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. Products/projects
   - Skip; too little time
5. Gas turbines
6. Subsea oil & gas

Fundamentals of integration

Role of software and users

Reflections on systems integration

Wrap-up

7 Great presentations
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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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

scheduled delivery date
realized delivery date

delay
and cost overruns
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How do you rank your project or program?
## Practical Limitations

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

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

x expected answers from Kongsberg industry
Why is Systems Integration understood so poorly?

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SIRKlogoFundamentalsIntegration
V-Model

needs
specification
system design
subsystem design
component design
component realization

validation
verification
system test
subsystem test
component test
Why is Systems Integration understood so poorly?

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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

Why is Systems Integration understood so poorly?

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Integration Takes Place in a Bottom-up Fashion

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SIRKievels
## KSEE 2013 work form

<table>
<thead>
<tr>
<th>Niels Braspenning</th>
<th>System Integration at ASML: Linking Technical Content, Test Configurations, Timing... And People!</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alejandro Salado</td>
<td>Validation risks of using development methodologies in a hierarchical fashion - When contracts meet architecture ownership</td>
</tr>
<tr>
<td>Andreas Thorvaldsen</td>
<td>Changing A System From Within – And Get Hit By The Unexpected Surprises</td>
</tr>
<tr>
<td>Benoît Le Bihan</td>
<td>Laggan Tormore Project System Test: when new Subsea Solutions For Harsh Environment Meet Reality</td>
</tr>
<tr>
<td>Jim Armstrong</td>
<td>Systems Integration: What Are We Waiting For?</td>
</tr>
<tr>
<td>Terje Jensvik</td>
<td>A software centric approach to Electronic Systems Engineering.</td>
</tr>
<tr>
<td>Eldar Tranøy</td>
<td>Early phase need analysis – Can we ease systems integration?</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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</table>

### Current Status

**What type of failures pop-up during your Integration?**

### Potential Improvements

**How could these failures be found earlier? What means or strategies can you employ to find them earlier?**
Example 2: Performance Again

Why is Systems Integration understood so poorly?

1980
1 viewing performance
2 acquisition performance

1990
3 solution information
physical skip; too little time

2000
products/projects skip; too little time

2010
4 gas turbines
5 subsea oil&gas

fundamentals of integration
fundamentals of systems engineering
role of software and users
reflections on systems integration
wrap-up

7 great presentations
Example 2: Integration of MRI Acquisition Subsystem

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Repetition Time MRI

imaging = repeating similar pattern many times

Gy = 0
Gy = 127

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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SIRKimaging
Fundamentals of Systems Engineering

Why is Systems Integration understood so poorly?

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Why is Systems Integration understood so poorly?
99% of Organization has a "Parts" Focus

- Engineering knowledge
- System specification
- System design
- Source data
- Parts data base
- Production procedures
- Qualification procedures
- System documentation

- Procurement
- Production
- Installation
- Quality assurance
- Lifecycle support

- Knowledge DB
- Doc DB
- CAD
- SCM
- ERP
- PDM

- Past experience
- Project documents
- Mechanical electrical design database
- Source code management
- Resource planning, e.g. SAP
- Product data management

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SPF Engineering
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
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.
Solutions: Integration of Multiple Products

integration examples

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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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The Information Model Swamp

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.

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Risks of “Near Identical” Data Models

URF monitor output: fixed size letters at fixed grid

Workstation

- tumor>

- tumor>

other rendering causing a dangerous mismatch between text and image

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SIRKfontRendering
Role of Software

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theory

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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

- function
- function
- function

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

**parts**

**system**

**subsystem 1**
- subsub system A
  - atomic part
- subsub system B
  - atomic part
- subsub system N
  - atomic part

- ...

**subsystem n**
- subsub system A
- subsub system B
- subsub system N

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

- 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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SIRKpartsFunctionsQualities
Hardware and Software Typically Meet at the End

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

environmental factors

social status
  relation
  family

group influence
  fashion

culture
  taboo
  cultural

location

time

education

mental status
  trauma
  emotional status

physical status
  allergy
  handicap

religion
  taboo

preferences
  taste

personal factors

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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


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Analysis of Subsea System Test

Why is Systems Integration understood so poorly?

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

Why is Systems Integration understood so poorly?

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SIRKlogoReflections
### Imperfect Processes

| Outside world | · result and delivery oriented |
|              | · artifact oriented (documents!) |
| Customers    | · “check mark” syndrome |
| Lifecycle support | |
| Specifications | |
| Design | |
| Technology | |
| People | |

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

- Result and delivery oriented
- Artifact oriented (documents!)
- “Check mark” syndrome

Why is Systems Integration understood so poorly?

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| Outside world | • see only a small part of the big picture |
| Customers     | • are unaware of their blind spots         |
| Lifecycle support | • are adaptable and intelligent          |
| Specifications |
| Design        |
| Technology    |
| People        |
| Process       |
### Imperfect Technology

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<tr>
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<td>Customers</td>
<td>builds on math, physics, etc.</td>
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<tr>
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<td>even experts do not understand all</td>
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Why is Systems Integration understood so poorly?

- builds on math, physics, etc.
- even experts do not understand all
- vendors may supply it

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SIRKreflectionsTechnology
Why is Systems Integration understood so poorly?

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### Imperfect Specifications

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

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</table>
Imperfect Lifecycle Support

Outside world

Customers

Lifecycle support

Specifications

Design

Technology

People

Process

- many lifecycles
- many stakeholders
- many rhythms
Imperfect Customers

Outside world

Customers

Lifecycle support

Specifications

Design

Technology

People

Process

- complicated environment
- politics
- do not know what they need
- do the unexpected
Outside world

- 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**
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Wrap-up
Conclusion on Reflections

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SIRKreflectionsConclusion

plenty of imperfections!
How to Counter all of this?

Trends:
- Increased integration
- Features
- Performance expectations
- Amount of software

Integration Surprises:
- Required time to market
- Globalization use
- Globalization in development and logistics
- Increased black box re-use
- Increased black box complexity

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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