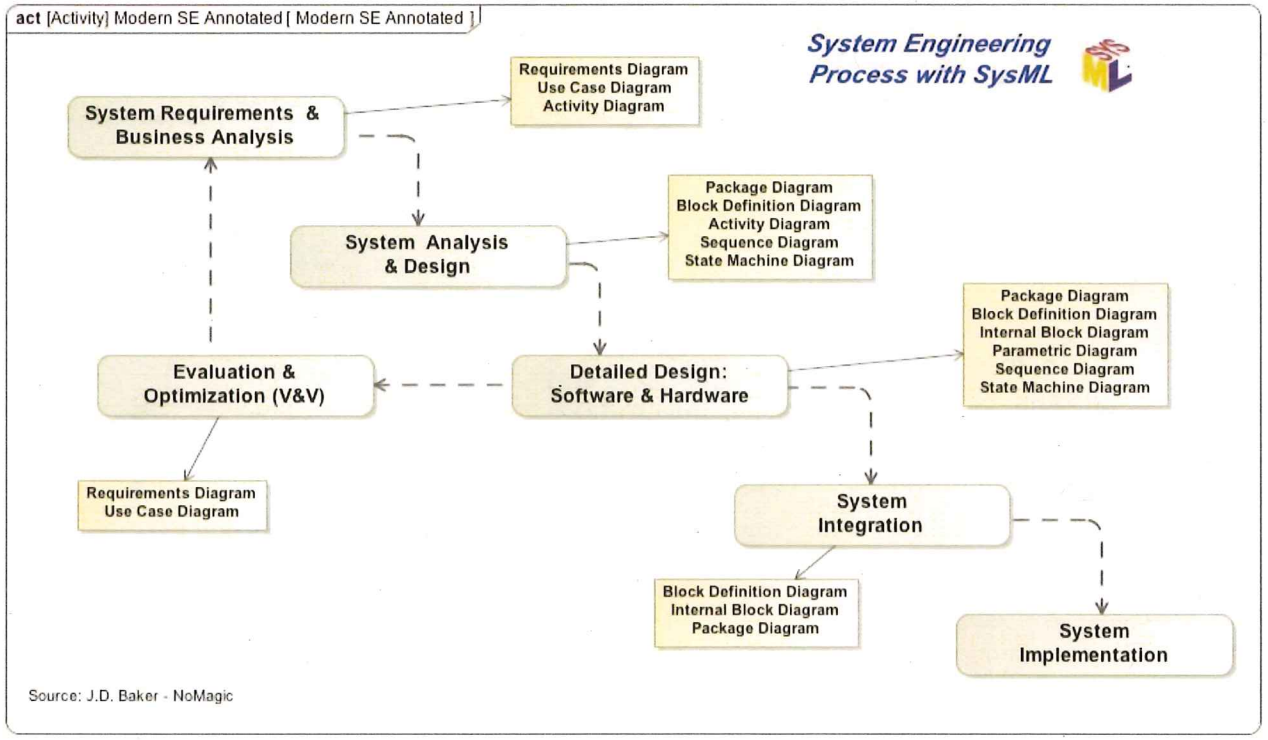
METHODOLOGY TO THE STUDY

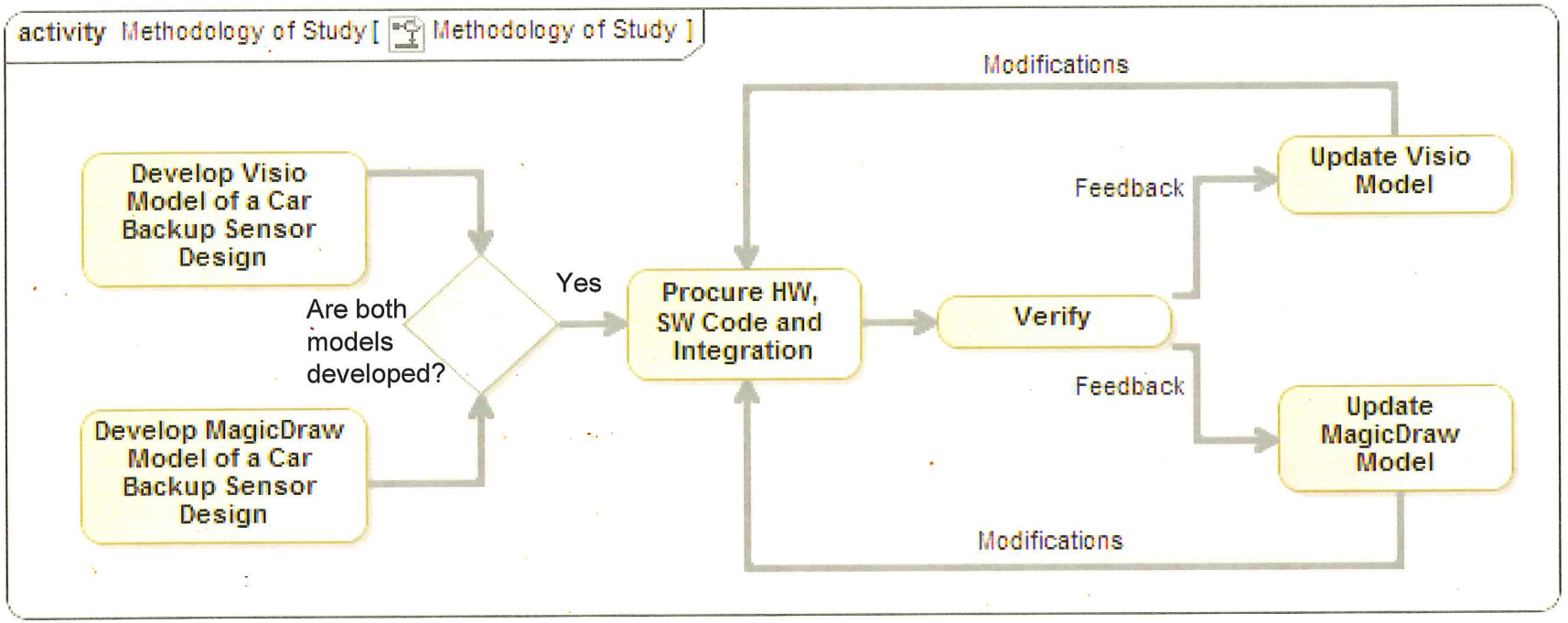
- **A mock product development effort was conducted with MBSE processes to compare each tool through the system lifecycle due to:**
  - Material from industry work could not be used due to security reasons
  - Needed an accelerated product development timeline to use these tools through design, implementation, integration, and verification phases within the time allotted



MOCK DEMONSTRATOR PRODUCT

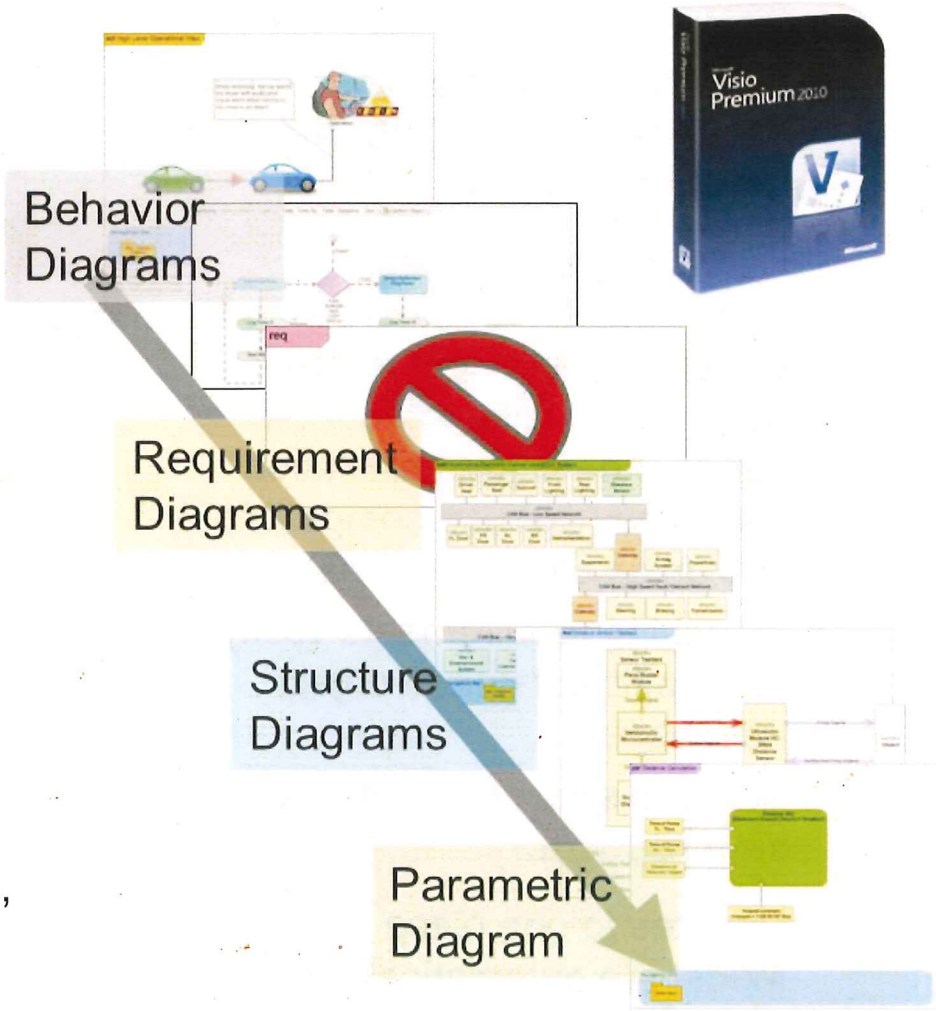
- A car backup sensor was selected as the product demonstrator to be tested using entry-level(Visio) and professional (MagicDraw) MBSE tools
- Evaluated each tool through the exercise of going through the MBSE process

Image from
http://ts3.mm.bing.net



DEVELOPING THE VISIO MODEL

- **Initial Visio modeling is manageable**
  - Few objects to maintain
  - Becomes more difficult as the model grows through each system phase
- **No object awareness or re-use**
  - Time **wasted** to manually find all references of the same object to perform updates across diagrams
- **Poor traceability**
  - Cannot effectively manage requirements and traces
  - Had to resort to traditional requirement tools like separate database tool or spreadsheets
  - Could not effectively allocate activities, requirements, and test cases to components without creating a significant number of dedicated allocation diagrams



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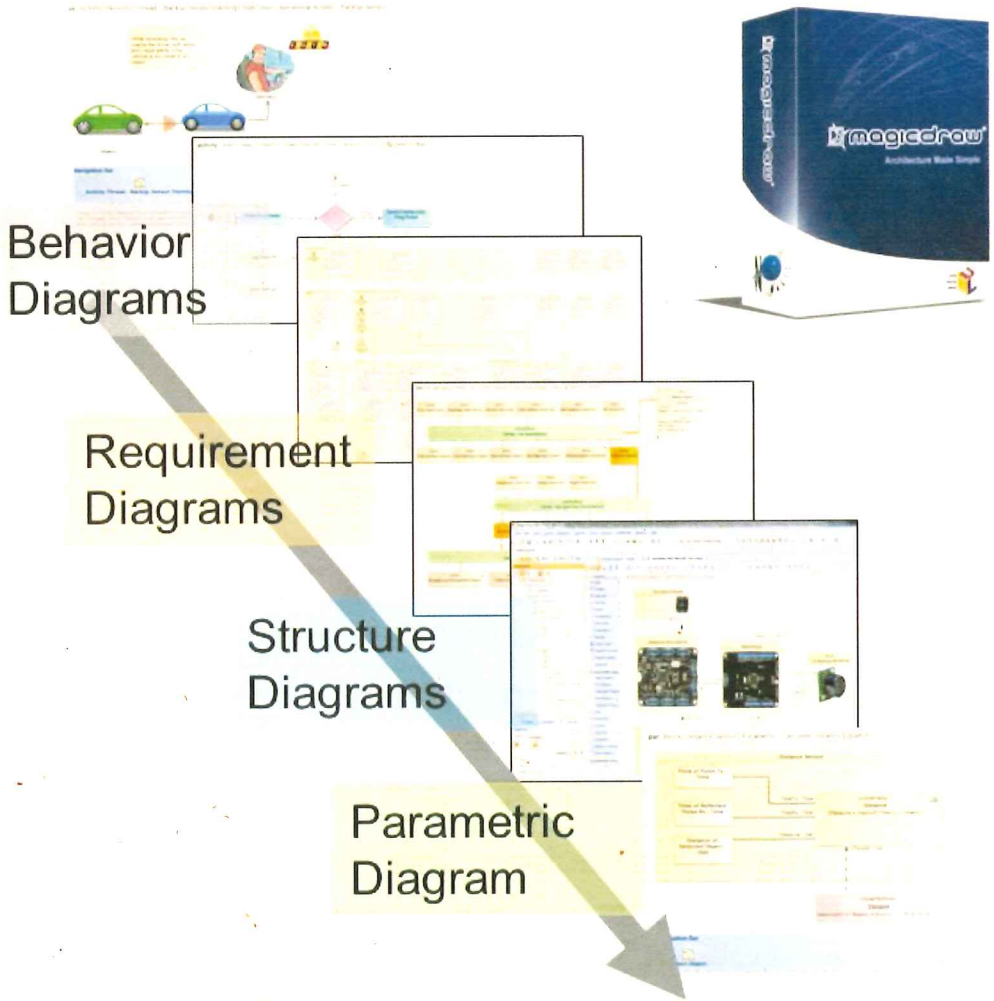
www.microsoft.com

DEVELOPING THE MAGICDRAW MODEL

- **MagicDraw Models have object awareness, level of abstraction, and encapsulation**
  - Can allocate activities, requirements, and test cases to system components through background links without the need for dedicated allocation diagrams (can use compartment info on existing diagrams)
  - Managing requirements vastly more efficient due to object traceability
- **Parts are sourced from the same repository**
  - Updates to one place in the model are automatically replicated in other areas of the model



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www.nomagic.com

DESIGN & VERIFICATION FEEDBACK LOOP INTO MODEL EXAMPLE

- Once both Visio and MagicDraw system design models were completed, the HW/SW was implemented and verified against the model
- Verification process discovered that the first sensor prototype failed to meet performance requirements so a redesign was needed in the system design model

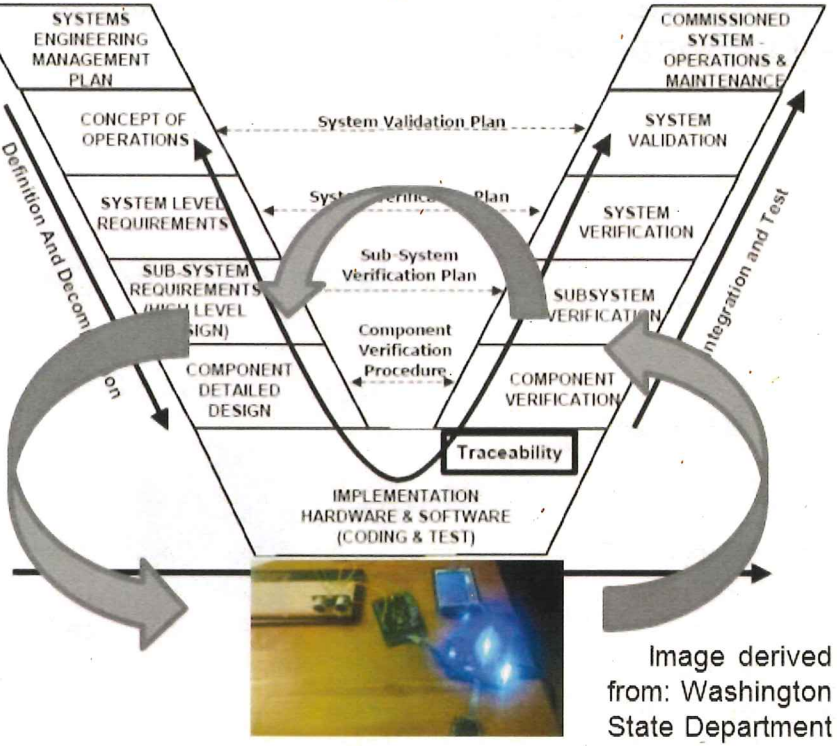


Image derived from: Washington State Department of Transportation

«performanceRequirement»
Distance Detection Min

Id = "DIS3"
risk = High
Text = "The Distance Sensor shall detect objects starting at least to 30 cm."
verifyMethod = Test

THE RE-DESIGN SYSTEM

- The NetduinoGO microcontroller was contributing additional latency to time measurements due to HW/SW interrupts so objects were only detectable starting at ~60 cm by the HC-04
- Re-design solution moved the time measurements and distance calculations away from the microcontroller to the sensor hardware
- The model had to be updated to reflect the new design and use of a MB1300 XL-MaxSonar®-AE0 sensor

Initial Prototype: HC-04 Ultrasonic Sensor and NetduinoGo Microcontroller

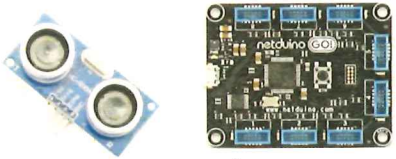
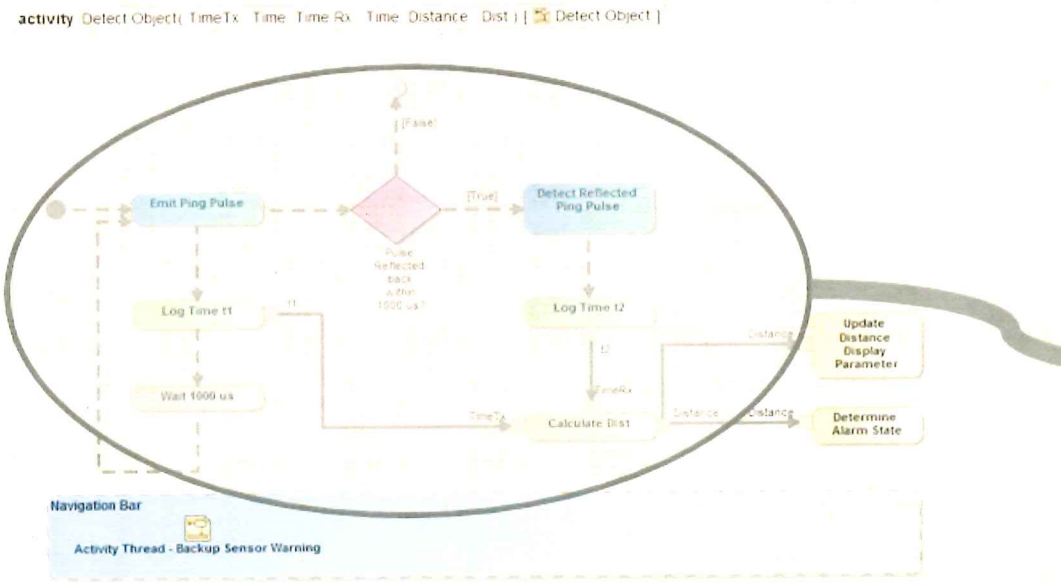


Image source:
www.imall.iteadstudio.com
www.netduino.com

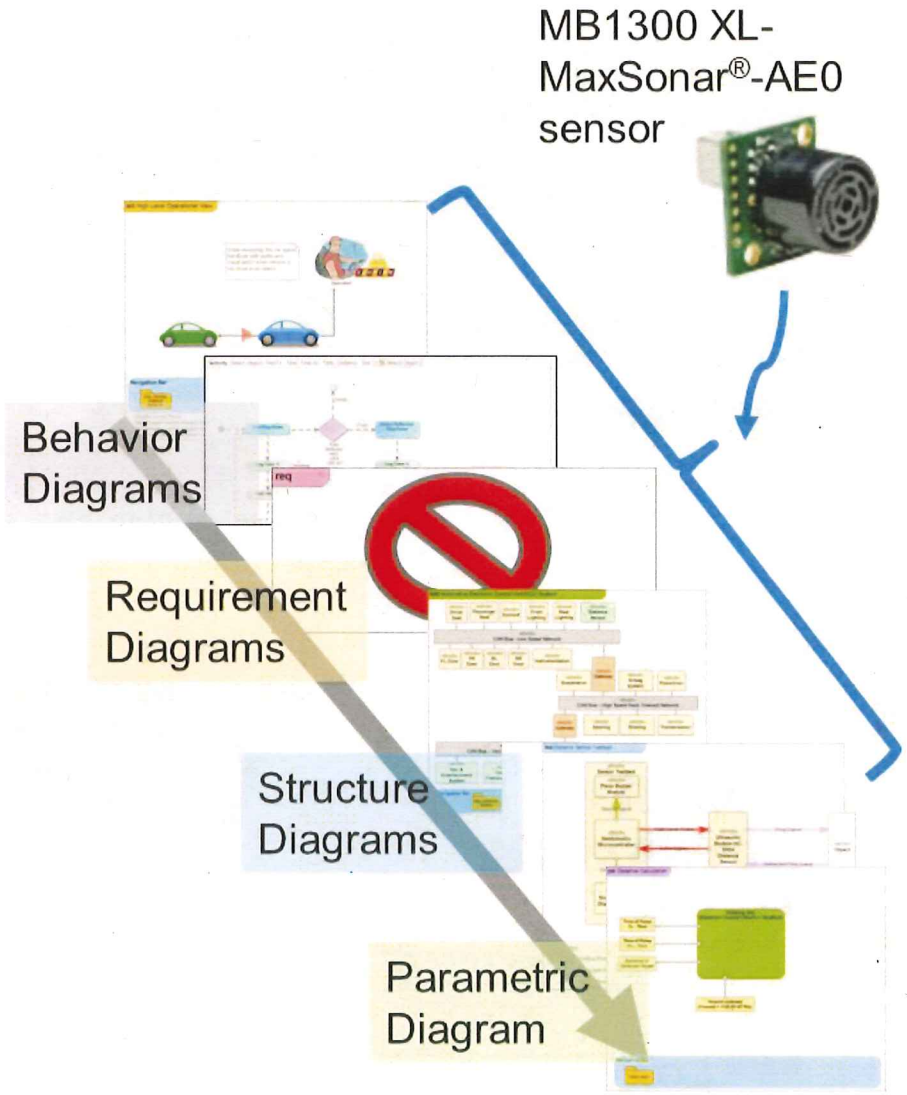


New Sensor Design:
MB1300 XL-MaxSonar-AE0

Image source:
www.maxbotix.com

INCORPORATING RE-DESIGNS INTO THE MODEL COMPARISON

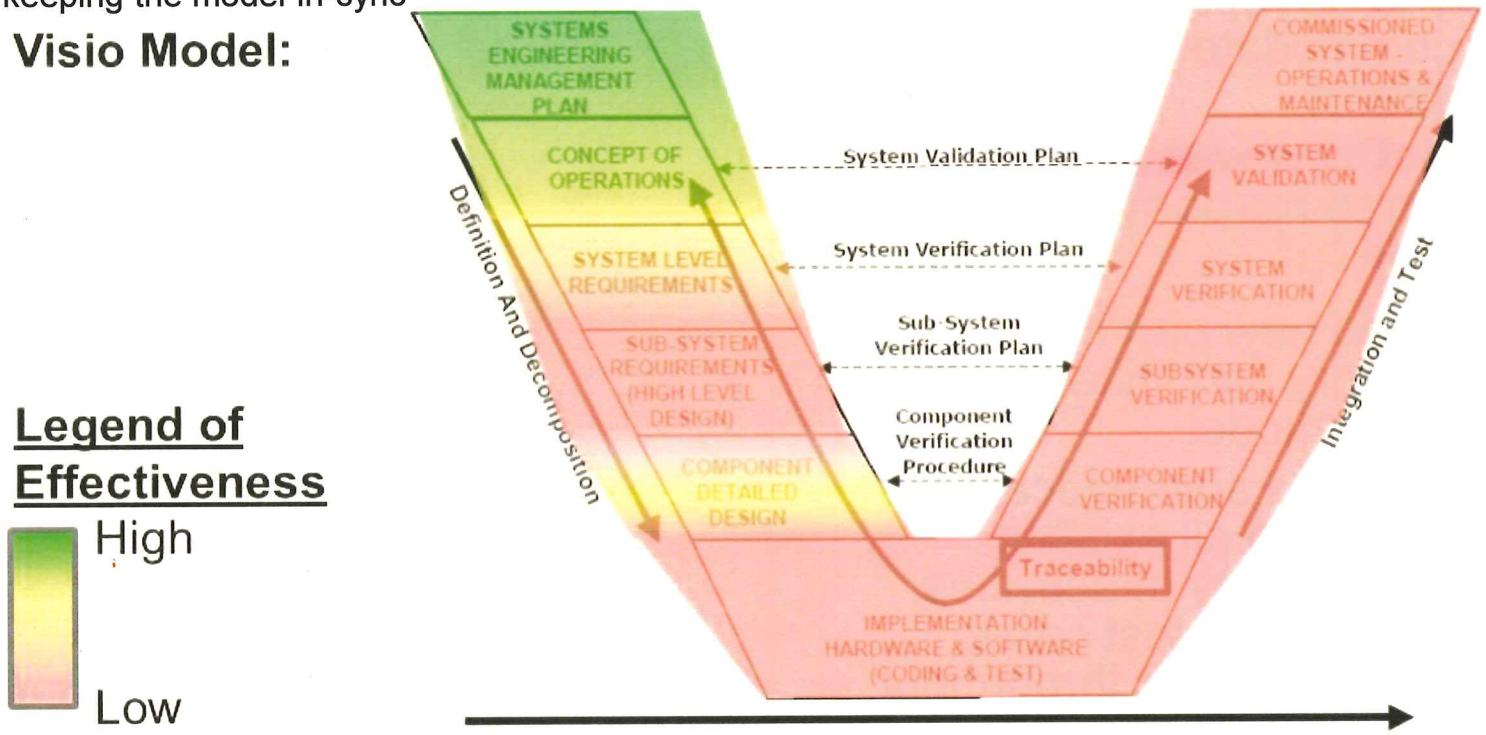
- **Concluded Visio was not flexible to change**
  - Replacing the sensor caused significant manual updates in the model
  - Several diagram linkages had to be repaired to accommodate new diagrams
- **MagicDraw was better suited to respond to change**
  - Created new part in repository and linked to existing model
  - Allocations automatically reflected on all existing compartments of activities, requirements, test cases, and components throughout the model



VISIO MODELING EFFECTIVENESS DURING THE LIFECYCLE

- **Visio sufficient in early phases of a system lifecycle**
  - Visio models provides more accessible ecosystem than document base engineering in a more centralized location for content viewers
  - More consistent format - Visual-based instead of textual
- **Visio becomes insufficient in later phases of a system lifecycle as the model grows and allocations are performed**
  - Visio effectiveness does not scale well as model size grows and changes through the system lifecycle
  - Model Content producers will spend additional labor hours populating, maintaining, and keeping the model in-sync

Visio Model:



Legend of Effectiveness

Image derived from: Washington State Department of Transportation

PROFESSIONAL MBSE TOOL EFFECTIVENESS DURING THE LIFECYCLE

- **Professional MBSE tools scales well with any model size**
  - Software aided features to reduces the amount of manual effort to keep model contents in-sync
  - Re-use from repository reduces the number of unique elements to minimize model size and complexity

MagicDraw Model:

Legend of Effectiveness

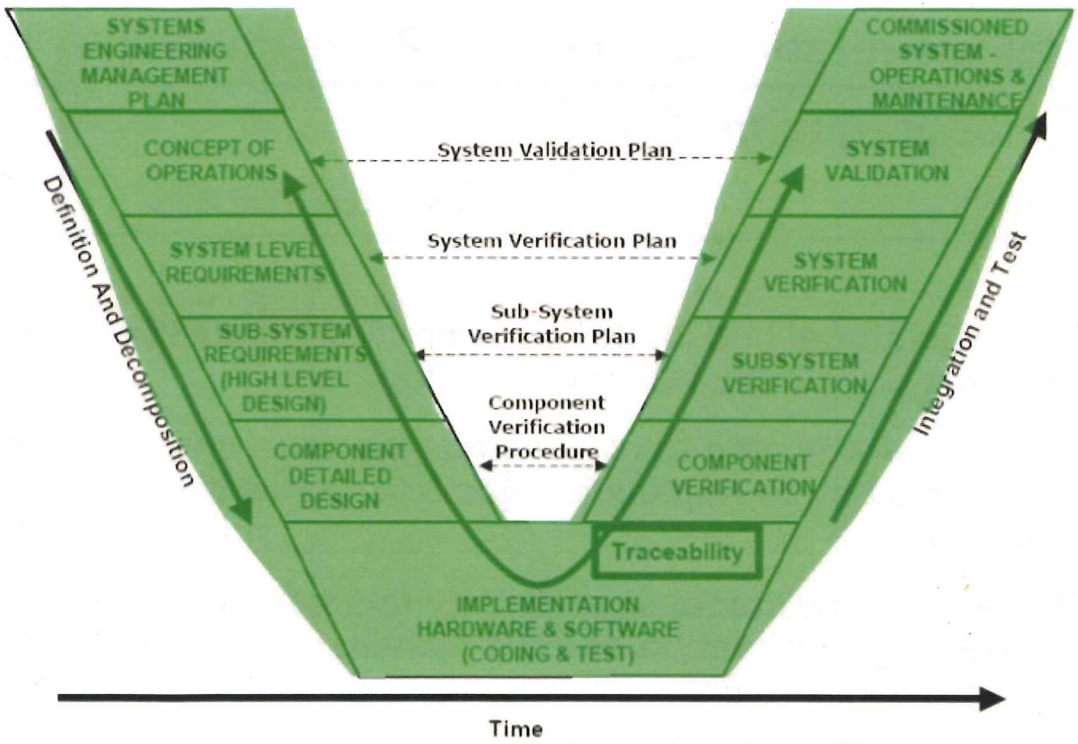


Image derived from: Washington State Department of Transportation

METRICS BETWEEN THE MODELING TOOL ENVIRONMENTS

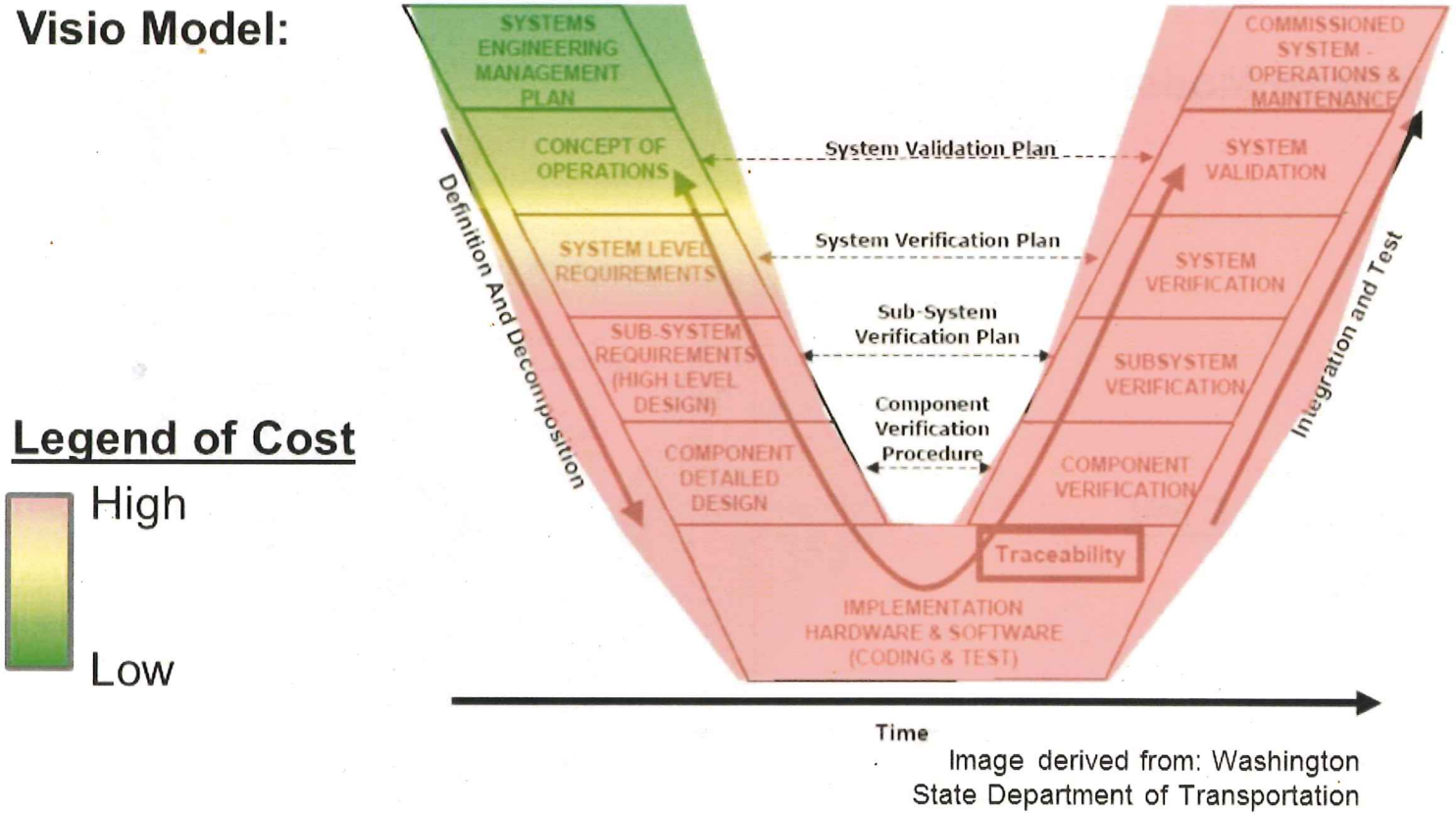
	Visio Model Element Quantity	MagicDraw Model Element Quantity
# of unique objects	316 objects	64 objects
# of unique relationships	198 relationships	101 relationships
Total # of unique model elements	**514 elements**	**165 elements**

- The Visio model had 3x the number of elements than the MagicDraw model for the same Car Backup Sensor development
- MagicDraw was able to re-use and reference elements from its repository, while Visio had to duplicate objects to represent the same entities across diagrams
- The MagicDraw model significantly reduces complexity of capturing and maintaining information about a system, which translates into reduce cost and time for a project

VISIO MODELING COST DURING THE SYSTEM LIFECYCLE

- **Initial software cost and learning curve are low**
- **Long-term system costs are high**
  - As Model size grows, the difficulty in managing the model grows exponentially
  - Visio models were highly susceptible to becoming out-of-sync as design changes are required through the normal design and verification feedback process or if an emergent behavior occurs

Visio Model:



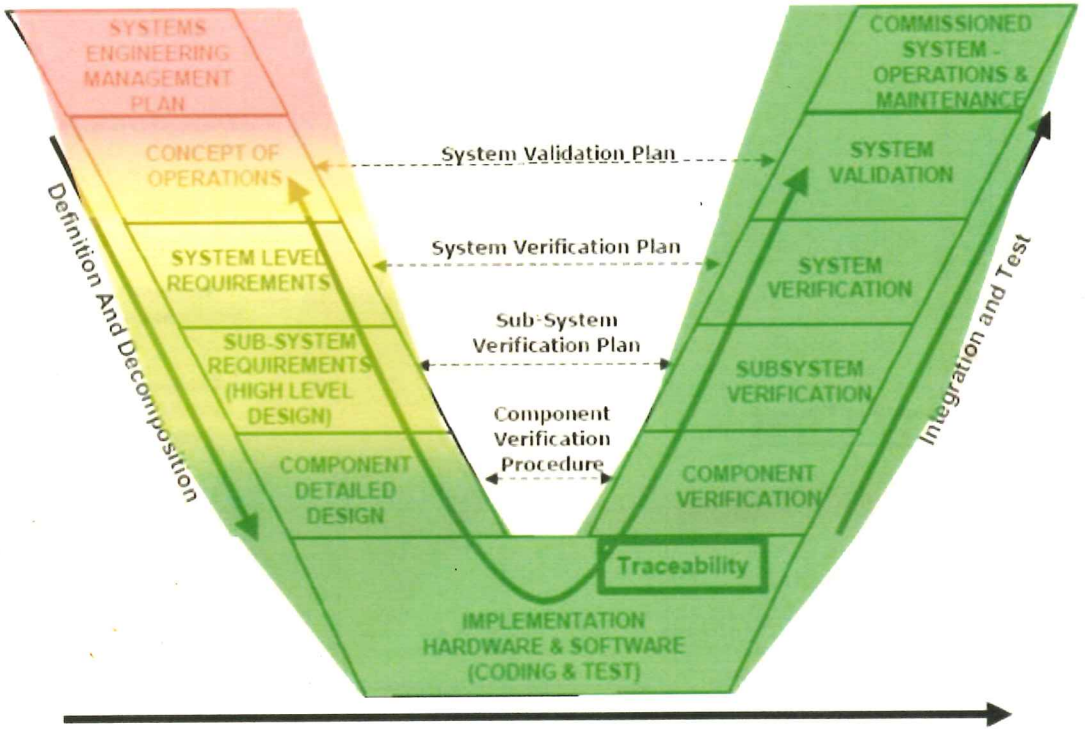
Legend of Cost

Image derived from: Washington State Department of Transportation

PROFESSIONAL MBSE TOOL COST DURING THE LIFECYCLE

- **High upfront cost, but lower long-term cost**
  - Higher software and training costs are high at startup
  - Efficiency gains through the system lifecycle pays for itself as managing system information becomes easier with software aides to help update the model when design changes occur

MagicDraw Model:



Legend of Cost

Image derived from: Washington State Department of Transportation

MBSE TOOLS IN SUPPORT OF LEAN PRINCIPLES

- **Professional MBSE tools support Lean principles**
  - Professional MBSE tools provides **value** to projects by offering better visibility into the system
  - The **value stream map** of a project easily maps within the integrated system models
  - Users could see the system **flow** and disconnects in the models
  - Users can see the requirements and allocations that provides the **pull** for a person or product to performed a task
  - Software aides from professional MBSE tools can help keep models in-sync and consistent in support of the pursuit of **perfection**
- **Visio struggles to keep up and even fails in terms of being able to show the flow within the model at later stages of the lifecycle**
  - Requirements management had to be managed outside of the tool

ETHICAL CONSIDERATIONS AND IMPORTANCE OF STUDY

- **Cannot continue to conduct business as usual**
  - 98 Major Defense Acquisition Programs from FY2010 collectively ran $402 billion over budget and were an average of 22 months [Center for Strategic and International Studies, 2011]
- **Owe it to the customer to provide best value**
  - Should strive to reduce waste
  - Should strive for more effective solutions
  - Should strive for continuous learning and growth

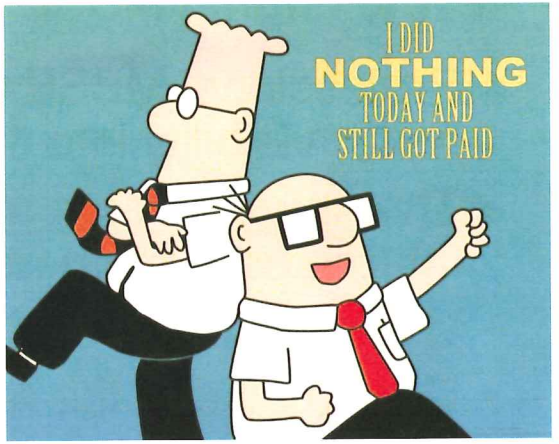
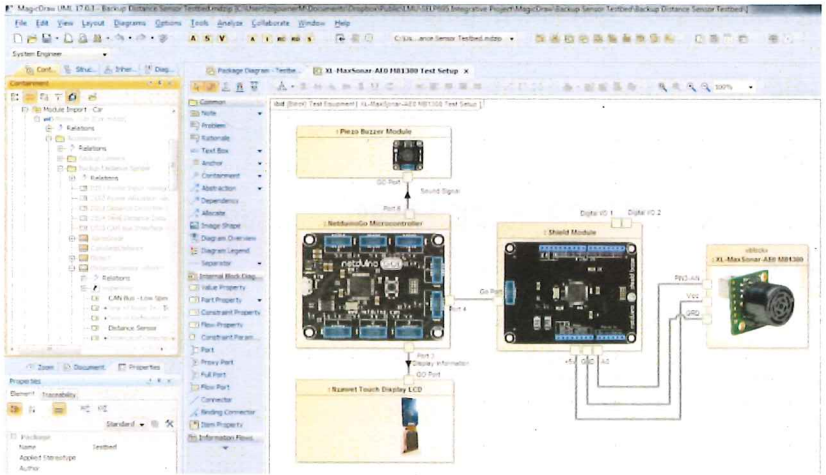


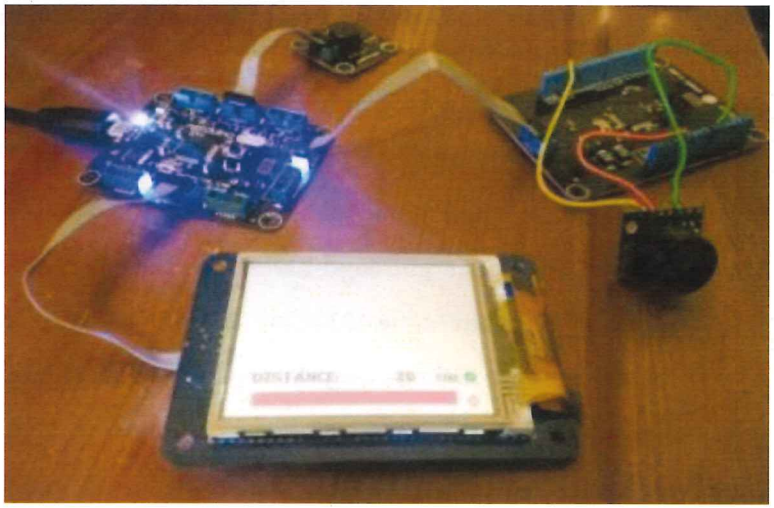
Image Source:
www.fc05.deviantart.net

Image Source:
www.rcmp-grc.gc.ca

SUMMARY

- **Avoid choosing the cheapest upfront solution**
  - Although an entry-level MBSE tools are an improvement over document-based approaches, they are still too inefficient to responding to change
  - A Visio model using a SysML stencil may look like SysML, but it does not have the smarts behind SysML
- **Professional MBSE tools are recommended to be used to reduce long-term costs throughout a system lifecycle**





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