Systems Integration: What Are We Waiting For

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Repeat Errors: Fire Engine Too Big

- Florida
  1. New truck to long for station
  2. Added to front of station
  3. Not enough clearance to access street

Arched doors in Boston

- Others:
  - Boston – didn't fit in historic station
  - Tuscumbia, Alabama – too tall
  - Dunfermline, Scotland – too big for streets
  - Saranac Lake NY – too tall & too heavy
  - Montcuq in the Lot, France – too big for streets
  - Tarentum, PA – too tall & too heavy
  - Elkville, Ill – New station not built yet
  - London, Ontario, Canada – too tall (measurement error)
  - Edmondson, AR – too wide
  - Morant Bay Jamaica – too wide for streets

Late Integration of Enabling Systems

Repeat Errors: Conclusion

"It's not that we shoot ourselves in the foot that surprises me…

…it's how fast we reload!"

- Anonymous

Can We Learn?

It is said that only a fool learns from his own mistakes, a wise man from the mistakes of others.

– Otto von Bismarck

Vasa

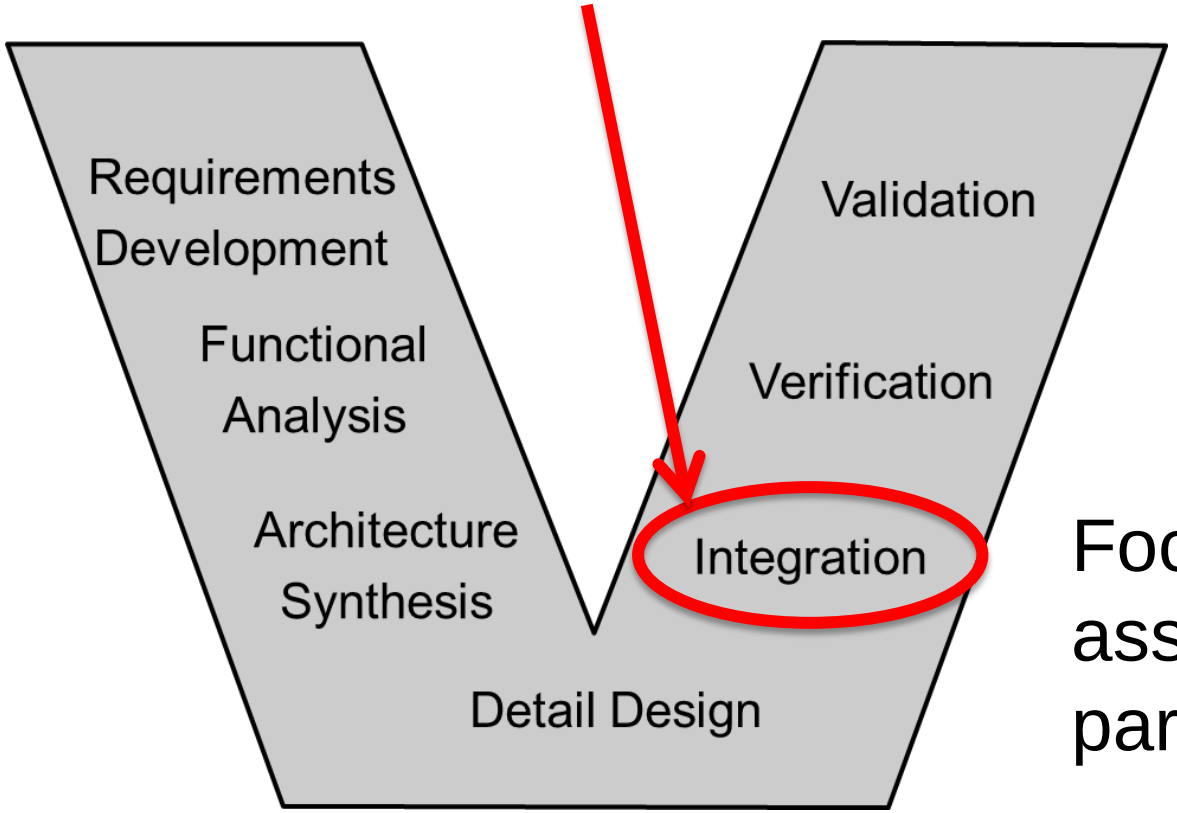
Do We Learn?

Spain’s S-80 series submarine

- 100 tons overweight
- Will submerge
- Won’t surface

Problem Root Cause

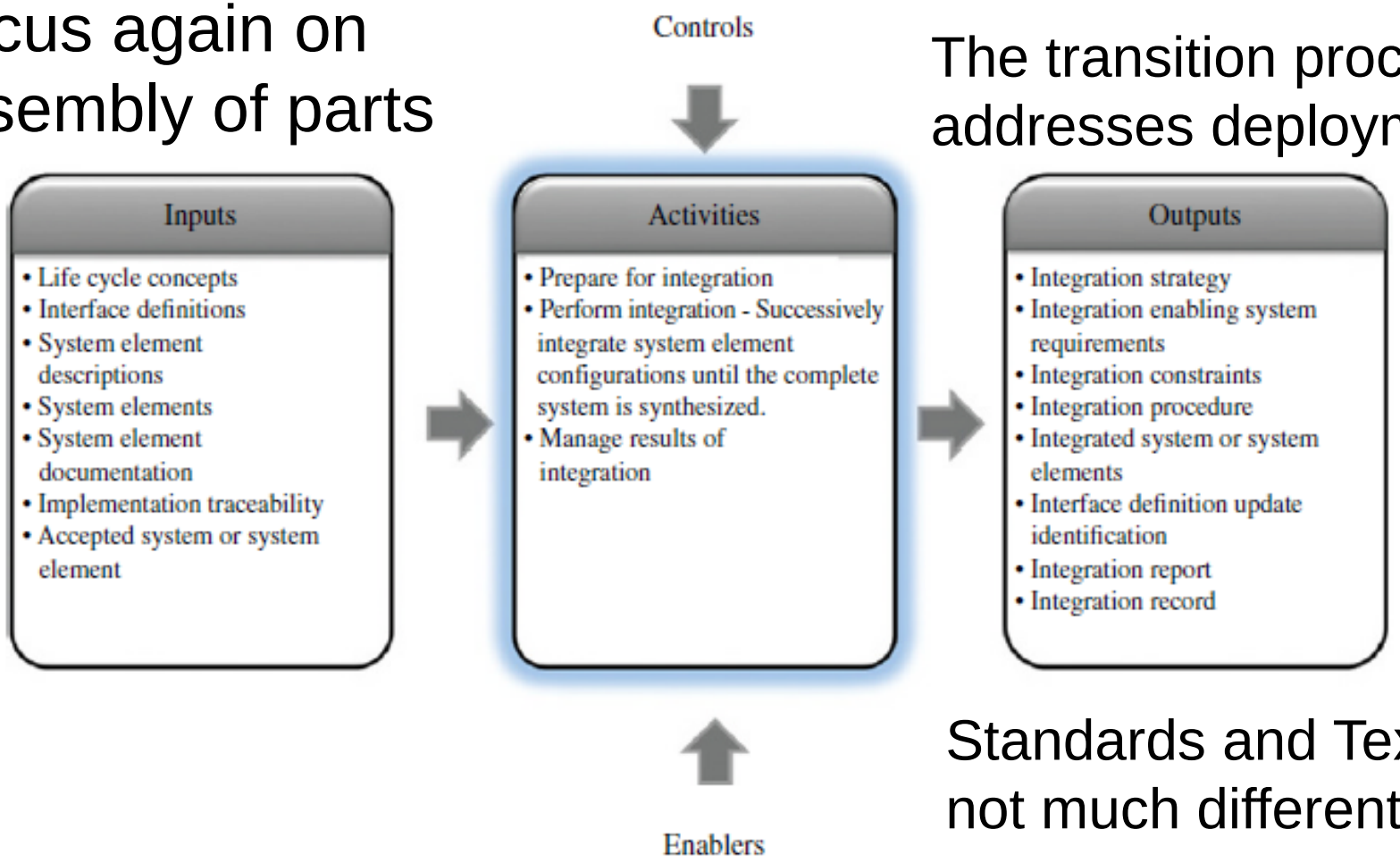
View of integration as being only here



Focus on assembly of parts

SE Handbook IDEF Diagram

Focus again on assembly of parts



The transition process addresses deployment

Standards and Texts not much different

Better Ideas

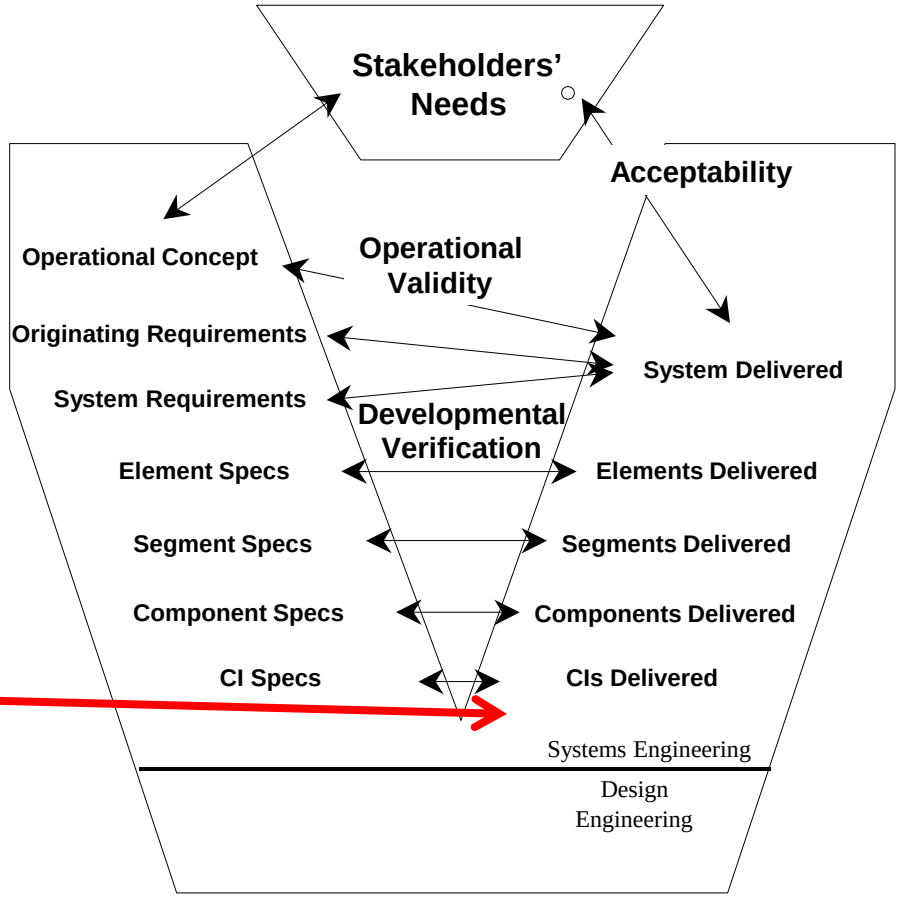
So what can be done…

- **Early** actions
- Strategy
- Conway's Law
- Participate in requirements process
- Allocate and track
- Integrate architecture
- Cross-path Integration
- External interfaces and environment
- Human Systems Integration
- Model-based integration
- Consider multiples
- Integration Readiness Levels
- Deployment

Start Early

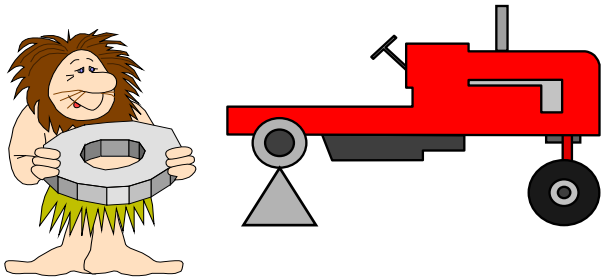
- **Integration starts here!**

- **Start of assembly is too late**

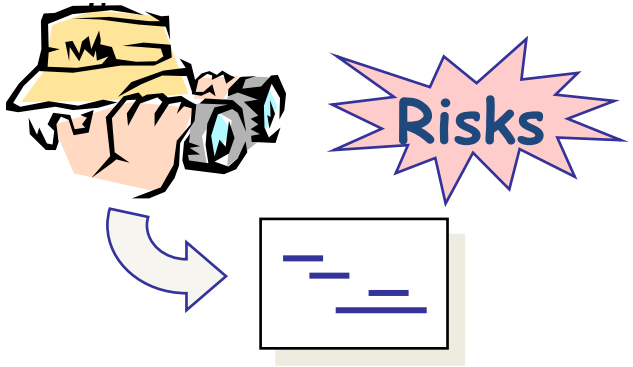


Integration Strategy

- **Common: Assemble components as built**
  - Simple
  - Reactive
  - Risky



- **Better: Identify integration and deployment risks and mitigate in advance**
  - More early activities
  - Proactive
  - reduces risks



- Note: CMMI says to define integration strategy, formerly said to define the assembly sequence

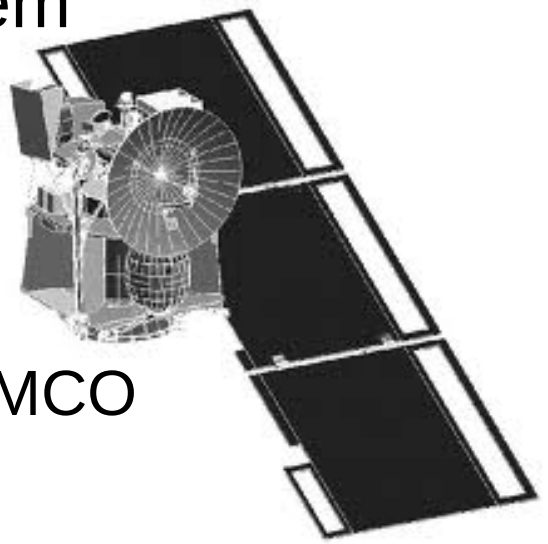
States of Systems Integration

Mische's (1998) four states of systems integration strategy:

- **Interconnectivity** — system components and equipment connect and work (basic interaction) together.
- **Interoperability —** system components and equipment function and interact with each other.
- **Semantic consistency —** Interactions are understood correctly, data has the same meaning.
- **Convergent integration**—system integrated with business processes, people, skills, and knowledge.

Conway's Law

- Any organization that designs a system (defined broadly) will produce a design whose structure is a copy of the organization's communication structure.
- Organizational problems lead to system problems



- Example: Mars Climate Orbiter
  - Ground model used metrics - JPL
  - Spacecraft expected 'English' (feet) - LMCO
- Lesson: Integrate the enterprise first

DC Metro and Fire Systems

Delays in response during January fire in tunnel

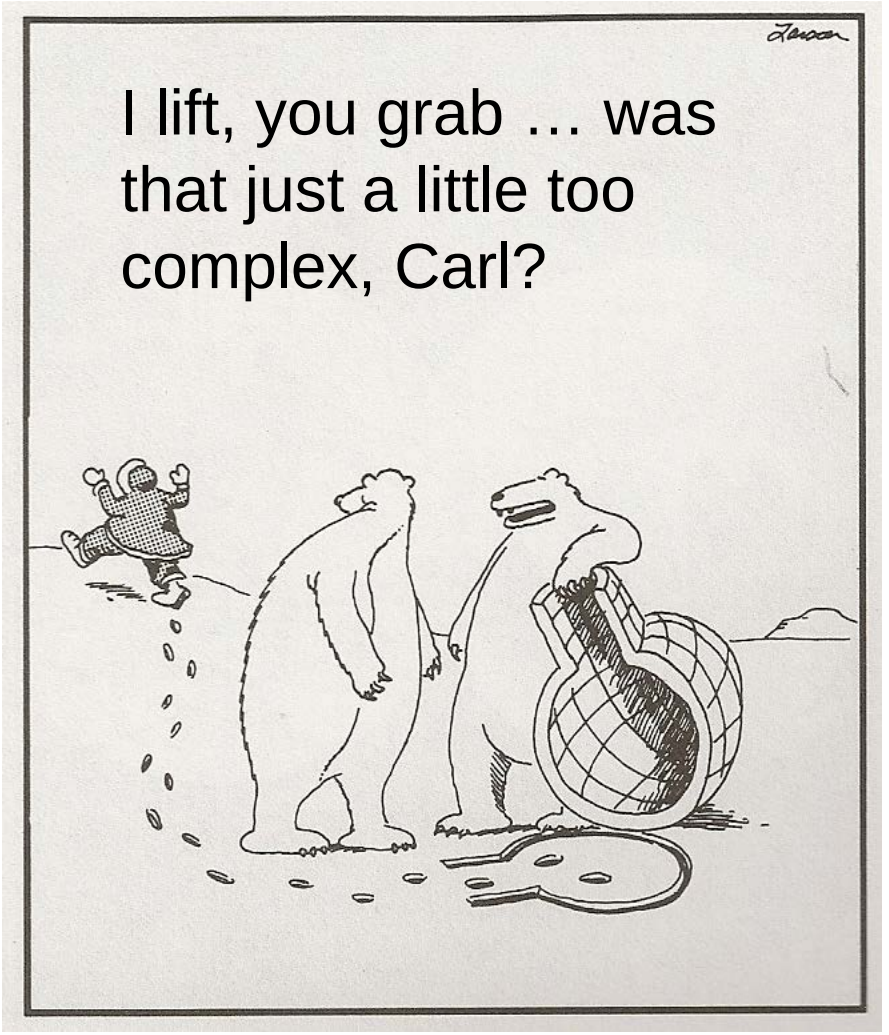
Fire liaison position instituted in rail control center

Integrate Requirements

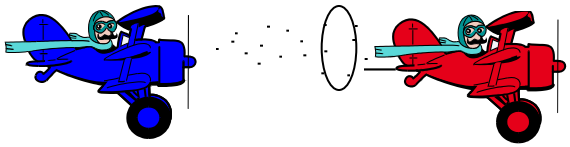
- Not all interface requirements are in ICDs
  - Environment
  - Human interface
  - Service agreements
  - MOUs
  - Hidden anywhere
- Provide requirements for integration
  - Access to measurement at interface
- Find conflicting requirements

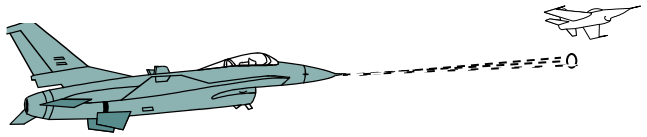
Allocate and Track

- Know which parts contribute to performance and how
- Allocate critical parameters carefully
- Track frequently and at design level
  - Technical Performance Measures (TPMs)



Allocations Happen





- Shotgun spread due to motion & time between shots
- Improvements in flight control and Gatling gun – one misses, all miss!
- Fix – shaker, then flexible mount

- Others with same or similar: F-104, B-52 Tail Gun, A-10, Cobra gunship, Roman arrow catapult

Late Integration of Technologies

Allocation Example

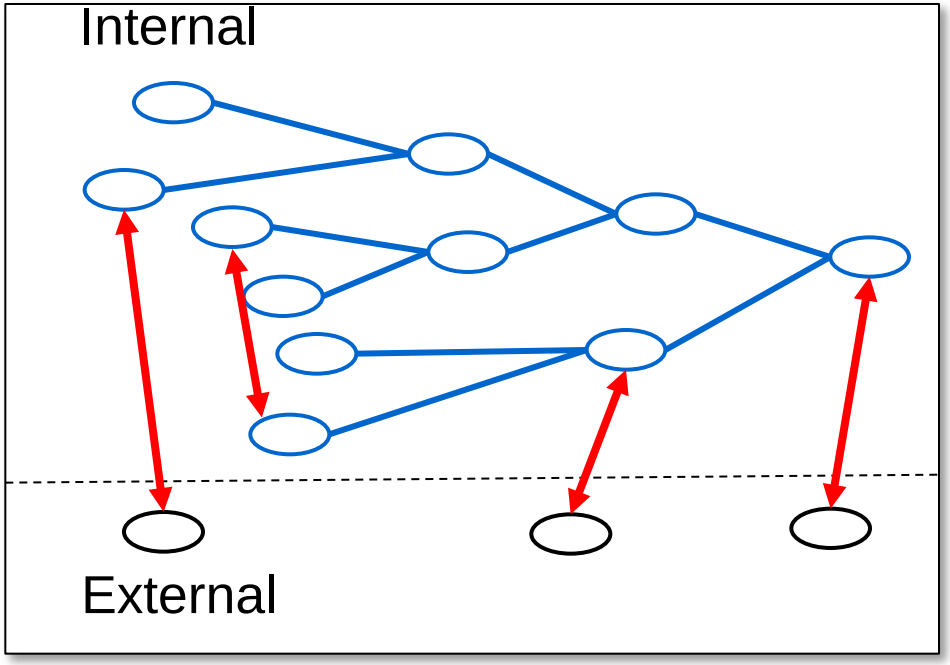
Function	*Requirement*	*Component*
Destroy Target	X% damage/hit	Bullets
Go to Target	+/- X degrees	Bullets
Propel Bullets	+/- X fps **+/- X bullets/second** +/- X degrees	**Gun**
Stabilize Bullets	+/- X RPM	Gun
Aim Gun	+/- degrees	Mount/airframe
Control Aircraft	**+/- stability**	**Flight control**
Find and Display Target	+/1 accuracy	Radar
Guide Aircraft	+/- control accuracy	Pilot
Provide Aerodynamics	+/- stability & response	Airframe

Integration of Architecture

- Physical
  - Does the structure work
  - Are things missing
- Approaches
  - Bottom up
  - Top down
  - Big bang

Early Cross-Path Integration

- Internal
  - Between components
- External
  - Other systems
  - Legacy
  - Operations
  - People
  - Environment



External Environment

Sydney Morning Herald – 10/13/97

- Cars exhibit problems
  - Brakes jam on
  - Doors lock
  - Engines shut down
- Sources
  - Traffic light sensors
  - Taxi and police radios
  - Broadcast transmitters
  - Underground power lines

Human System Integration

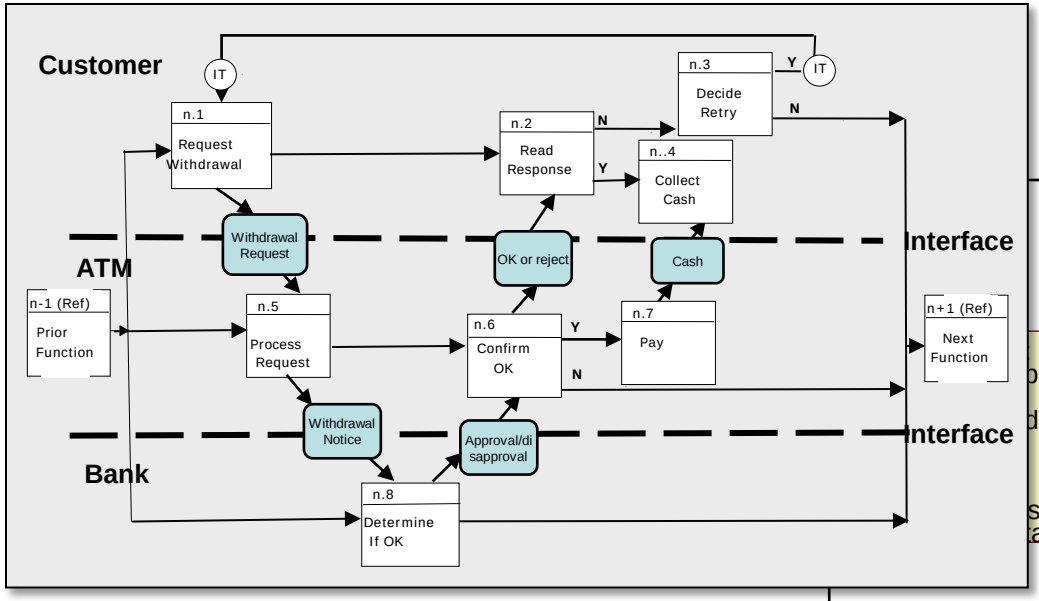
- **Downing of Iranian airliner**
  - Washington Post headline: “System works, operator makes error”
  - But the operator is part of the system!
- **Air France Flight 447**
  - Automation turns off
  - Quick reaction required
  - Questionable data
  - Human response as expected?
- **Therac-35**
  - Operators faster than anticipated
  - Software didn’t accept input
  - Patients died

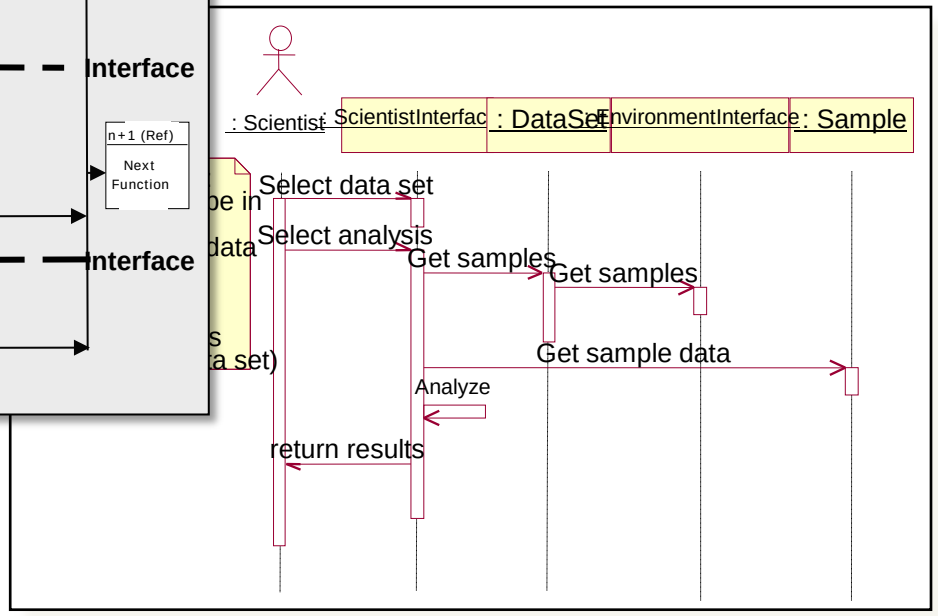
Integration of Architecture (cont'd)

- Functional
  - Is functional architecture defined
  - Model based integration
- Approach
  - Threads
    - Logical/functional
    - Temporal
    - Sequential
    - Communications
    - Procedural

Model-based Integration

- Executable models are valuable for interfaces





Model-based Integration

- Comanche Helicopter
  - Full model of gun operations
  - Included:
    - Equipment – new and old
    - Pilot – fresh and tired
    - Missions
- Navy ATC Communications
  - Full model
  - Identified protocol errors in switch from 4-ship to individual aircraft
  - Components integrated into model as developed

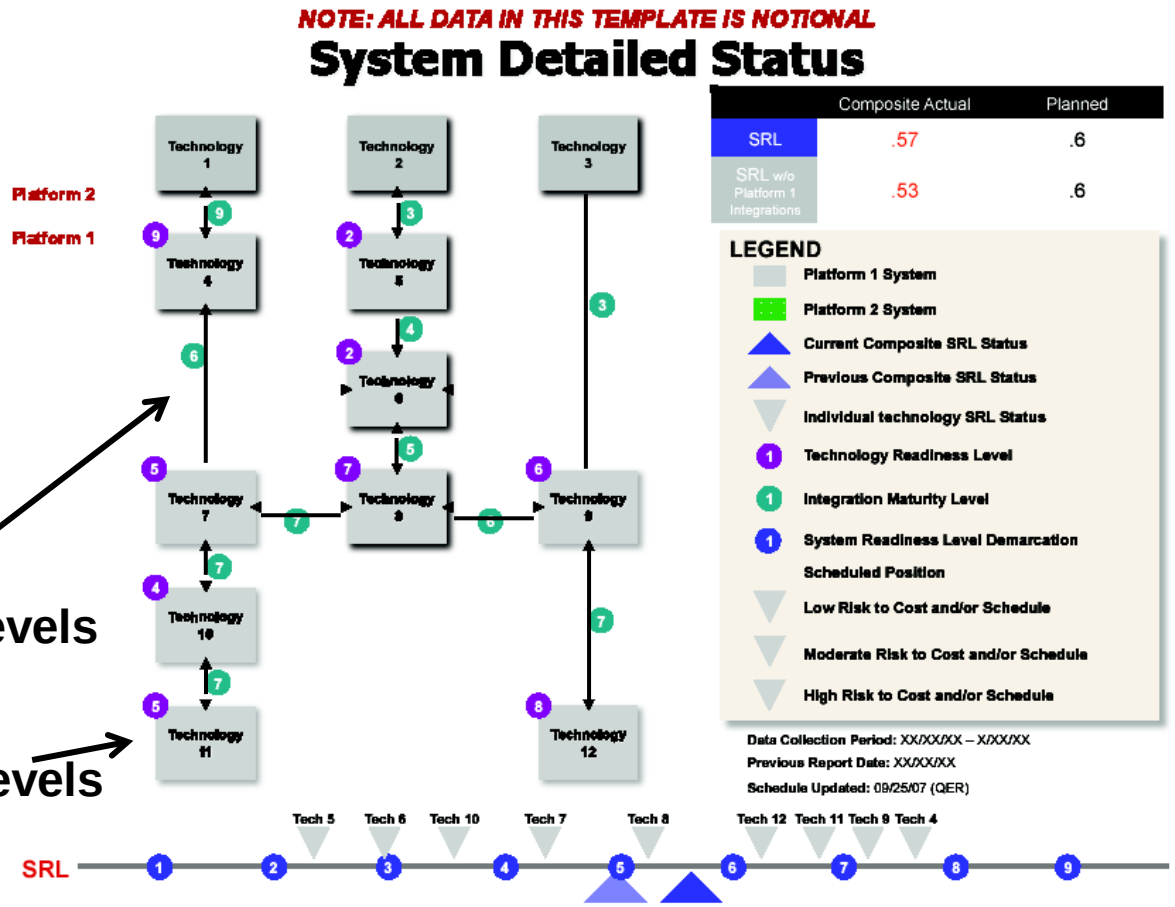
Integration Readiness Level

S(ystem)RL = IRL x TRL IRL = Integration Readiness Level

- Have these technologies been used together before?

Integration Readiness Levels

Technology Readiness Levels



sse.stevens.edu/fileadmin/cser/2006/papers/126-Sauser-TRL%20SRL.pdf

Multiple Copies

US Advanced Automation System

- New video recording function
  - Full update every 12 seconds
  - Worked fine on single scope
- Laboratory Established
  - 6 full size scopes
  - 94 emulated
  - Crashed all four networks

Why not found by modeling early?

Integration of Testing

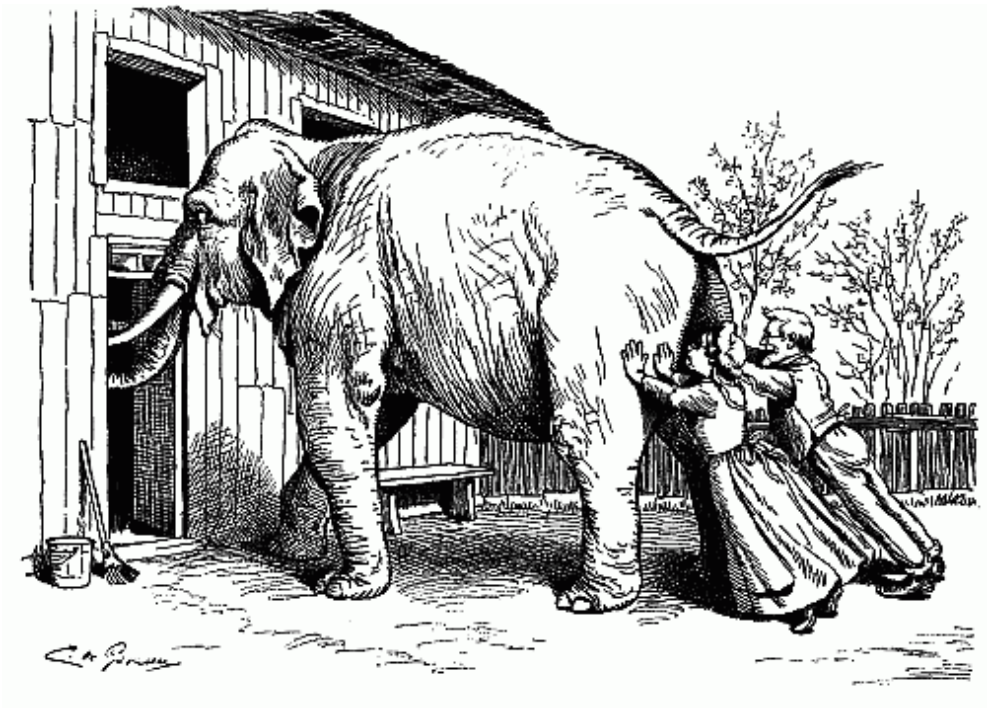
- Small satellite failed on launch
- Failure analysis unable to reproduce failure during single parameter test
- Combined thermal and vibration test revealed cause

- Decade later, same organization repeats same mistake!

Late Integrated Approach to Testing

Deployment

- Will it fit?
- Is support ready?
- Transportation?
- Training?
- Local customs?
- Environment?
- Schedule?
- Geography?
- Does it work for the user in their operations?



Integration Management Methods

- Interface Control Working Groups (ICWG)
  - Members from both (all) sides of the interface
  - Addresses interface issues
- Systems Engineering Interface Team (SEIT)
  - Members from IPTs on a program
  - Addresses interface issues
  - Maintains commonality of discipline approaches
- Configuration Management of ICDs
  - Specific process for interface related changes
- Interface Design Review
  - Between PDR and CDR
  - Focus on only the interfaces

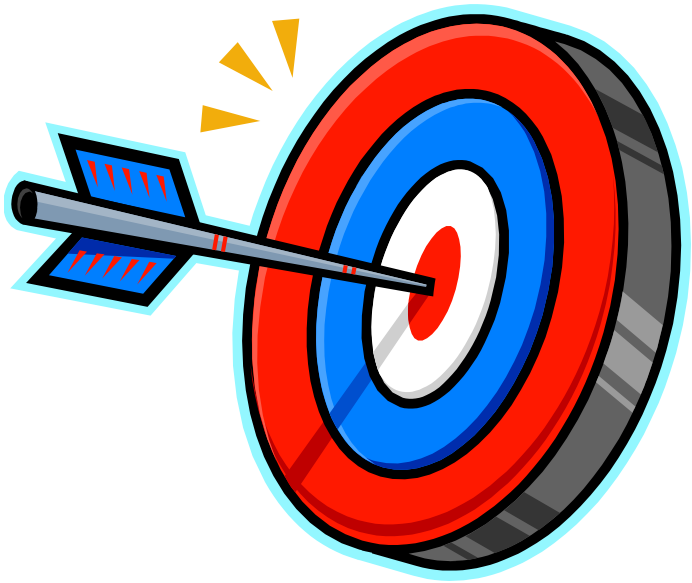
England’s High Speed 2

- Considering integration with
  - Existing rail
  - Air
  - Where you live
  - Where you are going

INCOSE Presentation, IS 2012, Rome, Italy

Conclusion

- Yes, we can do better with…
  - Early start
  - Continued effort
  - Systems thinking



There is a lot of integration to do before and after putting the pieces together!

Questions?

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