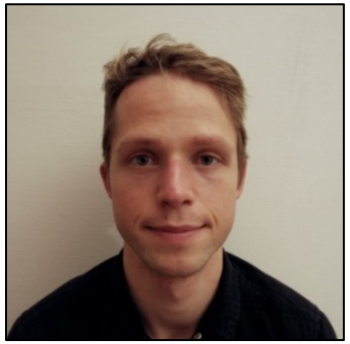
27th annual INCOSE international symposium
Adelaide, Australia
July 15 - 20, 2017

ENGINEERS AUSTRALIA
SESA

Evolving tolerance management for increased robustness of subsea installation operations



Lars Petter Bryn and *Gerrit Muller*
Presented by Maarten Bonnema

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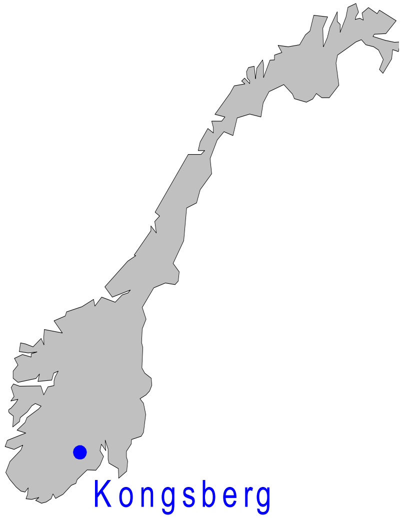
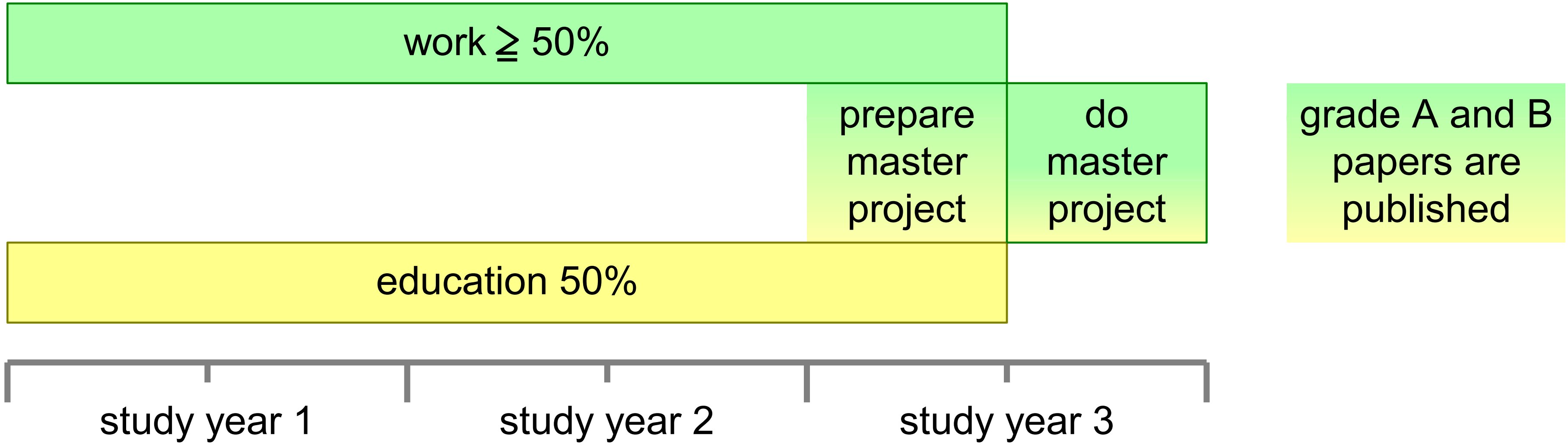
Technology park Kongsberg



Research Model Master Students Systems Engineering in Kongsberg, Norway

students know:
+ domain
+ SE methods
and techniques

students:
+ apply
+ reflect
+ evaluate



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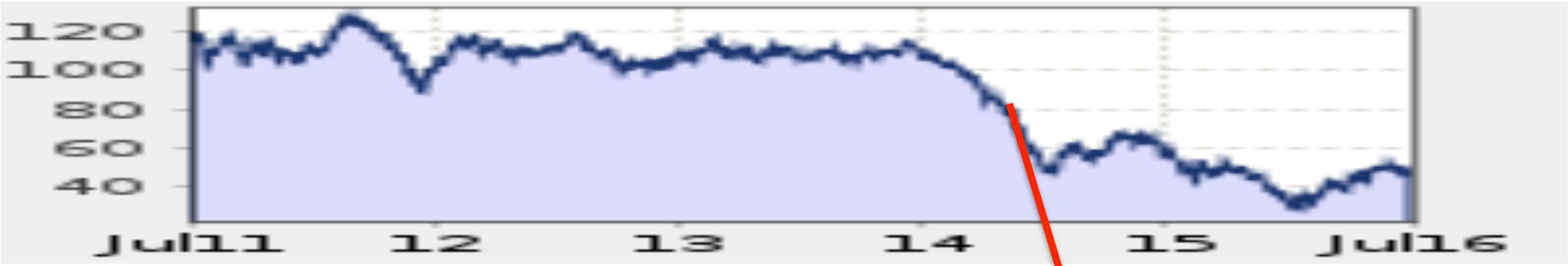
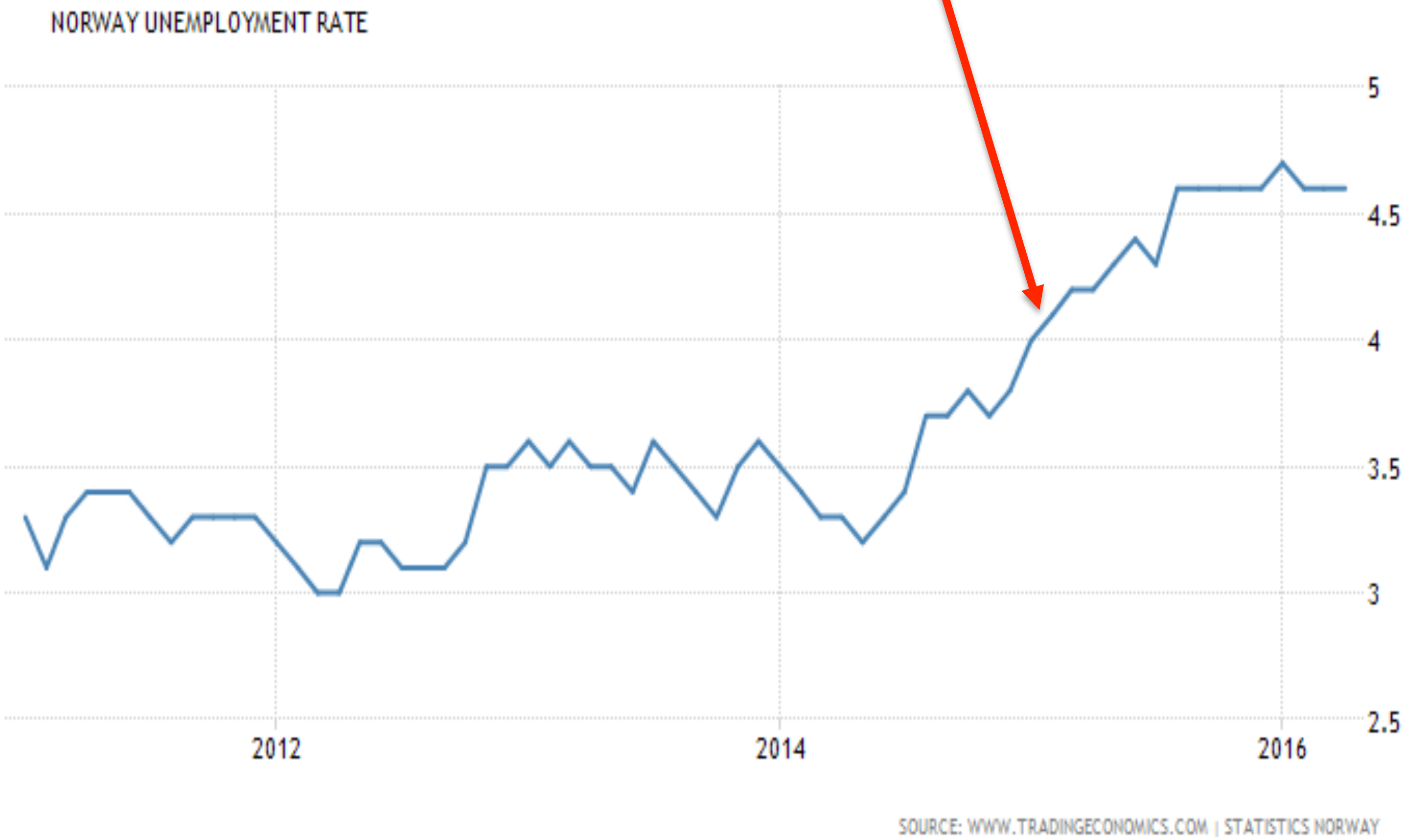
Context: Low oil prices hit Norway hard.



oil price

From oil-price.net



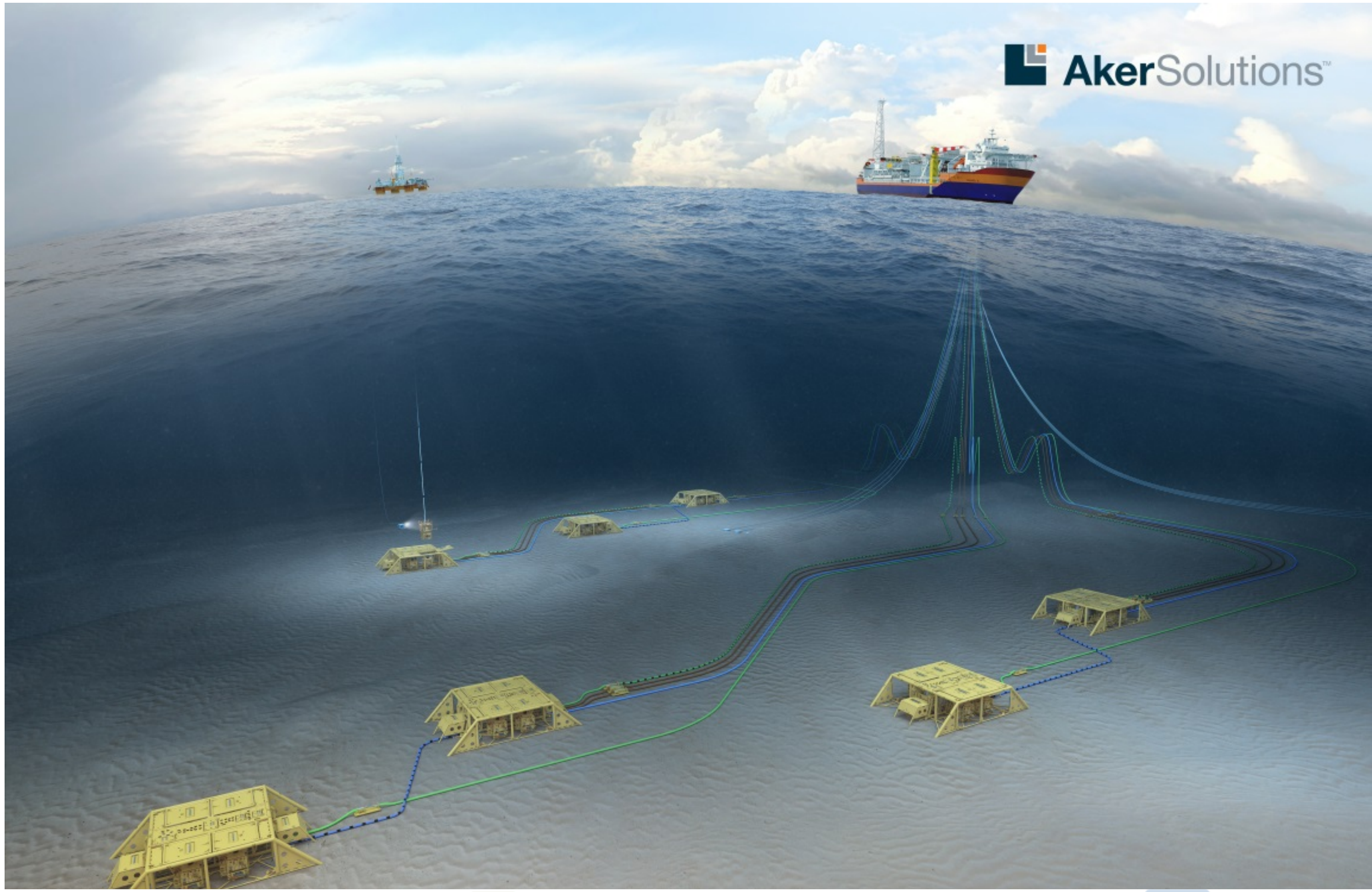
Norwegian Unemployment rate

Domain: Subsea oil and gas production

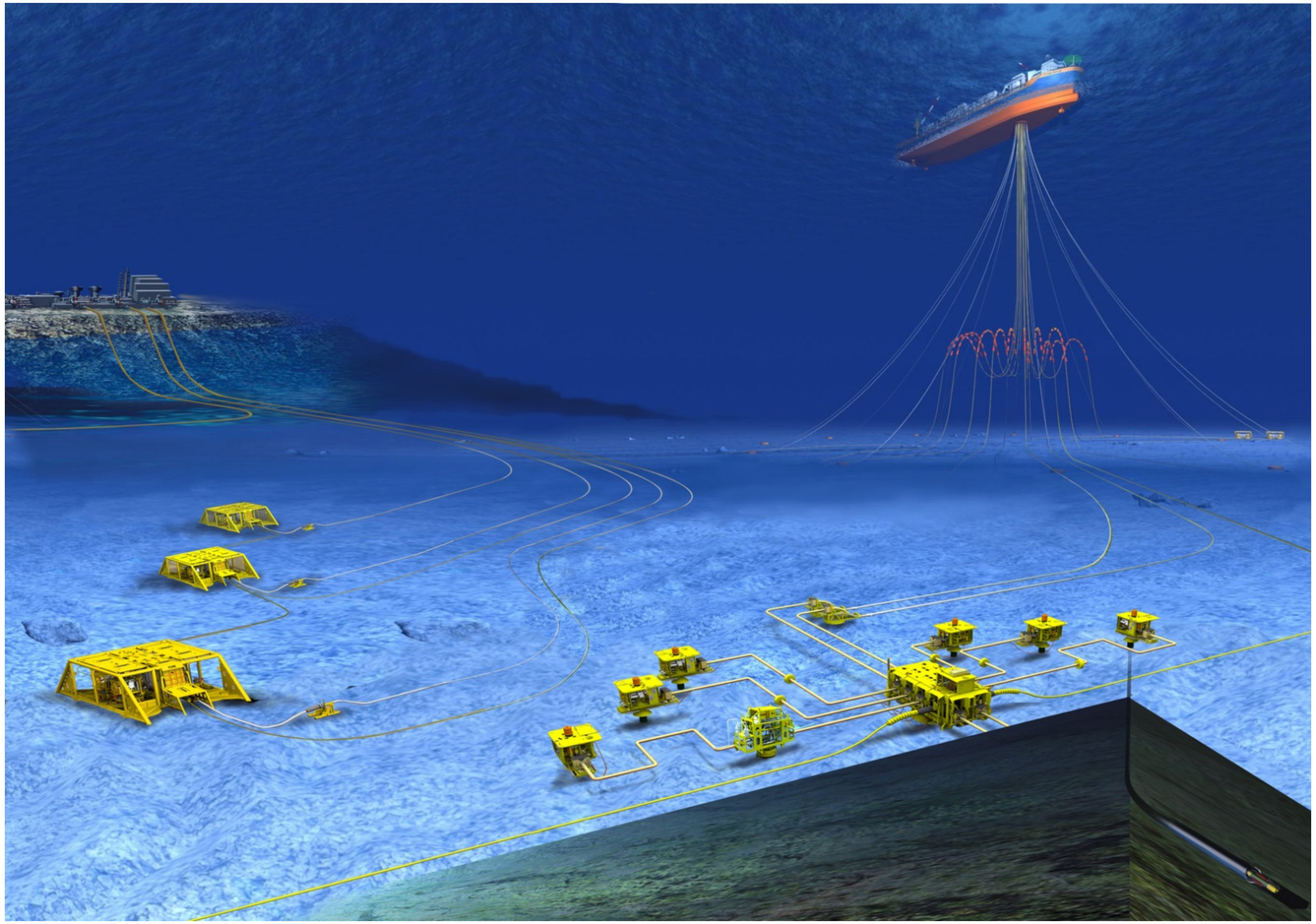
- Deeper water, harsher environment – increasing complexity
- Low oil price – need for cost reductions
- Shelved investments – 400 million USD (january 2016)
- 258000 layoffs - and increasing (december 2015)
- Need for new projects – shared responsibility

Company of research

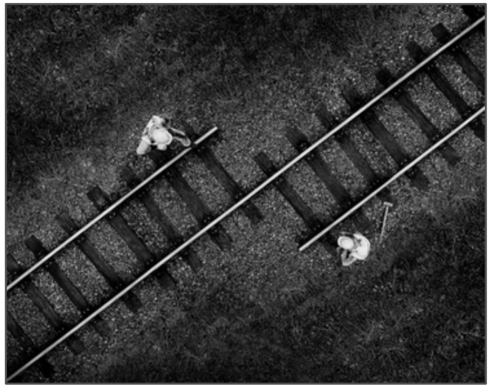
- Aker solutions AS
- Provides products and services to the oil and gas industry
- 2014: 16.000 employees in 20 different countries



Subsea production system



Tolerances

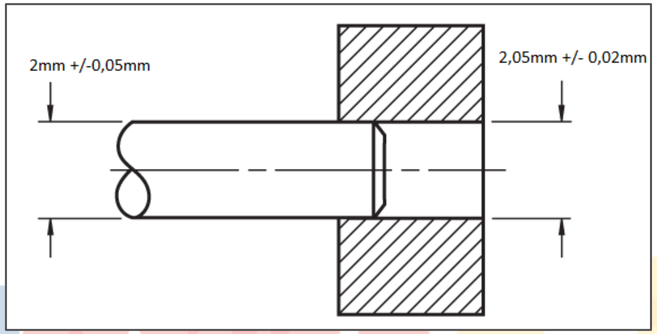


Installation – maximum possible misalignment for successful installation

Tolerance management

Manufacturing – Deviation from nominal

Clearance – Needed envelope for installation



SPS project costs:

- Installation costs:
  - Rig rental: 8 milion NOK per day
  - Installation of one single XT: 2-4 weeks
  - Typical XT cost: 40 million NOK
  - Expensive installation
- Potential for cost reductions by increasing robustness of installation

Motivation for research:

- Challenging times:
  - Cost reductions
  - Increasing complexity
  - Few projects
  - Increase competitiveness
- Inconsistency of tolerance management:
  - Standarize method for tolerance analysis

Robustness of installation

- Robustness of installation:
  - Getting it correct the first time, within the given time and cost limits
  - Reduces installation costs
  - Reduces the break-even rate
  - Increases competitiveness

Appropriate tolerance management?

- Various approaches
  - Software vs. Manual calculations
  - RSS (worst-case) vs. RMS (Statistical)
- Manually calculated tolerance budgets supported by system modelling - validation

Research questions

- How can current tolerance analysis methods evolve to improve tolerance management?
- How can tolerance management ensure robustness of installation?

Three projects:

- Project A:
  - Coast of Congo
  - Sea depth: 1350 m
  - Large international oil and gas company
  - Phase: Installation
- Project B
  - Coast of Angola
  - Sea depth: 1500
  - Large international oil and gas company
  - Phase: Delivery
- Project C
  - Barent sea, Norwegian continental shelf
  - Sea depth: 1250
  - Large Norwegian oil and gas company
  - Phase: Study

Research method:

- Interviews with AKSO clients for identification of needs
- Comparative research of project A and B
- Conduction of tolerance management in project C

- Tolerance issues:
  - Quantity and reason

- Focus: Reliability and credibility

Tolerance management:

- Project A
  - Software
- Project B
  - Manual calculations
- Project C
  - Manual calculations supported by system modelling

Project A – Software analysis

- Geometrical Dimensioning & Tolerancing method (GD&T)
- Accurate calculation of the tolerance chain
- Utilizes manufacturing drawings for input
- Direct link between manufacturing and analysis
- Statistical tolerance analysis – Monte Carlo simulation with a uniform probability distribution

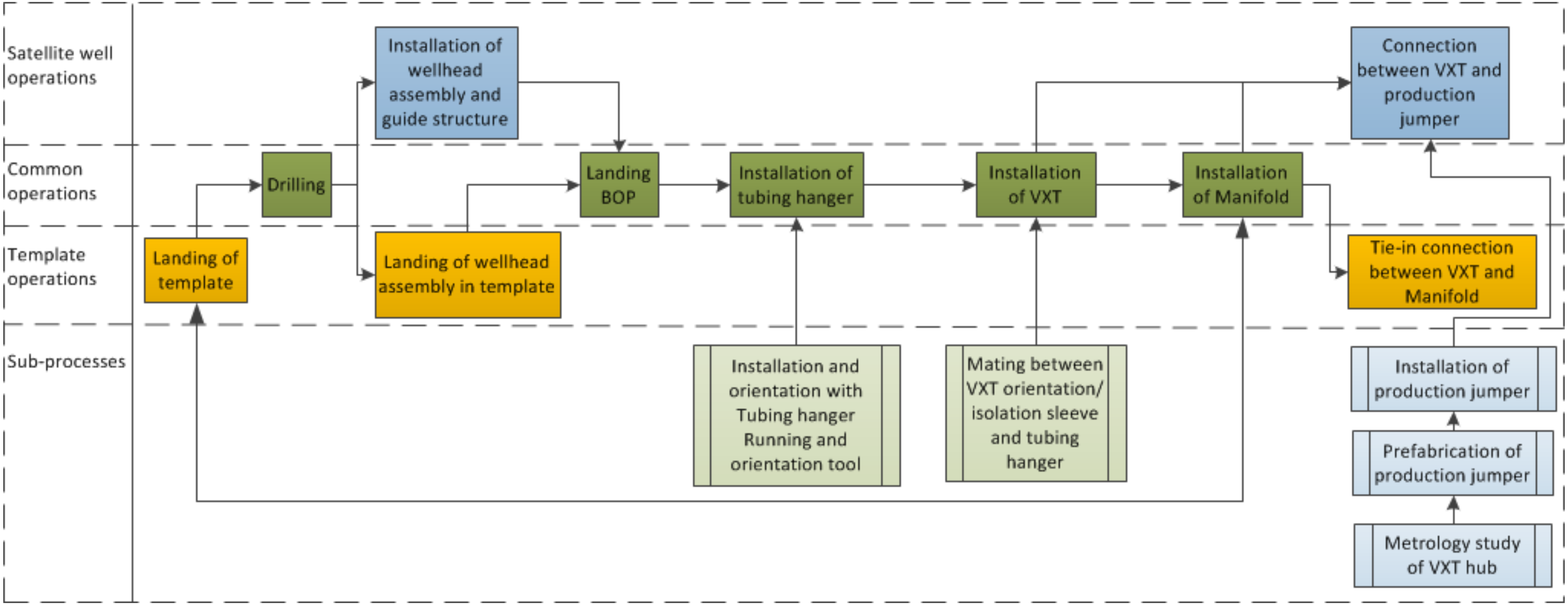
Project A – Software analysis

- Inconclusive
- GD&T – time consuming
- Does not enhance understanding
- Software skills needed
- Lack of control over internal processes
- Adjustments difficult

Project B – Manual calculation

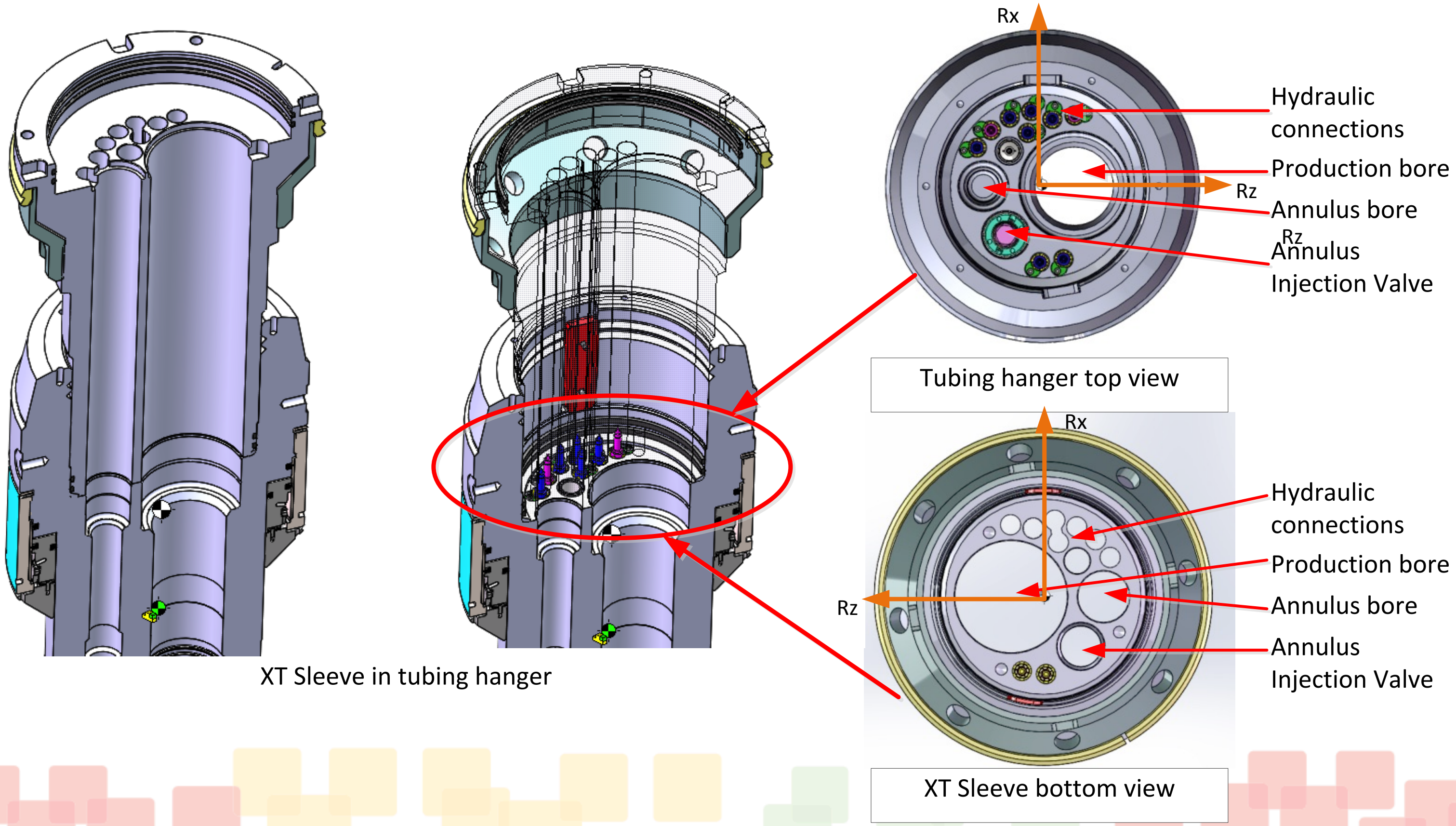
- Worst-case analysis
- Manufacturing drawings as input
- Enhances understanding of the tolerance chain
- Less time spent on analysis
- Did not perform itteratively
- Lack of cooperation between WPs

Installation sequence



Specific issue:

- Positional tolerances of THs and TH running tools



XT Sleeve in tubing hanger

Specific issue:

- Worst-case analysis vs. Statistic analysis
- Same issues

- Root cause: Errors in manufacturing
  - Maturity of manufacturing process and equipment

Tolerance issues - reliability:

- Project A
  - 57 recordings of tolerance related issues
  - 3500 hours invested in tolerance analysis
  - 6121 items produced (BOM level 3)

107.4 units/NCR
0.13% time spent
No insight created

- Project B
  - 158 recordings of tolerance related issues
  - 2200 hours invested in tolerance analysis
  - 16454 items produced (BOM level 3)

104.1 units/NCR
0.10% time spent
Insight

Conclusion:

- Marginal differences in performance
- Same issues occured in both projects, and thus using both methods

⇒other causes?

⇒impact of manufacturing?

Tolerance management in project C:

- Tolerance budgets supported by system modelling
- Study phase
- Visualized nodes in tolerance analysis
- Review meetings with all WPs
- Iterative process
- Enhancing communication

System modelling

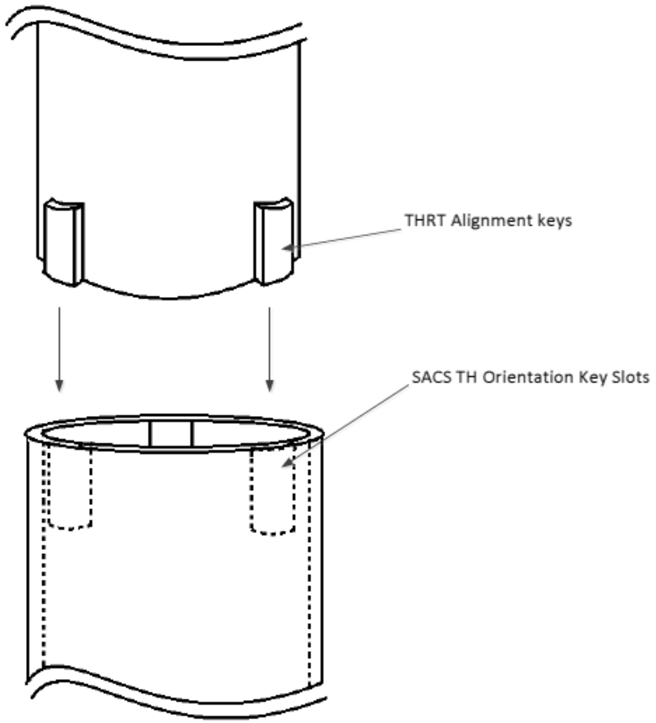
DESCRIPTION
Node S3: SACS key slot to THRT alignment key

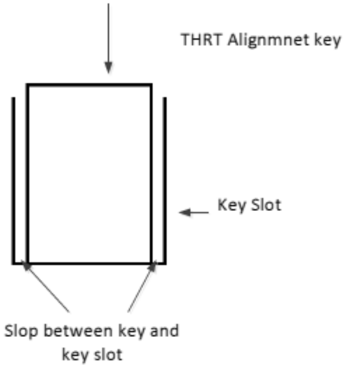
INTERFACING SURFACES

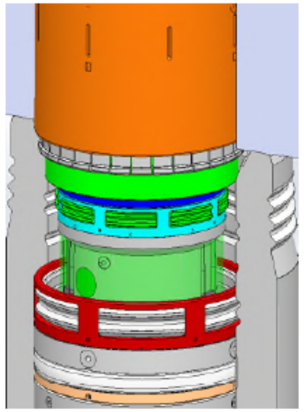
NOTES
There is a «gap» between the THRT keys and the key slots in the TH interface. This contributes to the tolerance chain, not only in the calibration, but also during the TH installation runs.

REFERENCES

S3







Tolerance for slop between THRT alignment keys and TH orientation key slots:
minimum angular deviation from nominal, main key + angular tolerance range, main key =
-3.664x10^-3deg+0.043deg = 0.039 deg

Seabed

Results

- Early implementation:
  - Changed tie-in system to mitigate tolerance issues in the tie-in connection
- Lessons learned:
  - Issues in setting of Tubing Hanger
  - Included in tolerance analysis
  - Mitigating action: Centralizer

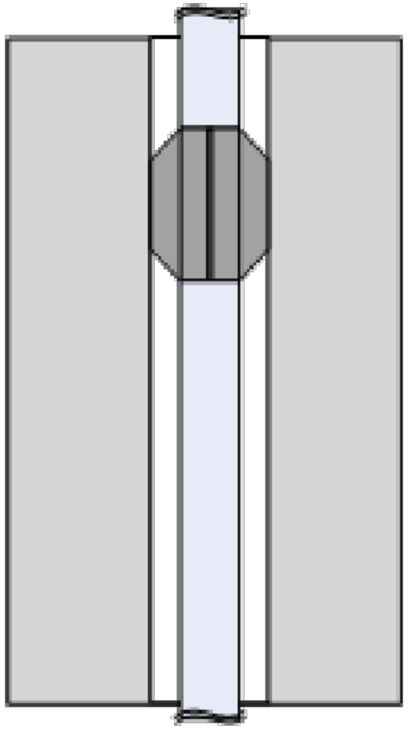


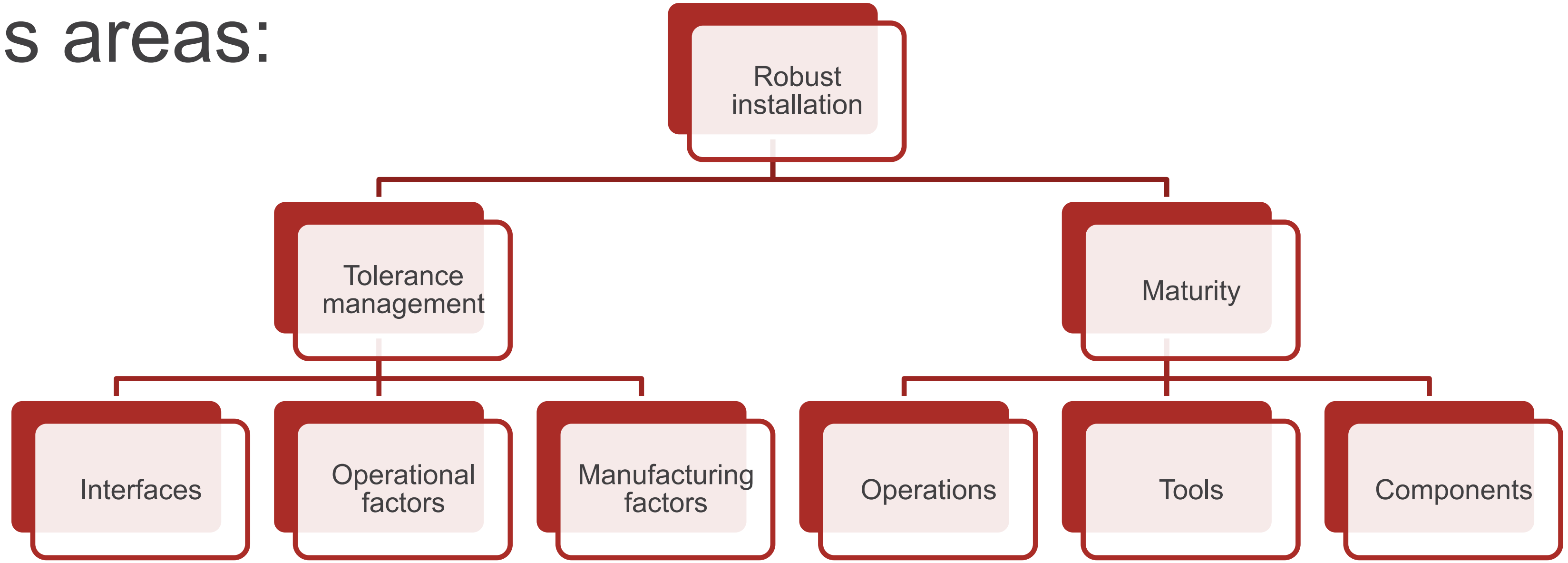
Figure 8. Centralizer to mitigate torsion effects

Conclusion

- **Software calculation** – results in accurate data, no insight
- **Manual calculation –** requires understanding, enables iteration and adjustments
- **System modelling** – enhances understanding, supports communication and exploration
- **Combination of worst-case and statistical analysis** – evaluate each tolerance on whats most appropriate
- **Early phase start-up** – enables iteration, adjustments and changes without additional costs
- **System engineering responsibility** – Multidiciplinary task, cross cutting work packs

Robustness in installation:

- Knowledge transfer from other projects
- Focus areas:



- Supports robust installation sequence

Summary

- Appropriately conducted tolerance management supports robustness in installation
- Tolerance analysis method not decisive for successful tolerance management:
  - Suggested method for standardization