26th annual INCOSE international symposium
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Concept selection through illustrative ConOps – A Holistic Decision

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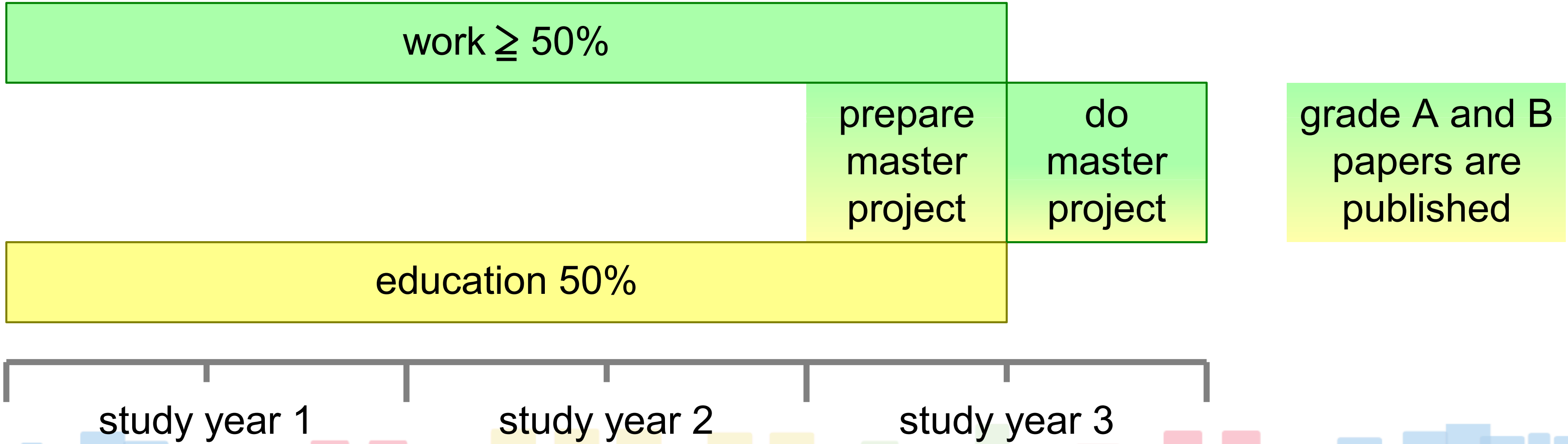
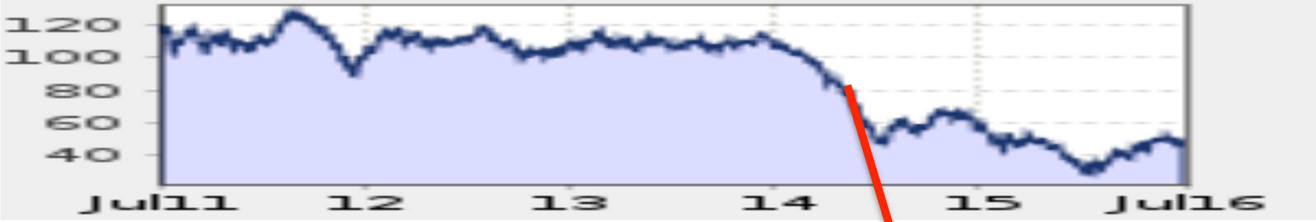
Research Model Master Students Systems Engineering in Kongsberg, Norway

students know:
+ domain
+ SE methods and techniques

students:
+ apply
+ reflect
+ evaluate

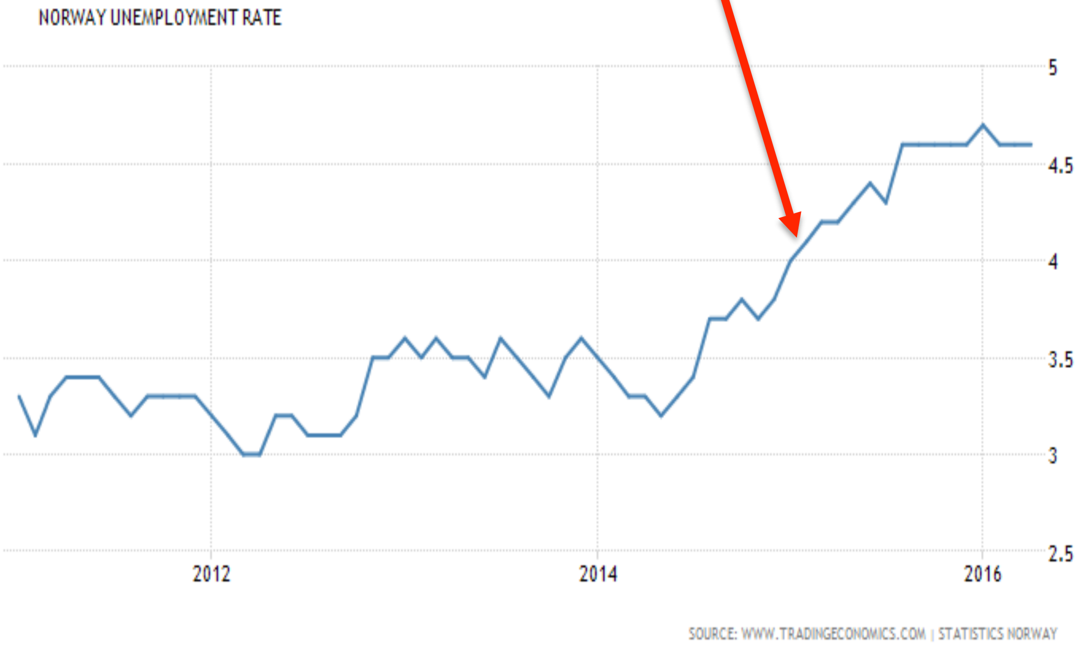


Context: Low oil prices hit Norway hard.



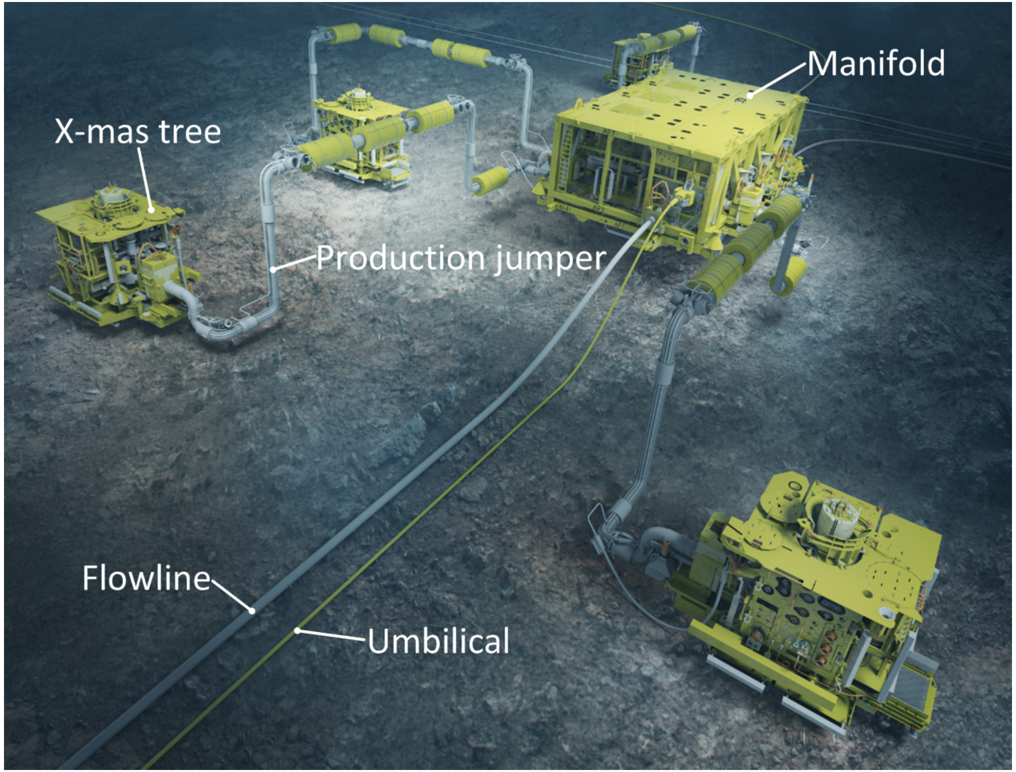
oil price

From oil-price.net



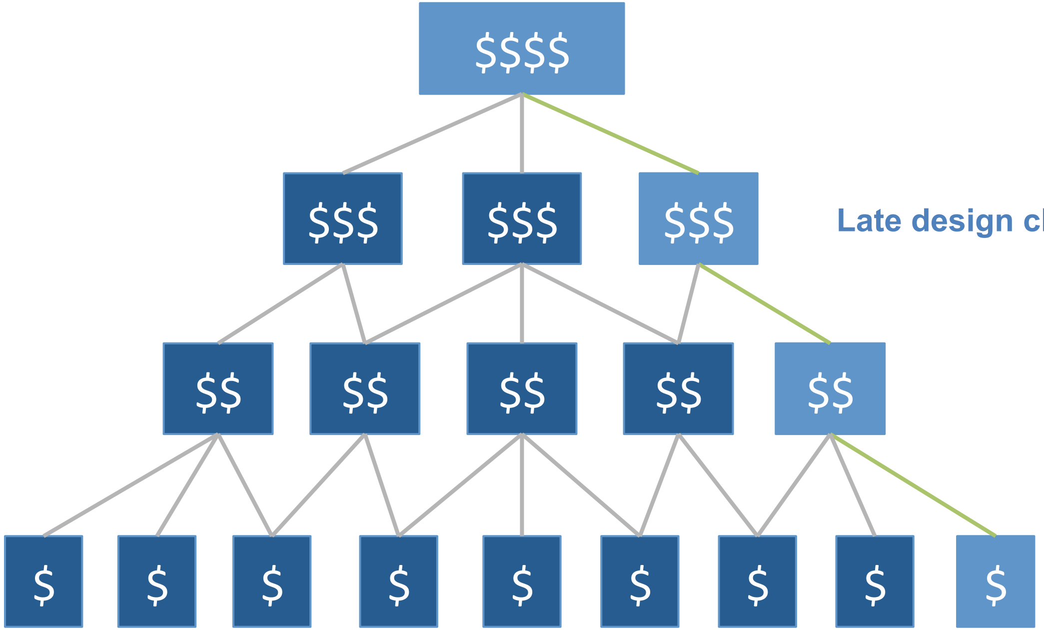
Norwegian Unemployment rate

Subsea production system overview



The Company Aker Solutions

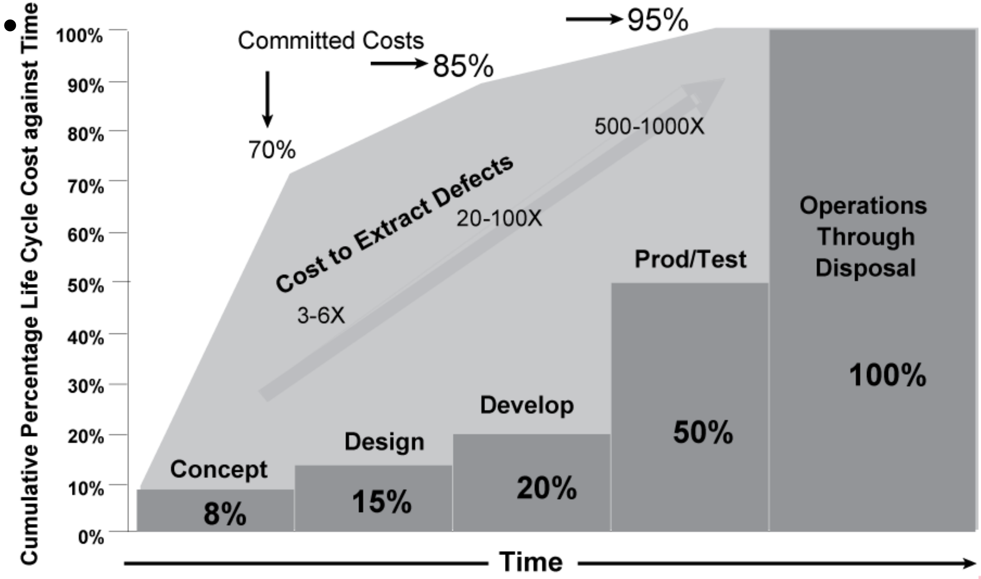
- Aker Solutions (AKSO) is a Norwegian supplier of products and systems to the international offshore oil and gas industry.
- AKSO has approximately 17 000 employees
- in about 20 countries,
- and had a revenue of 33 billion NOK in 2014



Late design changes

Late design changes

- Technology qualification
- Shorter execution times → Less time on System definition
- Late identification of operational needs
-



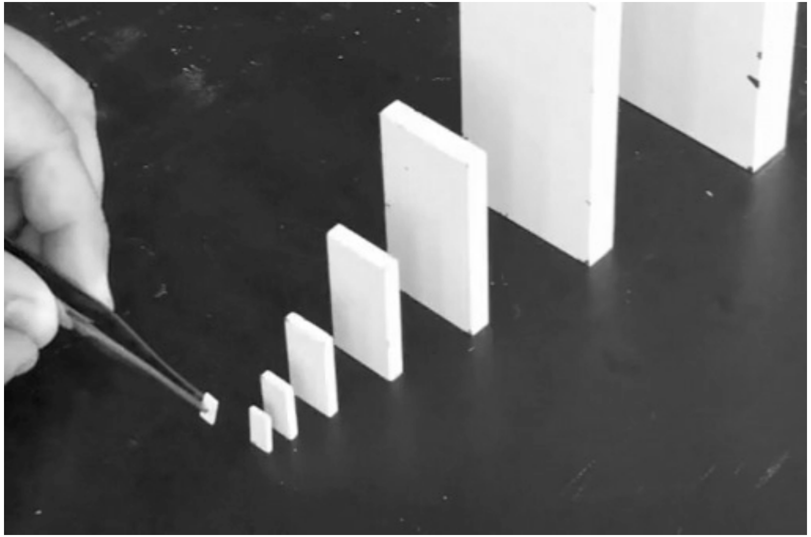
From INCOSE System Engineering Handbook: A Guide for System Life Cycle version 3.2.2

Late design changes

- Late identification of operational needs
  - Main focus on fulfilling requirements, operational needs "discovered along the way"
- Lack of knowledge transfer
  - Repeated mistakes. Previous lessons and experience not utilized efficiently

From INCOSE System Engineering Handbook: A Guide for System Life Cycle version 3.2.2

How can we start off right?



Methods of interest

Concept of Operation:

- Method for analysis and understanding of system needs throughout the system life cycle.

[Kossiakoff, System Engineering Principles and Practice]

- Describes the way the system works from the operators perspective.

[INCOSE System Engineering Handbook: A Guide for System Life Cycle version 3.2.2]

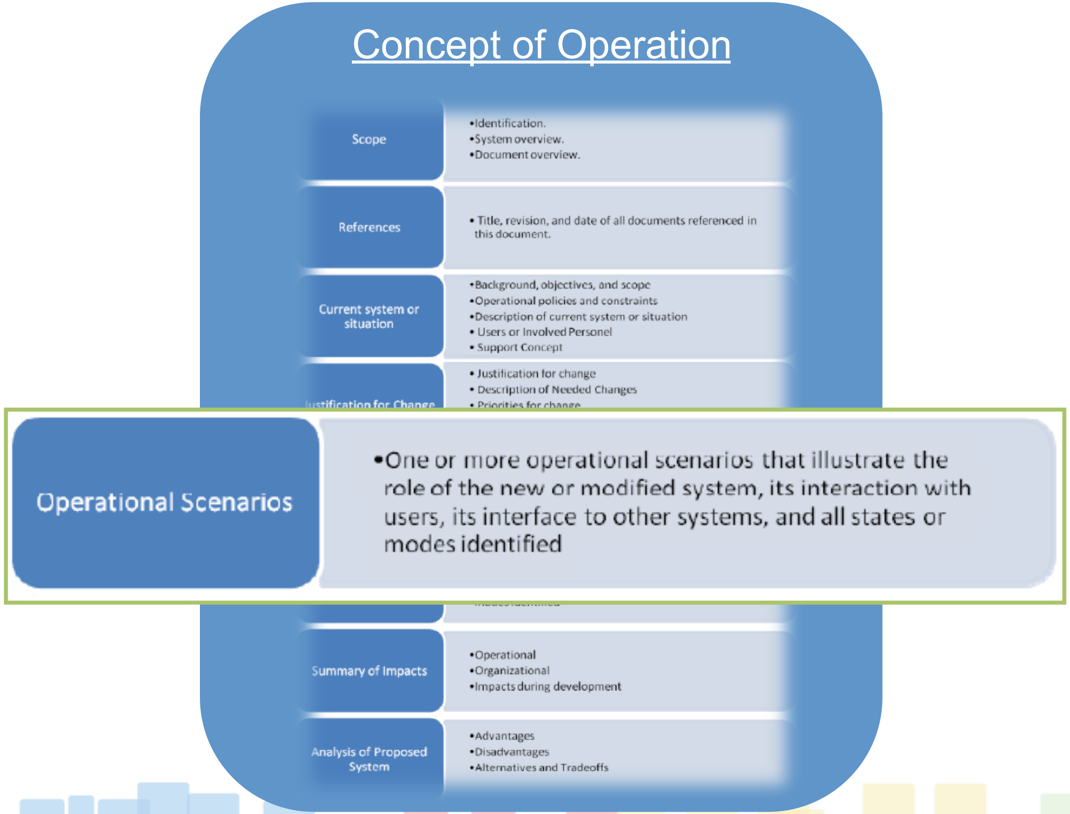
- A “meeting of the minds” between user, developer, and other stakeholders.

[Investigation of a Graphical CONOPS Development for Agile Systems Engineering. SERC 2009]

Pugh Matrix

- Multi criteria decision making method in matrix format.
- Allows for comparison of multiple design candidates towards a set of criteria.
- Communicates the main characteristics of the proposed system.

ConOps



DI-IPSC-81430 CONOPS Elements (DoD)

- Usually a collection of lengthy documents. Utilizes mostly text.
- Not easy to convey the content of the ConOps to involved parties. Difficult to use actively.
- Looked at the operational side of the life cycle.
- The Outcome is large amount of requirements/criteria that the concepts must fulfill.

Pugh Matrix

- Essential with a structured approach to analyze and evaluate concepts against requirements.
- Pugh matrix presents the evaluation systematically for the decision makers.
- Arrange and rank the concepts against the criteria to view the full picture of performance

Pugh Matrix

	Design Concept A	Design Concept B	Design Concept C	Design Concept D	Design Concept BC	Design Concept BD
Criteria 1	S	+	S	+	+	+
Criteria 2	S	-	S	+	S	+
Criteria 3	S	S	S	+	S	+
Criteria 4	S	-	+	+	+	+
Criteria 5	S	-	+	+	+	+
Criteria 6	S	-	S	-	S	-
Criteria 7	S	+	S	-	+	+
Criteria 8	S	+	S	-	+	+
Criteria 9	S	-	S	-	S	-
Criteria 10	S	S	-	S	S	S
TOTAL +	0	3	2	5	5	7
TOTAL -	0	5	1	4	0	2
TOTAL SCORE	0	-2	1	1	5	5

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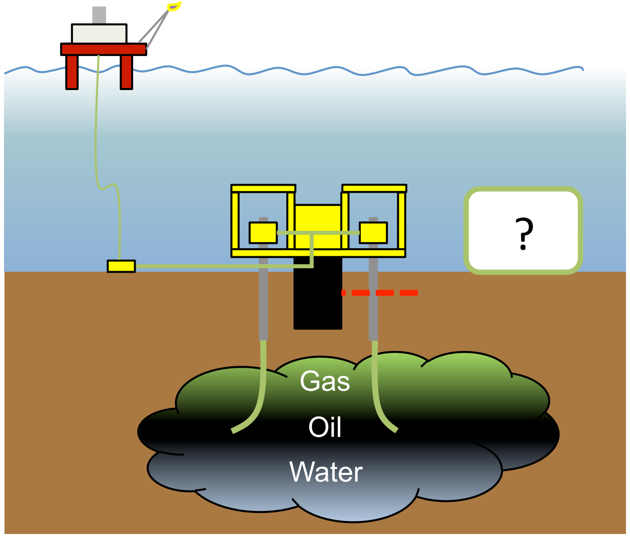
Research Questions

- Can we utilize these tools to perform an early validation of proposed concepts?
- How do these methods affect the engineering mind-set when it comes to holistic thinking of new solutions?
- Can these methods result in late change reduction?

Case – Subsea contingency well

- We used a Contingency satellite subsea well as case for the research.
- Based on a report on the case.
- Idea is to have a back-up system ready to reduce production downtime in the case of a damaged well. By connecting a new well to an existing system.

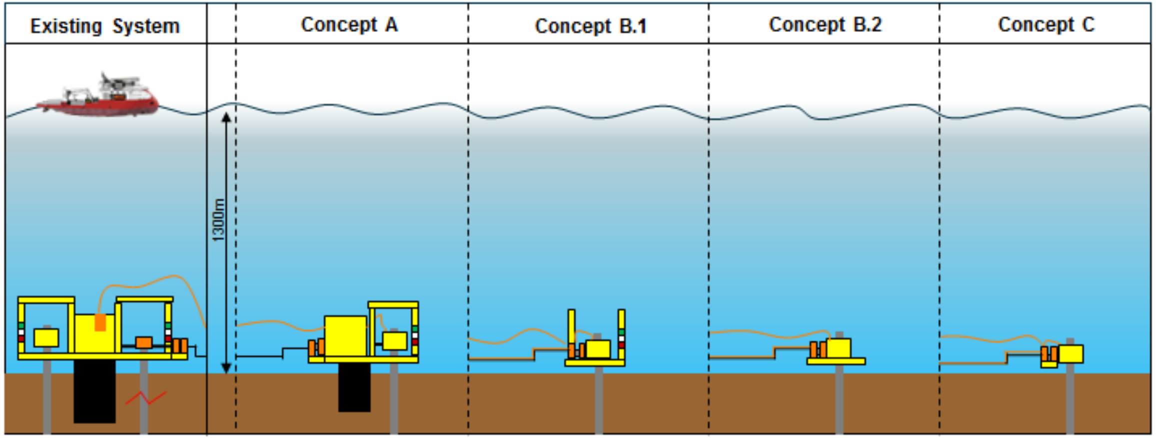


1. a fully spec compliant solution
2. a minimal low-cost solution

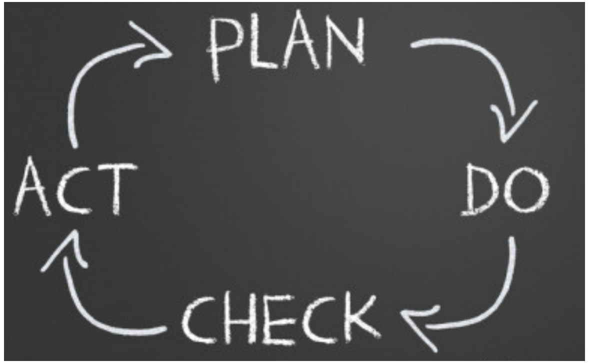
Application of the Tools

Illustrative ConOps:

- Create a common understanding of the concepts amongst project personnel and stakeholders.
- Gather and display known vital information in an comprehensible way.
- Act as an early validation of the concepts.
- Reveal operational needs.



Iterations



1. Examine initial information. Evaluation of Stakeholders.
2. Logical operational sequences. Constraints beyond own equipment.
3. Operation of the system.

Illustrative ConOps

1. Operation sequence/step

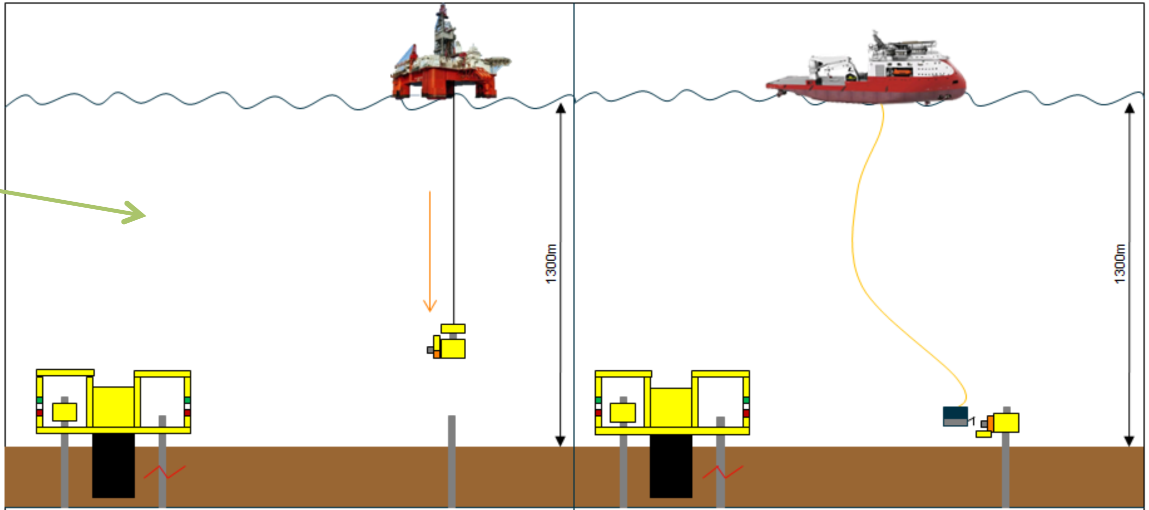
2. Simple illustration of the operation step

3. Short summary of operation step

4. Key information:
- Stakeholders
- Operation platform
- Constraints/ opportunities
- Trigger words for discussion

3. Installation of XT on wellhead

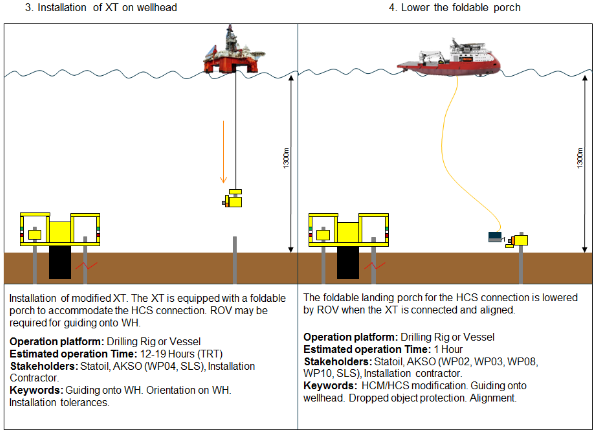
4. Lower the foldable porch



3. Installation of XT on wellhead	4. Lower the foldable porch
Installation of modified XT. The XT is equipped with a foldable porch to accommodate the HCS connection. ROV may be required for guiding onto WH.	The foldable landing porch for the HCS connection is lowered by ROV when the XT is connected and aligned.
Operation platform: Drilling Rig or Vessel **Estimated operation Time:** 12-19 Hours (TRT) **Stakeholders:** Statoil, AKSO (WP04, SLS), Installation Contractor. **Keywords:** Guiding onto WH. Orientation on WH. Installation tolerances.	**Operation platform:** Drilling Rig or Vessel **Estimated operation Time:** 1 Hour **Stakeholders:** Statoil, AKSO (WP02, WP03, WP08, WP10, SLS), Installation contractor. **Keywords:** HCM/HCS modification. Guiding onto wellhead. Dropped object protection. Alignment.

Evaluation of the concepts

ConOps



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Criteria 9	S	-	S	-	S	-
Criteria 10	S	S	-	S	S	S
TOTAL +	0	3	2	5	5	7
TOTAL -	0	5	1	4	0	2
TOTAL SCORE	0	-2	1	1	5	5

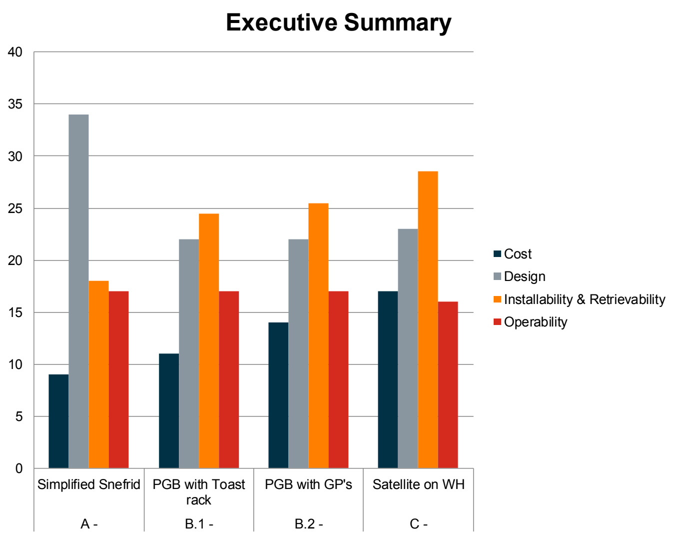
Pugh Matrix

User input

	Criteria	Priority setting	A Simplified Snefrid	B.1 PGB with Toast rack	B.2 PGB with GP's	C Satellite XT on WH
Cost	Hardware Cost	High	2	3	4	5
Cost	Installation Cost	Standard	2	2	3	4
Cost	Operational Cost	Standard	3	3	3	3
Design	Engineering hours (Amount of new engineering, re-use, analysis)	Standard	5	3	3	2
Design	Design familiarity (Is the design known in AkSo? Previously delivered?)	Standard	4	2	3	3
Design	Requirement compliance	Standard	5	4	3	2
Design	Deliverytime from call-off (Long lead items, fabrication time)	High	3	3	3	4
Design	Amount of new qualifications (TQP's)	High	5	2	2	2
Design	On-shoreTestability (Availability of necessary equipment and procedures)	Standard	4	3	3	4
Installability & Retrievability	Number of installation runs required	Standard	1	2	2	5
Installability & Retrievability	Installation time	Standard	1	2	3	4
Installability & Retrievability	Weather vulnerability (Metocean constraints, Hs)	Low	2	4	4	4
Installability & Retrievability	Need for special tools	Low	4	3	3	3
Installability & Retrievability	Guide system robustness	High	4	4	3	2
Installability & Retrievability	Size of vessel required (Rig, heavy lift vessel, installation vessel)	Standard	1	2	3	5
Installability & Retrievability	Weight & Size	Standard	1	3	4	5
Installability & Retrievability	Retrieval flexibility of equipment	Standard	3	4	4	2
Operability	ROV access	Standard	3	4	4	4
Operability	Flow assurance (Hydrate/Scale, pipeline friction, pressure bleed-off)	Standard	3	3	3	3
Operability	Dewatering & start-up (Service access, injection points, etc.)	Standard	3	4	4	4
Operability	Reliability	Standard	3	4	4	4
Operability	Interchangeability	Standard	5	2	2	1
	Indicating summary:		78	74,5	78,5	84,5

The concepts listed are ranked on a scale from 1-5 based on their attributes for each criteria. 3 is the mean value and describes a good enough performance to the criteria. A higher number shows a better performance, while a lower number shows a worse performance on the criteria listed.
The priority setting enables you to prioritize individual criteria to a higher or lower importance. If the priority is set to low for a criteria, that criteria will count less compared to a standard or higher prioritized one.

Rating	Description
1	Unfavorable performance
2	Less than satisfactory performance
3	Satisfactory performance
4	More than satisfactory performance
5	Excelent performance



Final Pugh Matrix

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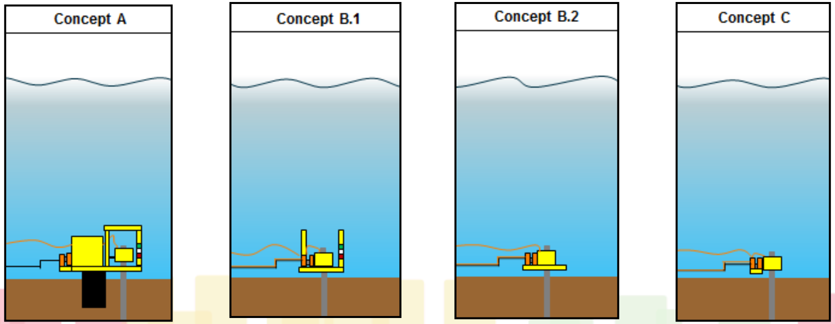
- The matrix should be easy to use on a day-to-day basis, and with a low threshold for use.
- Proposed concept score a performance rank from 1-5 against each requirement. (For instance, short installation time; high score. High hardware cost; Low score)
- Creates an overview of how the concepts perform overall.
- Implements impact of the customer needs and priorities (i.e. hardware cost and delivery time) through the priority setting. Increases the impact of the score on that requirement.
- Communicates the semi-qualitative comparison of the concepts, and enables a holistic decision making.

Can we utilize these tools to perform an early validation of proposed concepts?

- Initial assumption was that Concept B.2 was the best alternative for the low cost solution.
- By analysing the concept through the illustrative conops and pugh matrix, we see that Concept C was a better candidate based on the criteria with most importance to the costumer.
- Indicates that Concept C should have been investigated further.
- Gives us the overview needed to take the best decisions.



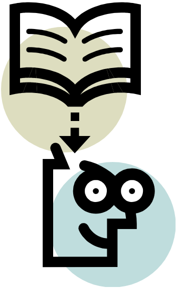
How do these methods affect the engineering mind-set when it comes to holistic thinking of new solutions?

- Involved personnel quickly grasped the difference in use and operations between the concepts.
- Gives the project engineers the possibility to understand the Concept of Operation and bring the operational needs into their design.
- Communication
- Enables the stakeholders to see a joint full picture, and avoid different views of the concept.

Can these methods result in late change reduction?

- Not enough data to draw a clear conclusion.
- But our research reaffirms that implementing validation tools for systems engineers is vital for discovering potential late changes at an early stage.
- Alignment of project personnel and stakeholders towards the operational needs is fundamental.
- Illustrative conops and pugh matrix may be candidates by taking the concepts into the operational environment, and show a joint holistic picture to all stakeholders.

Conclusion



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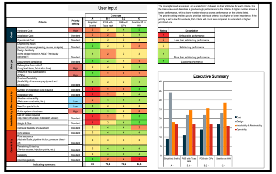
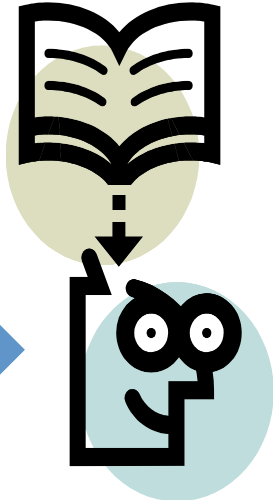
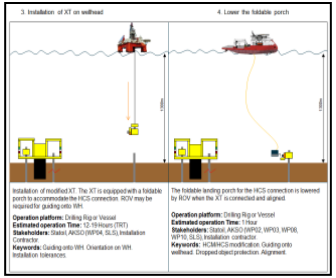

User input
Executive Summary

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Q & A