Why is Systems Integration understood so poorly?
Reflections on 3 decades of unforeseen failures

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Abstract

Nearly all systems developments run into problems in the late project phases, where unforeseen surprises disrupt careful planning. We will discuss a framework for systems development and integration and use a number of examples to explore what happens during systems integration. We assert that the entire project plan should be designed in reverse order, taking systems integration as driving concern.
Why is Systems Integration understood so poorly?

1. Viewing performance
2. Acquisition performance
3. Solution information
   - Physical
     - Skip; too little time
4. Gas turbines
5. Subsea oil & gas

Theory
- Fundamentals of integration
- Fundamentals of systems engineering
- Role of software and users
- Reflections on systems integration

Integration Examples
- 1980
  - 1 viewing performance
  - Fundamentals of integration
  - 7 great presentations
- 1990
  - 2 acquisition performance
  - Fundamentals of systems engineering
- 2000
  - 3 solution information
  - Role of software and users
  - Physical
    - Skip; too little time
  - Products/projects
    - Skip; too little time
- 2010
  - 4 gas turbines
  - 5 subsea oil & gas
  - Reflections on systems integration
  - Wrap-up

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Why is Systems Integration understood so poorly?

Example 1: Integration of Treatment Planning System

1980, first job:
- display firmware
integration drama:
- image retrieval 20s
  (spec: less than 1s)
cause:
- too much overhead
- too many layers
- too much process
communication
root cause:
lack of system design

Why is Systems Integration understood so poorly?

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SIRKfirmwareExample
Why is Systems Integration so Poorly Understood

Why do we always get delays and cost overruns during integration?

Why seems everything OK until integration?

Why do so few people understand what happens during integration?

Do you have any design issues for the design meeting?

The default answer is: No.

During integration numerous problems become visible

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SIRKintegrationQuestions
How do you rank your project or program?

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<th></th>
<th>poor</th>
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<th>good</th>
<th>very good</th>
<th>excellent</th>
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**Practical Limitations**

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</table>

*Perfect processes, people, technologies, designs, or specifications do not exist*

*Imperfections sometime, somewhere, will show up; always at an inconvenient moment*

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**Why is Systems Integration understood so poorly?**

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Fundamentals of Integration

integration examples

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7 great presentations

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V-Model

- needs
  - specification
    - system design
      - subsystem design
        - component design
          - component realization
    - subsystem test
  - component test
- validation
  - verification
    - system test
      - subsystem test
        - component test
Why is Systems Integration understood so poorly?
Limitations in Front-End Cause Failures

failures found during integration can be traced back to *unknowns*, *unforeseens*, and *wrong assumptions*

Why is Systems Integration understood so poorly?
Typical Concurrent Product Creation Process

- 1 strategy
- 0. feasibility
- 1. definition
- 2. system design
- 3. engineering
- 4. integration & test
- 5. field monitoring
- 6. product operational life cycle

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Integration Takes Place in a Bottom-up Fashion

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SIRKlevels
Fill in this form during KSEE 2013!

<table>
<thead>
<tr>
<th>KSEE 2013 work form</th>
<th>Current Status</th>
<th>Potential Improvements</th>
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</thead>
<tbody>
<tr>
<td>Niels Braspenning</td>
<td>What type of failures pop-up during your Integration?</td>
<td>How could these failures be found earlier? What means or strategies can you employ to find them earlier?</td>
</tr>
<tr>
<td>Alejandro Salado</td>
<td>Validation risks of using development methodologies in a hierarchical fashion - When contracts meet architecture ownership</td>
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<tr>
<td>Andreas Thorvaldsen</td>
<td>Changing A System From Within – And Get Hit By The Unexpected Surprises</td>
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<tr>
<td>Benoît Le Bihan</td>
<td>Laggan Tormore Project System Test: when new Subsea Solutions For Harsh Environment Meet Reality</td>
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<tr>
<td>Jim Armstrong</td>
<td>Systems Integration: What Are We Waiting For?</td>
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<tr>
<td>Terje Jensvik</td>
<td>A software centric approach to Electronic Systems Engineering.</td>
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</tr>
<tr>
<td>Eldar Tranøy</td>
<td>Early phase need analysis – Can we ease systems integration?</td>
<td></td>
</tr>
<tr>
<td>Gerrit Muller</td>
<td>Why is Systems Integration understood so poorly? Reflections on 3 decades of unforeseen failures</td>
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</tbody>
</table>
Example 2: Performance Again

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SIRKlogoAcquisition
Example 2: Integration of MRI Acquisition Subsystem

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Repetition Time MRI

imaging = repeating similar pattern many times

Gy = 0

Gy = 127

Gy

RF transmit

TE

TR

typical TE: 5..50ms

receive

problem:
TR > 1 s.
spec less than 10 ms
more than factor 100 off!

causes:
floating point arithmetic
too many layers

root cause:
functionality focus

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2010
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99% of Organization has a “Parts” Focus

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Why is Systems Integration understood so poorly?
Few Understand Key Performance Parameters

Systems Engineering: responsible for customer key drivers and key performance parameters of system

- process quality
- throughput
- reliability

- mechanical engineering
- mechatronics
- electrical engineering
- optics
- measurements
- embedded control
- software engineering

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Typical Order of Integration Problems

1. The (sub)system does not build.
2. The (sub)system does not function.
3. Interface errors.
4. The (sub)system is too slow.
5. Problems with the main performance parameter, such as image quality.
6. The (sub)system is not reliable.
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Example 3: Integrated Clinical Solutions

Integrated Clinical Solutions: integrate stand-alone products to offer clinical integrated functionality

Note the similarity with Kongsberg Maritime’s achievements with K-master and operator stations

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Every application, release, product, product family, and vendor has its particular interpretation of information, despite standardization.

Convertors, wrappers, and adapters are nearly everywhere.

The cynical name of our product was *Shit Concentrator* since the integrating product has to resolve any inconsistency.

<table>
<thead>
<tr>
<th><strong>standardization stack</strong></th>
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<tbody>
<tr>
<td>high innovation rate</td>
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<tr>
<td>cardio analyse</td>
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<tr>
<td>CT</td>
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<tr>
<td>Siemens</td>
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<td>ACR/NEMA</td>
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</table>

**legend**
- applications
- product family
- vendor
- world standard

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SIRKinformationModels
Risks of “Near Identical” Data Models

URF monitor output: fixed size letters at fixed grid

Workstation

other rendering causing a dangerous mismatch between text and image

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SIRKontRendering
Why is Systems Integration understood so poorly?

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Software Characteristics and Role

quantified properties
- productivity: 100,000 images per hour
- speed: 100 frames/second
- max latency: 50ms
- max down time: 4 hrs/year

SW determines and limits properties

dynamic behavior
- control

SW defines functionality and dynamic behavior
- captures applications
- conducts all technologies

parts
- system
- subsystem 1
- subsubsystem A
- atomic part
- subsubsystem B
- atomic part
- subsubsystem N
- atomic part

parts
- system
- subsystem n
- subsubsystem A
- subsubsystem B
- subsubsystem N

SW has its own partitioning
- in e.g. components, units

SW has zero delivery time
- production is costless
- is ideal to solve last minute problems

SW is abstract and intangible
- is alien to “physical” engineers

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Segregation of hardware and software is a typical organizational problem. Such segregation ignores close coupling of hardware and software.

Erroneous assumptions about hardware are discovered late. Key performance parameters are visible late.

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User Behavior is a.o. Determined by

- mental status
- physical status
- trauma
- emotional status
- allergy
- handicap
- religion
- taboo
- culture
- taboo
- cultural
- location
- time
- education
- mental status
- trauma
- emotional status
- physical status
- allergy
- handicap
- religion
- taboo
- preferences
- taste

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ETexperienceFactors
Role of Users

Users:
• are autonomous
• behave under influence of internal and external drivers
• are creative
• “solve” problems
• have limited knowledge of the system
• have limited insight in their impact on the system

Users do the unexpected
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Errors Found after Functional Analysis and Quantification

PID before

PID after
changed due to functional analysis and quantification

from Knowledge Capture, Cross Boundary Communication and Early Validation with Dynamic A3 Architectures
Analysis of Subsea System Test

Where it should have been specified
Where it should have been tested
Where it was specified
Where it was tested

from master project by Åke Törnlycke and Rune Henden, FMC, 2012
Reflections on Systems Integration

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Imperfect Processes

Why is Systems Integration understood so poorly?

- result and delivery oriented
- artifact oriented (documents!)
- “check mark” syndrome
### Imperfect People

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- see only a small part of the big picture
- are unaware of their blind spots
- are adaptable and intelligent

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### Imperfect Technology

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<tbody>
<tr>
<td>Customers</td>
<td>builds on math, physics, etc.</td>
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<td>Lifecycle support</td>
<td>even experts do not understand all</td>
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<td>Specifications</td>
<td>vendors may supply it</td>
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<td>Design</td>
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Why is Systems Integration understood so poorly?

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SIRKreflectionsTechnology
Imperfect Design

Why is Systems Integration understood so poorly?

- multi-disciplinary
- many faceted (parts, functions, qualities)
## Imperfect Specifications

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<th>Specifications</th>
<th>Outside world</th>
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</table>

- are never complete
- are often polluted with solutions
- are often internally inconsistent
- tend to lack sharpness
Imperfect Lifecycle Support

- many lifecycles
- many stakeholders
- many rhythms

Why is Systems Integration understood so poorly?
Imperfect Customers

Outside world

Customers

Lifecycle support

Specifications

Design

Technology

People

Process

- complicated environment
- politics
- do not know what they need
- do the unexpected
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- social complexity (humans)
- natural complexity
- interaction between natural and artificial world
Without Measures it only gets Worse...

**trends**
- increased integration
- features
- performance expectations
- amount of software
- required time to market
- globalization use
- globalization in development and logistics
- increased black box re-use
- increased black box complexity

**integration surprises**

Why is Systems Integration understood so poorly?
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SIRKlogoWrapUp
Why is Systems Integration understood so poorly?

Why is Systems Integration understood so poorly?

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SIRKreflectionsConclusion

Conclusion on Reflections

Technology
Process
People
Design
Specifications
Lifecycle support
Customers
Outside world

plenty of imperfections!
How to Counter all of this?

plenty of imperfections!

**Fail Early:**
“proof” key performance ASAP
use partial integrations

**Improve System Development:**
modeling, analysis, tools
process, people

Focus on Systems Engineering

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| Outside world |
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