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A framework for integrating reliability and systems engineering: proof-of-concept experiences

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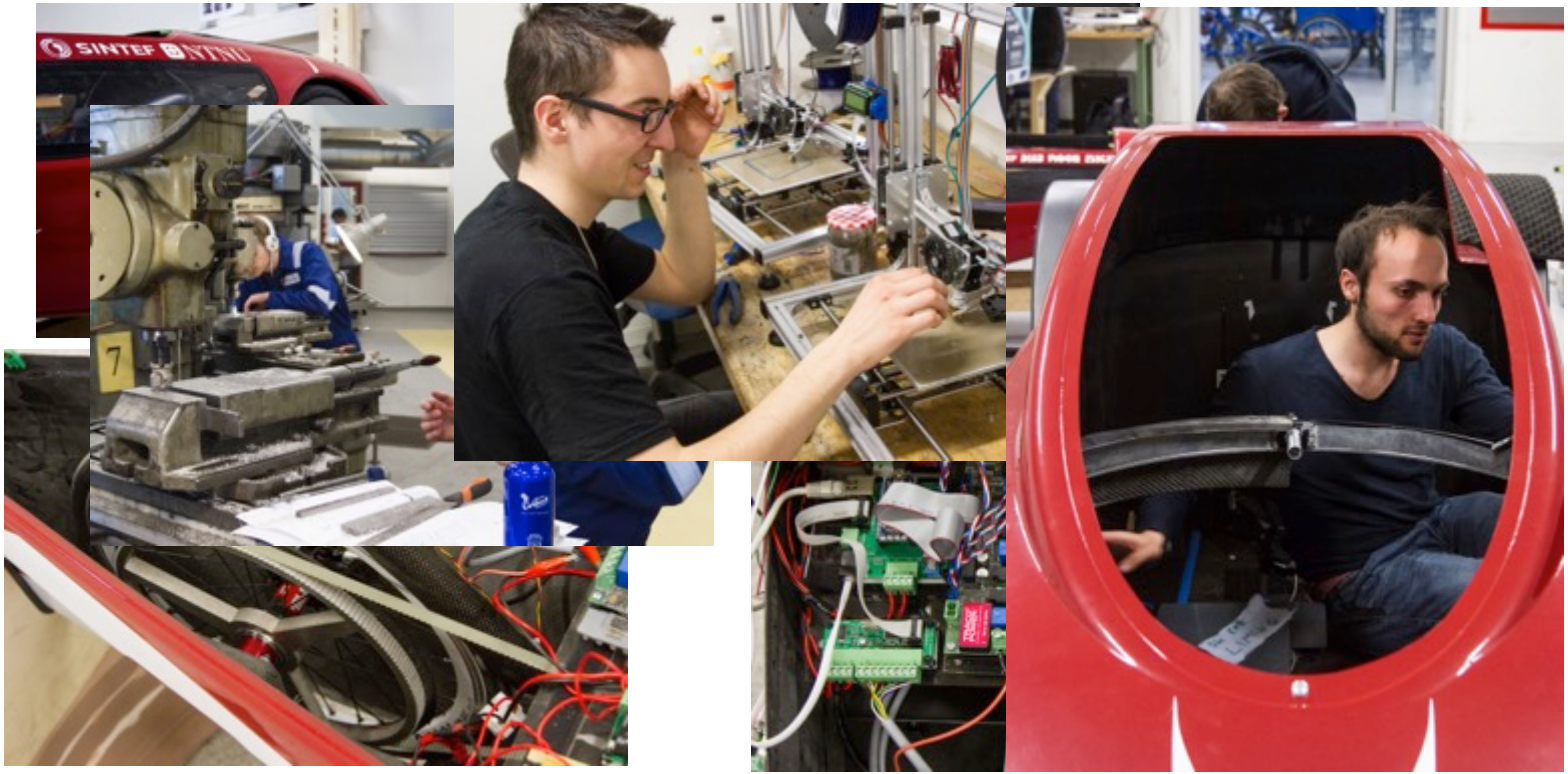
Case Study and Motivation

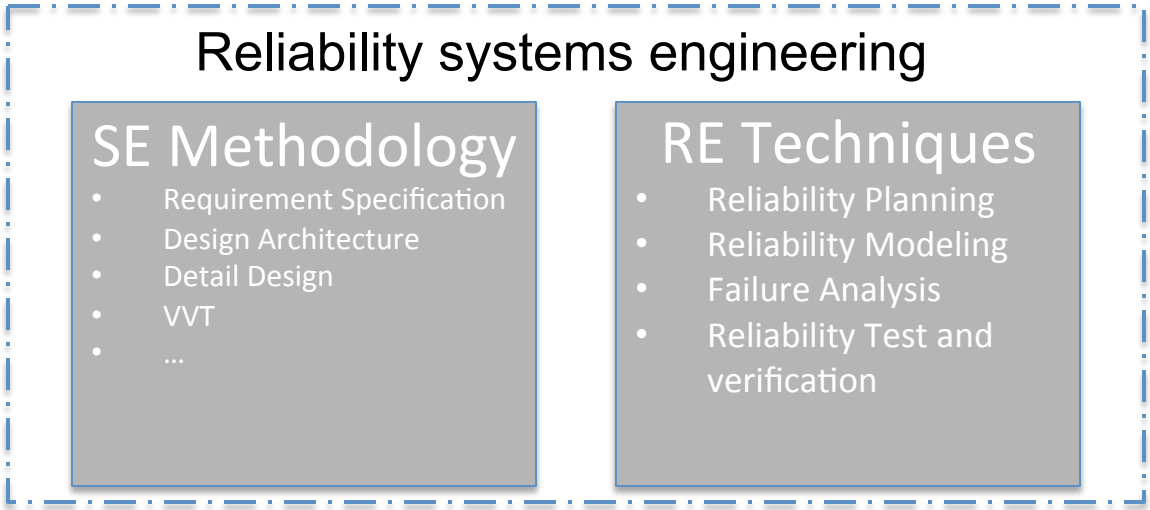
DNV GL Fuel Fighter

Case Study and Motivation



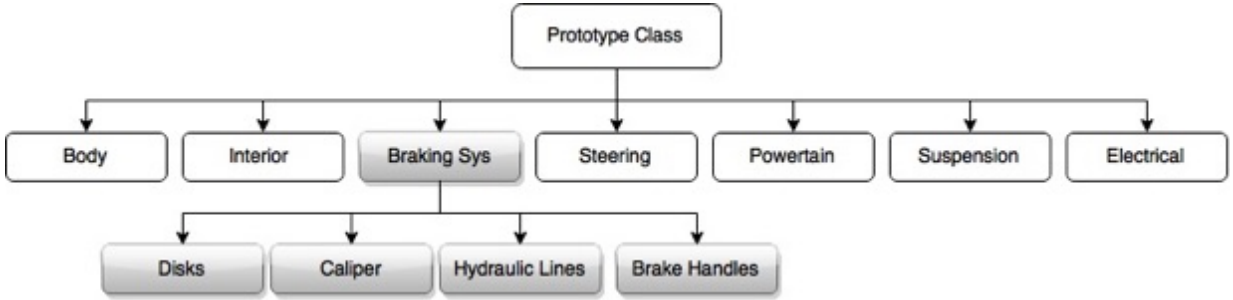
Case Study and Motivation

- Reliability and systems engineering



Case Study and Motivation

- Decomposition of the system

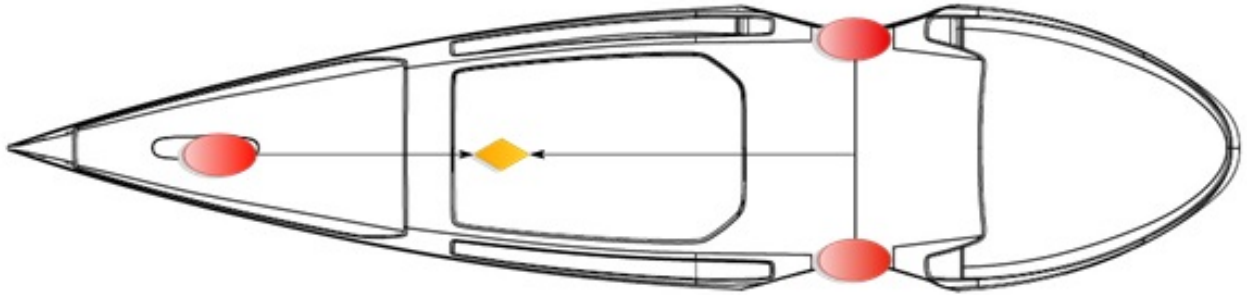


- Why braking system?

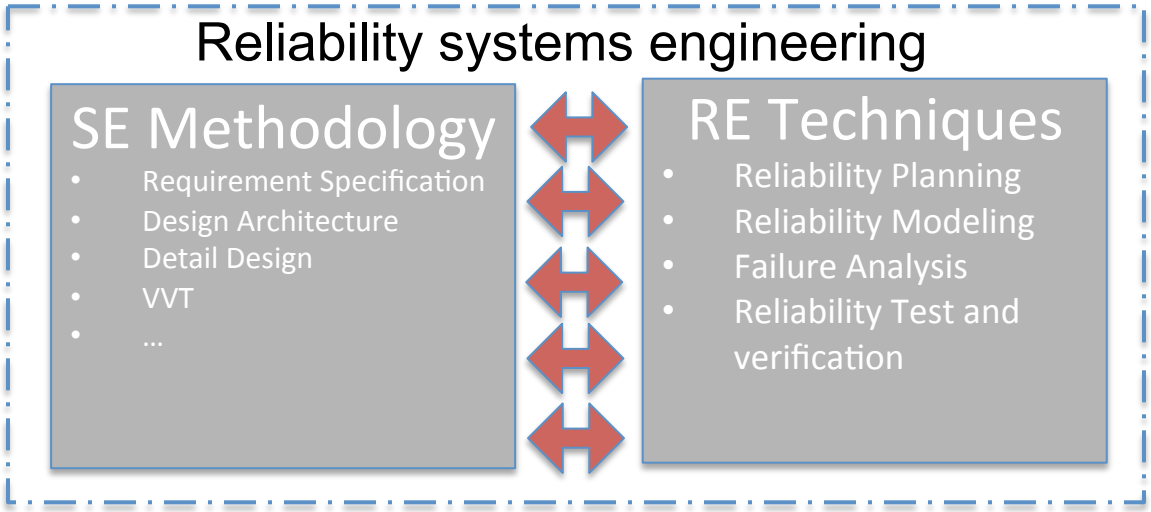
1. *The main problem of the previous team.*
2. *Braking systems is a safety system.*

Case Study and Motivation

- The structure of the braking system



Case Study and Motivation

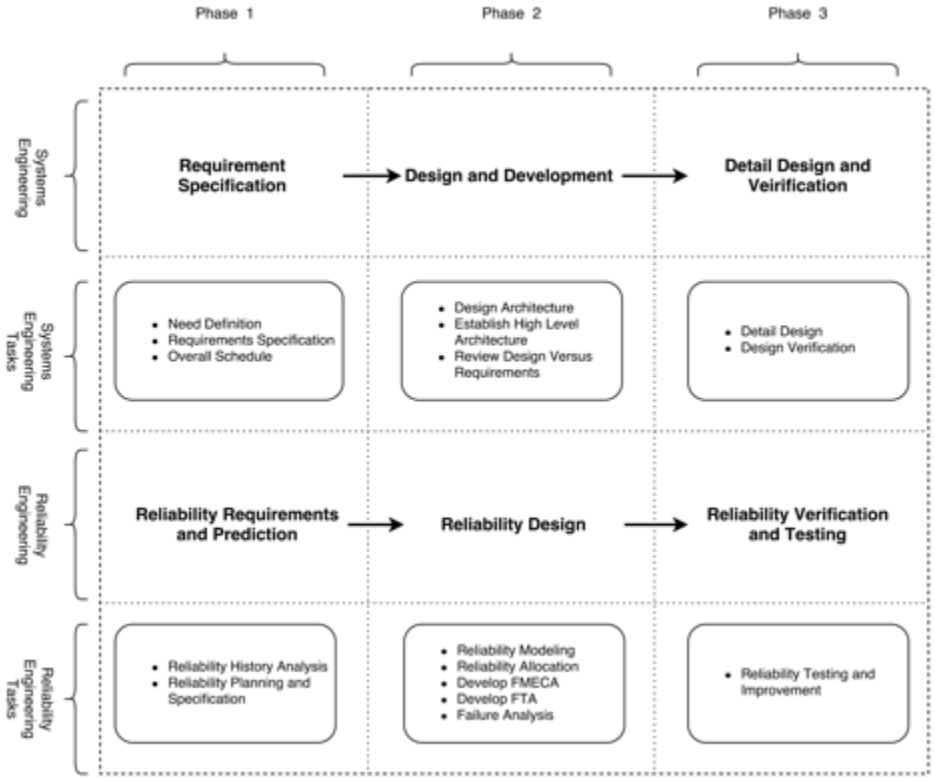


1. Vanek, F., Jackson, P., & Grzybowski, R. (2008). Systems engineering metrics and applications in product development: A critical literature review and agenda for further research. Systems Engineering,
2. Carter, S. D., & Deans, D. M. (2011). Reliability engineering as a practical application to improving system performance; From concept to system retirement
3. Clausing, D., & Frey, D. D. (2005). Improving system reliability by failure-mode avoidance including four concept design strategies.

Proposed framework and research questions

SE

RE



Proposed framework and research questions

Research questions:

1. *How can an integrated reliability and systems engineering framework bring value to the development of systems?*
2. *How can the proposed framework be used to assess the reliability of the system in the early design phases where there is high uncertainty due to lack of information?*

Proof-of-concept demonstrator

The integrated reliability and systems engineering process applied in the Shell Eco-Marathon project:

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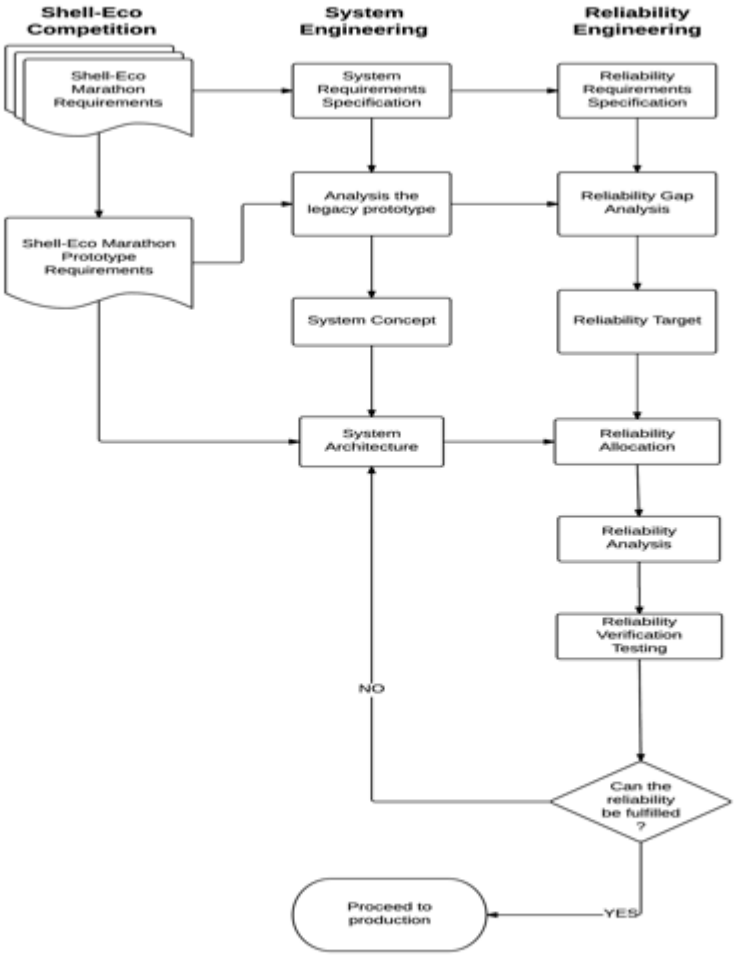


Proof-of-concept demonstrator

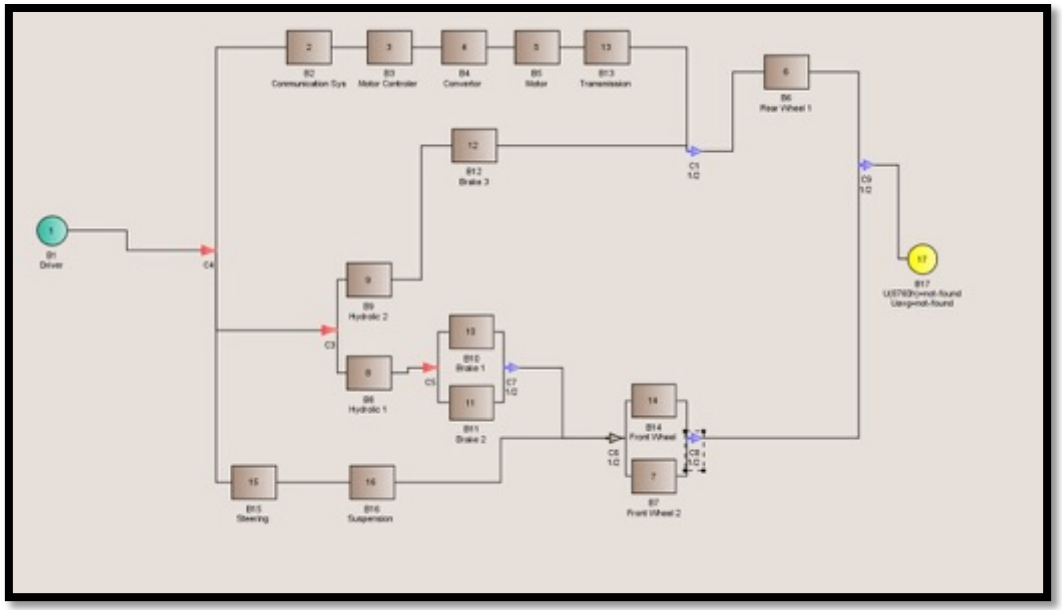
Reliability tools used in this project:

1. Reliability block diagram(RBD)
2. Failure mode effect and critically analysis(FMECA)
3. Fault tree analysis(FTA)

Proof-of-concept demonstrator

1. Reliability block diagram(RBD)

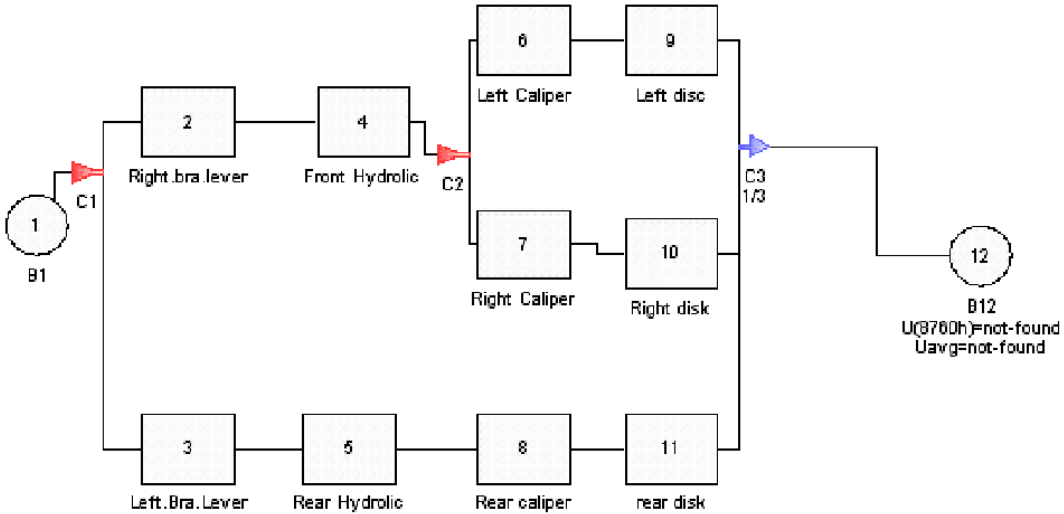
- Whole system (prototype vehicle)



Proof-of-concept demonstrator

1. Reliability block diagram(RBD)

- Braking system



$$R\downarrow LC,LD =$$

$$R\uparrow * = R\downarrow LC,LD +$$

$$R\downarrow RC,RD = R\downarrow LC,LD$$

$$\cdot R\downarrow 3 \cdot$$

$$R\downarrow BTSys = R\downarrow FB +$$

$$R\downarrow RB - R\downarrow FB \cdot R\downarrow RB$$

Proof-of-concept demonstrator

2. Failure mode effect and critically analysis(FMECA)

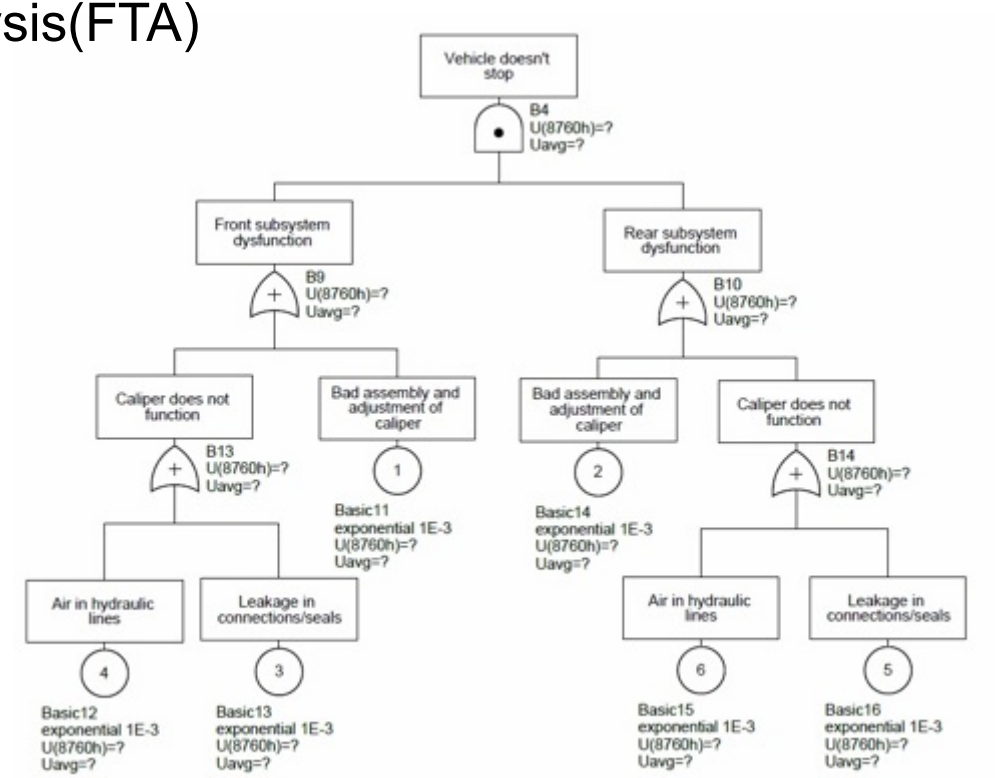
Systems: Prototype Braking system
Ref.No: 1.1

Performed By: Hossein Neizan Hosseini
Date: 28.10.2014

Description Of Units			Description of failure			Effect of failure		Failure Rate	Severity ranking	Risk reducing measures	Comments
Ref.No:	Function	Operational Mode	Failure Effect Mode	Failure Cause	Detection of failure	On the sub-system	On the system function				
1	Stop the Car	Ready to function on demand	Vehicle Stops too early	Bad assembly and adjustment	Detected	Friction force	Protected	4	Minor	Following the checklist	
				High Pressure Input	Detected	Reduce the durability of cliper and disk	Protected	4	Minor	Train the driver	
			Vehicle Stops too late	Bad assembly and adjustment	Detected	N\P	Protected	4	Minor	Following the checklist	
				Existing air in hydraulic lines	Detected	N\P	Protected	4	Major	Beeliding to remove the air	
				Low pressure input	Detected	N\P	Protected	4	Minor	Train the driver	
			Vehicle doesnt Stop	Bad assembly and adjustment	Detected	Fracture on disk	Unprotected	3	Catastrophic	Following the checklist	
				Leakage from seals/connectors/fasteners	Detected	loss of force flow	Unprotected	5	critical	Beeliding to remove the air	
				Caliper doesnt function	Detected	N\P	Unprotected	3	Catastrophic	Using spares parts	
				Existing air in hydraulic lines	Detected	N\P	Unprotected	4	Major	Beeliding to remove the air	

Proof-of-concept demonstrator

3. Fault tree analysis(FTA)



Proof-of-concept demonstrator

Failure analysis:

Assembly

Pressure

Hydraulic line

Discussion and future work

1. *How can an integrated reliability and systems engineering framework bring value to the development of systems?*

- Two main characteristic of the proposed framework: 1) SE and RE must be conducted concurrently. 2) The framework must be applied at early stages of development.

- Using the framework, the consequences of poor reliability requirements can be reduced by considering reliability requirements into the system specification as early as possible.

- Knowing beforehand the impact of potential failure(s) in system's design, reduces or eliminates the need for late changes in systems life cycle.

Discussion and future work

2. *How can the proposed framework evaluate the reliability of the system in the early phases where there is lack of information?*

- using RBD enabled us to see how the components of the systems are structured. Also, it indicated that how the components are functioning dependently or independently.

- FMECA, on the other hand, was useful to find potential failures at early stage of the lifecycle, and showed us how to mitigate their risks.

- FTA, also indicated that what are the critical events that must be avoided.

- A reliability checklist has been developed.

Discussion and future work

Reliability checklist for braking system:

Reliability Checklist

System _____ Ref.No. _____
Assembly _____ Date _____

NO.	M* or A*	Checklist question	Yes	No
1	M	Have the hoses been connected to the connectors?	❑	❑
2	M	Have the calipers been properly adjusted with suspensions?	❑	❑
3	M	Have the hydraulic systems been bled to remove the air?	❑	❑
4	M	Have the caliper pads been properly adjusted with disks?	❑	❑
5	M	Have the levers been properly mounted on steering wheel?	❑	❑
6	M	Have the bolts been checked to avoid leakage?	❑	❑

M* = Mandatory A*= Advisory

Discussion and future work

1. The SE part of this framework has applied for the whole system, and the reliability of that applied on braking system. The author believes both SE and RE part this framework could be applied on entire system lifecycle.

2. Also, the reliability assessment of the braking system was qualitative. The author suggests to conduct quantitate assessment as well.