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CUST 328 - Mission Impossible: Systems Engineering on a Global Scale with Integrity (A Case-Study of Trane)

Sean McCoy
Senior Systems Engineer, Trane/Ingersoll-Rand

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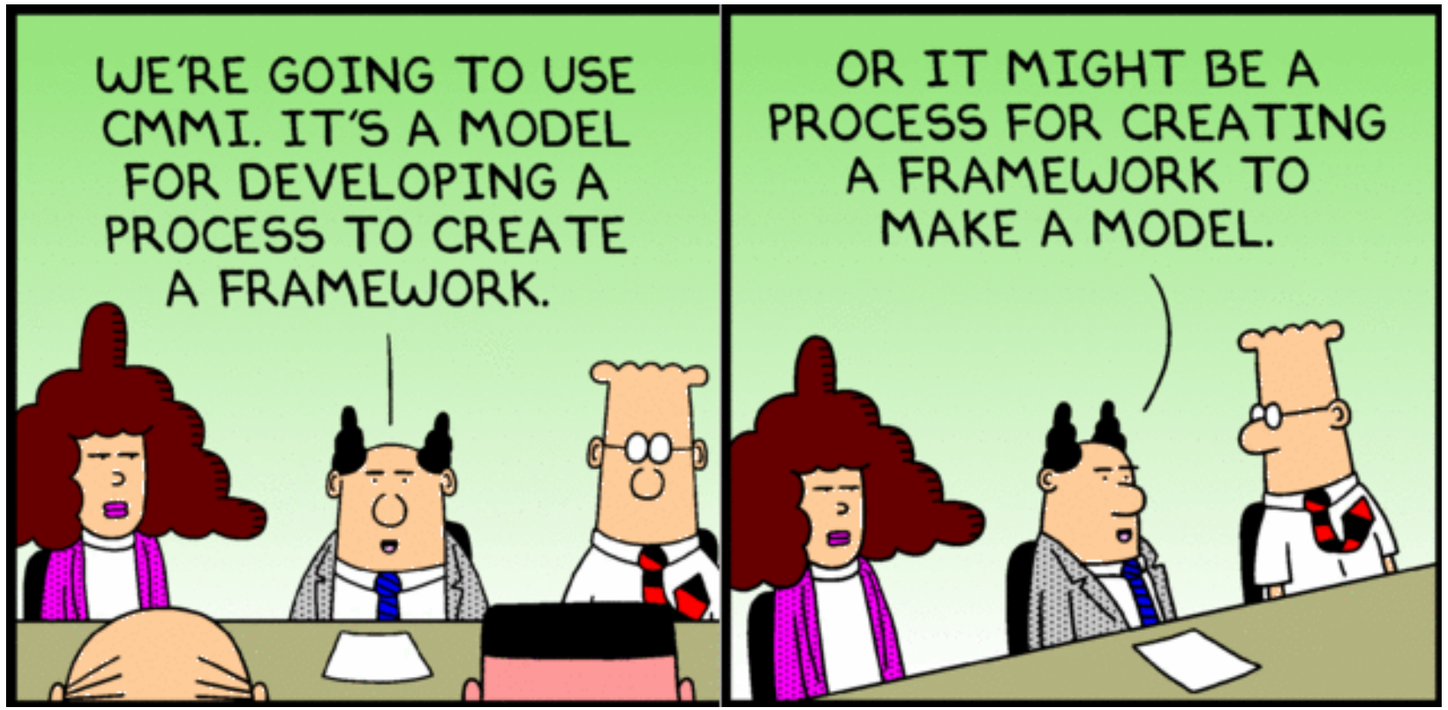
Agenda

- Introduction
- Background – Setting the context
- How Integrity is used at Trane
  - Organizational Process
  - Systems Engineering
  - Subsystems implemented in Integrity
- Lessons Learned
- Questions and Answers

Introduction

- My background… smccoy@trane.com
- Disclaimer: I am not an expert, not a manager, and not a sales-person.
- Sharing our experience… We make no claims on having the answers.



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Introduction to Ingersoll-Rand/Trane

- A $14 billion diversified industrial company
- 83* manufacturing facilities worldwide
- Operations in every major geographic region
- Strategic brands are #1 or #2 in their markets

Background – setting the context

- What is HVAC (Heating, Ventilation and Air-Conditioning) and a BAS (Building Automation System)
- Exploration into complexity and variation
  - “I’ve worked with the engineers that put a man on the moon, how hard can HVAC be?”
  - “It’s just HVAC, how difficult can it be?”

Review the INCOSE definitions

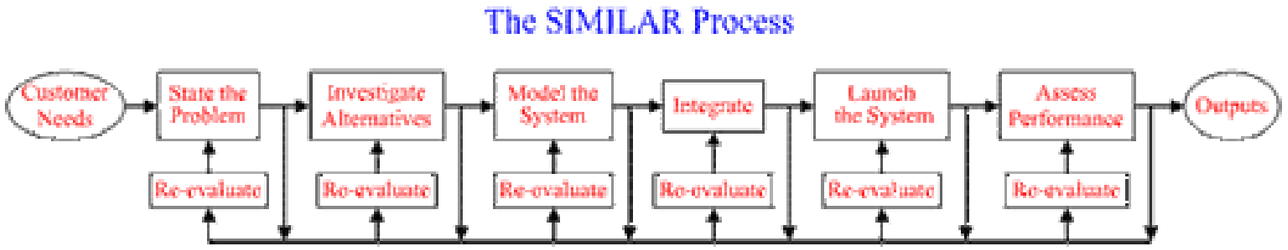
Definition of a system

A system is a construct or collection of different elements that together produce results not obtainable by the elements alone. The elements, or parts, can include people, hardware, software, facilities, policies, and documents; that is, all things required to produce systems-level results. The results include system level qualities, properties, characteristics, functions, behavior and performance. The value added by the system as a whole, beyond that contributed independently by the parts, is primarily created by the relationship among the parts; that is, how they are interconnected (Rechtin, 2000).

Review the INCOSE definitions

Systems Engineering

Systems Engineering is an engineering discipline whose responsibility is creating and executing an interdisciplinary process to ensure that the customer and stakeholder's needs are satisfied in a high quality, trustworthy, cost efficient and schedule compliant manner throughout a system's entire life cycle. This process is usually comprised of the following seven tasks: **S**tate the problem, **I**nvestigate alternatives, **M**odel the system, **I**ntegrate, **L**aunch the system, **A**ssess performance, and **R**e-evaluate. These functions can be summarized with the acronym
SIMILAR: **S**tate, **I**nvestigate, **M**odel, **I**ntegrate, **L**aunch, **A**ssess and **R**e-evaluate. This Systems Engineering Process is shown in Figure 1. It is important to note that the Systems Engineering Process is not sequential. The functions are performed in a parallel and iterative manner.



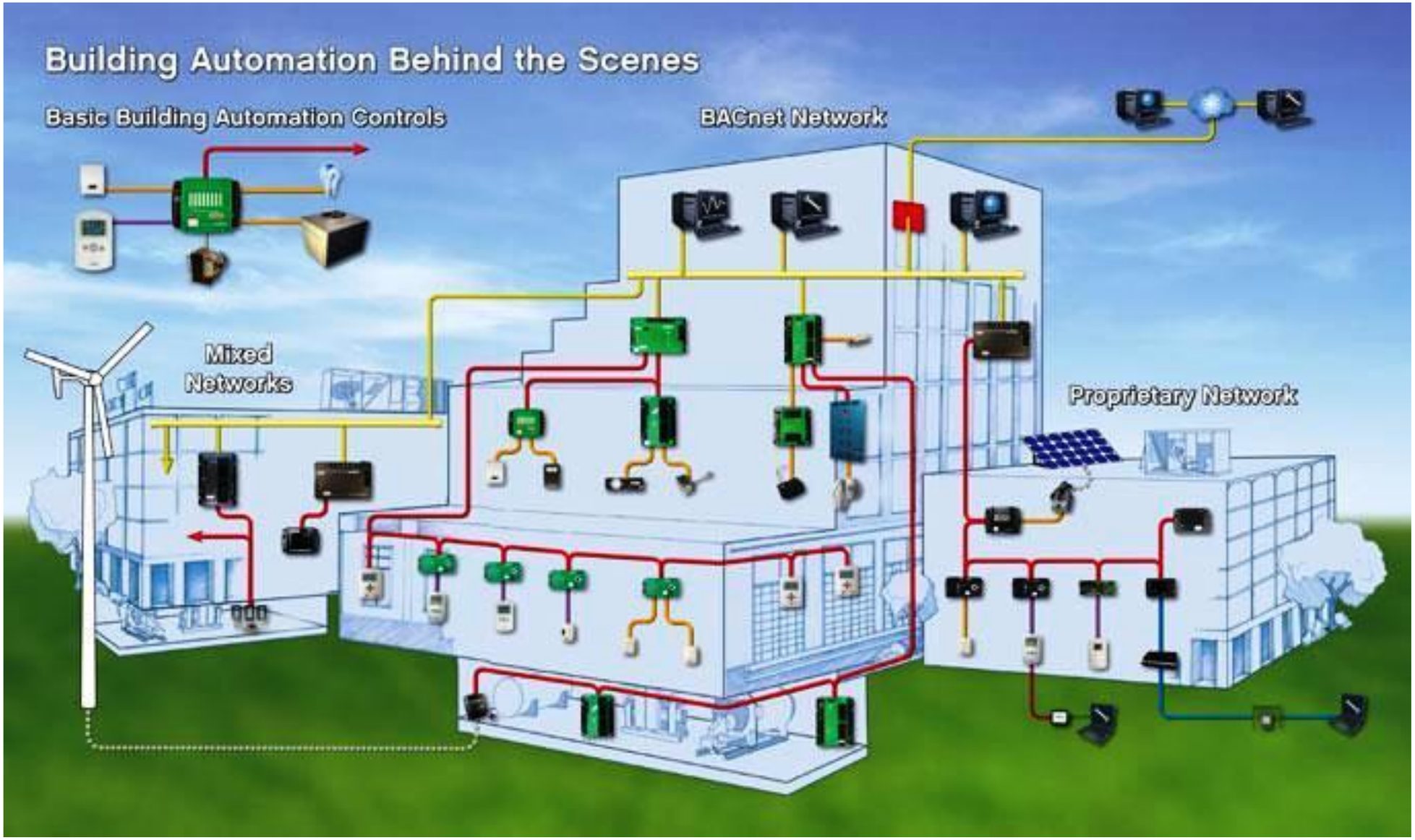
The Components of a BAS system

A set of applications to control, monitor, alarm, trend, schedule the operation of HVAC equipment in a building.

- Thermostats, Sensors, Meters
- Chillers
- Boilers
- Air Handlers
- Terminal Units
- Variable Air Dampers
- Exhaust/Fume Hoods
- Equipment Controllers
- Building Controllers
- Multiple-Building Management Systems
- Service Tools
- External Monitoring Systems
- Mobile Applications

Enormous variability in buildings – every building is custom

For folks that like visuals…



Variability doesn’t stop with the internal components

External “Interfaces” and the realities related to equipment in a building

- Power (gas and electric)
  - The peak electrical demand of one large chiller can be 2.5million watts per hour, or even more; the energy equivalent over 100 homes with everything on.
- Regulatory – EPA, FDA, UL, FCC, UUKL, BTL, CE, +many others
- Local Building Codes
  - Different Regulatory and Building Codes per location (Country, State, County, and City)

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Even More Interfaces – the other aspects of a building

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- Above and beyond HVAC, there other systems in a building…
  - Indoor Lighting, Outdoor Lighting
  - Blinds and Window Management
  - Security, Motion Detection, Occupancy Detection
  - Elevators and Escalators
  - Video and Ambient Audio
  - Fire Alarms
  - Food Storage (Refrigerators and Freezers)
- Many components from many vendors
- Military and FDA compliant building systems

Buildings come in all types

- There is additional variability in verticals
  - Education - various
  - Retail - various (food, pharmacy, clothing, etc…)
  - Manufacturing Facilities – various, including FDA compliant
  - Office Space - various
  - Restaurants - various
  - Hospitals - various
  - Military Complex – various
  - Law Enforcement and Correctional Facilities
  - Warehouse - various, including FDA compliant

- School District example:
  - 4 schools built over 8 years. Even though the floor plan is the same, the equipment and controls in the buildings are not necessarily the same
  - The 80 other schools were built over the past 50 years
  - Now… Apply a “Snow Day” or “Fire Drill” district-wide

Variability over time…

The lifespan of the components in a building

- The building: 50+ years
- A chiller: 40+ years
- Rooftop Unit: 12-20 years
- BAS Control System – 5-20 years
- Local Display – 1.5-3 years
- Software - ?
- Cellphone - ?

Let’s review the INCOSE definition, again

Definition of a system

A system is a construct or collection of different elements that together produce results not obtainable by the elements alone. The elements, or parts, can include people, hardware, software, facilities, policies, and documents; that is, all things required to produce systems-level results. The results include system level qualities, properties, characteristics, functions, behavior and performance. The value added by the system as a whole, beyond that contributed independently by the parts, is primarily created by the relationship among the parts; that is, how they are interconnected (Rechtin, 2000).

There’s more complexity to BAS and HVAC systems than most people would think.

Shifting Gears… Let's talk about context

- "Context is worth 80 IQ points." – Alan Kay
- "Context eats strategy for lunch." – Peter Drucker
- "Priority is a function of context." – Stephen Covey
- "Context is everything." - uncertain

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Poignancy of context

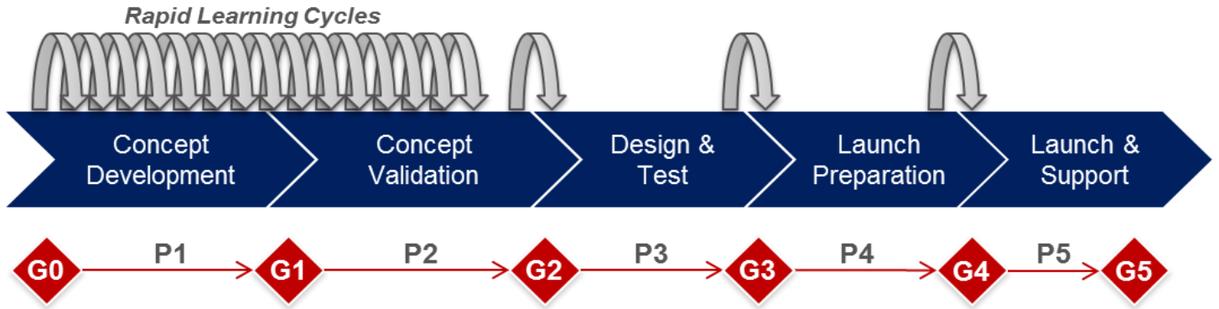
- Conway's Law…
  - h. the axiomatic law states "organizations that design systems… are constrained to product designs which are copies of the communication structures of these organizations".
  - A practical translation is that for a system to work it must be supportable by the org-chart, and systems that are not aligned to the org-chart are at a significant risk for failure.
  - This is one of the most critical and controversial aspects of assessing systems, performing systems engineering and applying process. It is where personalities, zealotry, emotions, and even corporate politics can run high. Seasoned practitioners know and understand this, less experienced and less knowledgeable people, not so much.

Practical axiom: You cannot fight the org-chart.

The Ingersoll-Rand Process

Systems Engineering and Agile development in the context of an organizational process

- Ingersoll-Rand Product Development Process (IRPDP)



- Learning Cycles
  - Definition of a business case hypothesis and *reduction of major uncertainties prior to Gate 2 commitment*
- Risk Management
  - Risk-based decisions (*forward looking view of project execution*)
- Gate Rigor
  - *Data-driven discipline*, and cross-functional ownership on gate decisions
- Governance
  - Not a framework - but *a standard to use* with clear process ownership

The Agile method is applied during the iterations of the "Rapid Learning Cycles".

Making the system..

30 Trane Commercial engineering/manufacturing locations world-wide

- Araucaria, Brazil
- Bangkok, Thailand
- **Bangalore, India**
- Brussels, Belgium
- Cairo, Egypt
- Charlotte, North Carolina
- Charmes, Vosges, France
- **Chennai, India**
- **Clarksville, Tennessee**
- Columbia, South Carolina
- Forsyth, Georgia
- Fort Smith, Arkansas
- Golbey, France
- **La Crosse, Wisconsin**
- Lexington, Kentucky
- Lynn Haven, Florida
- Macon, Georgia
- **Mumbai, India**
- Penang, Malaysia
- Pueblo, Colorado
- Rockingham, North Carolina
- Rushville, Indiana
- Sao Paulo, Brazil
- **Sophia, Bulgaria**
- **Shanghai, China**
- Springhill, Louisiana
- **St. Paul, Minnesota**
- Taicang, China
- Yangmei, Taiwan
- Waco, Texas

*Locations in **bold** have users in Integrity*

Do the math…

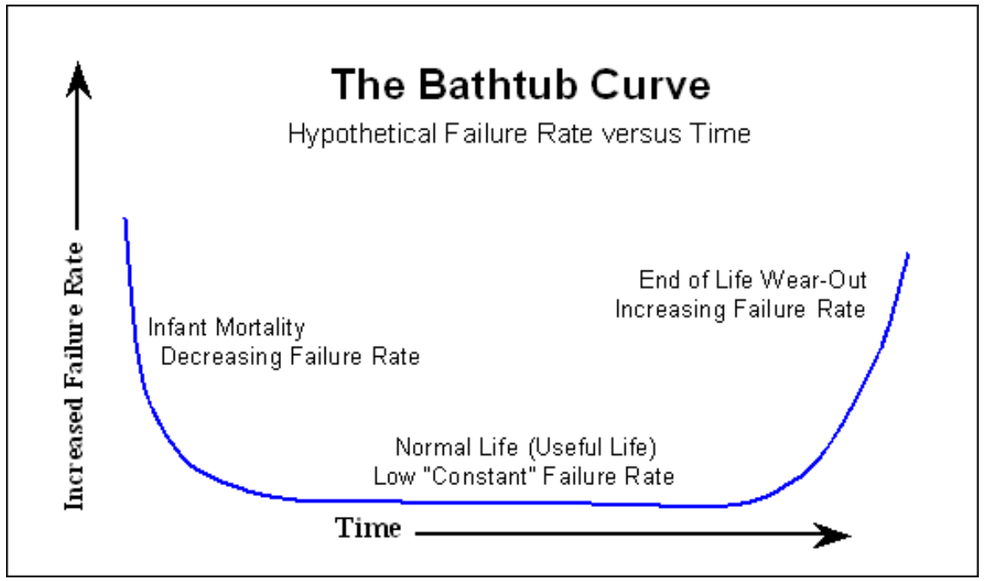
For all of the products (over 100), across all those locations…

- Software Technologies – C++, Java, C#, JavaScript, XML, HTML, +others
- Tools – Eclipse, Subversion, TFS, Rhapsody, Git, DOORS, Integrity, PTC Windchill, +others
- Libraries – Angular, Dojo, .NET, J2EE, WebKit, Swing, WinForms, WPF, +others
- Hardware Technologies - embedded, display, PC, mobile, tablet, and server products, +others
- Documents, Spreadsheets, Diagrams, Project Plans, Power Points, +others
- Processes – Agile, non-Agile, iterative, spiral, waterfall, incremental, hybrid, the other Agile, the other non-Agile, my other brother Agile, …

This is the "problem" posed to Trane's Systems Engineering teams

Trane-isms on Systems Engineering

- Reliability Engineering and Systems Engineering are inseparable
  - Reliability(system) = f(reliability(comp 1) * reliability(comp 2) * … reliability(comp n) +/- f(uncertainty and noise))
  - The “bathtub curve”



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Trane-isms on Systems Engineering

- Engineering systems that do not fail…
  - It's not that it won't fail, but we want to know all the conditions and criteria that cause failures- before we ship.
  - This is different discipline than engineering something that "can work".
- Seek Excellence, not Perfection
  - Elements of the system are imperfect, and that is okay
    - Knowledge is not perfect
    - Processes are not perfect
    - Tools are not perfect
    - People are not perfect
- Feeding business's ability to provide standard and extended warranties.
- To reiterate – understanding the context into which a system will be deployed is a "critical success factor".

3 contexts of Systems Engineering

Maturity of a Systems Engineering discipline…

- The Target System being designed/built is a system.
- The Context in which the Target System will operate is a system.
- The processes and tools that are used to design, build, manufacture, test, deploy, and maintain the Target System are, in fact, systems.

Quick Recap

- The “Target System” has an uncountable number of variations.
- The “Deployment Context” has an uncountable number of variations.
- The “Operational Context” has an uncountable number of variations.
- Systems Engineering for BAS and HVAC – how hard can it be, really?

- So… What did we do to tackle this problem?

The Integrity Solution at Trane

- Integrated Solution in Integrity
  - Program-Level/Marketing-Level Requirements
  - Product-Level Requirements
  - Specifications
  - Test Cases
  - Change Requests
  - Defects
- Custom Solution (not ALM or GSD) – Written from scratch specific to Trane's process(es)
- All flat-items, no document model

- Subsystems in Integrity
  - Requirements Management
  - Release Management
  - Platform/Product Management
  - *Program Management
  - Change Management
  - Defect Management
  - *Test Management

  * Deployment planned Q3/Q4
- Governance rules codified in Integrity to support and guide the process(es)

One tool to rule them all.

Blending them all

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Integrity supports our Organizational Process + Systems Engineering + Agile Development

	Process "Effectiveness"		
Key Project Activities	IRPDP (Organization)	Agile (Team)	Trane Systems Engineering
Concept Selection	✓		✓
Requirements Management	✓		✓
Risk Management	✓		✓
Modeling	✓		✓
Design		✓	✓
Coding		✓	✓
Development Testing		✓	✓
Acceptance Testing	✓	✓	✓
System Level Testing	✓		✓

Agile Development can be effective while still having a solid Systems Engineering discipline and a rigorous Organizational Process.

The Integrity Solution at Ingersoll-Rand

- Integrated Solution in Integrity
  - Marketing Requirements
  - Product Requirements
  - Design Responses
  - Module Requirements (Subsystem)
  - Component Requirements
  - Feature Requirements
- Custom Solution (not ALM or GSD) – Written from scratch specific to Ingersoll-Rand's IRPDP process
- All flat-items, no document model
- Subsystems in Integrity
  - Requirements Management
  - Test Management is under development
- No governance rules codified in Integrity
- Basic locking mechanism with version control

Lessons Learned

- Building a configured solution that is tailored from scratch is not as difficult as is commonly thought. However, it does require an experienced development team.
- Instead of attempting to force an “Out of the Box” solution to fit our process, it would have been more effective to leverage the flexibility of Integrity to configure our own solution from the start.
- For the needs of Trane and Ingersoll-Rand, the document model got in the way and was never applicable for our needs. In other words, we are not like the automotive and A&D industries.
- Multiple solutions on a single server is a challenge for administrators, developers, and users.
- Managing the variability and needs of 11 SBUs on a single server continues to be a challenge.
- The Web-Client proved to be quickly accepted by the user-base, the Thick-Client tool was a challenge for our users and never really accepted by the users.
- The users are ecstatic about our Integrity implementation when compared to our DOORS implementation.

Questions?

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- Questions?

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