Understanding mission objectives and priorities with QFD

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18. July 2016

Joint Strike Missile

Stakeholders
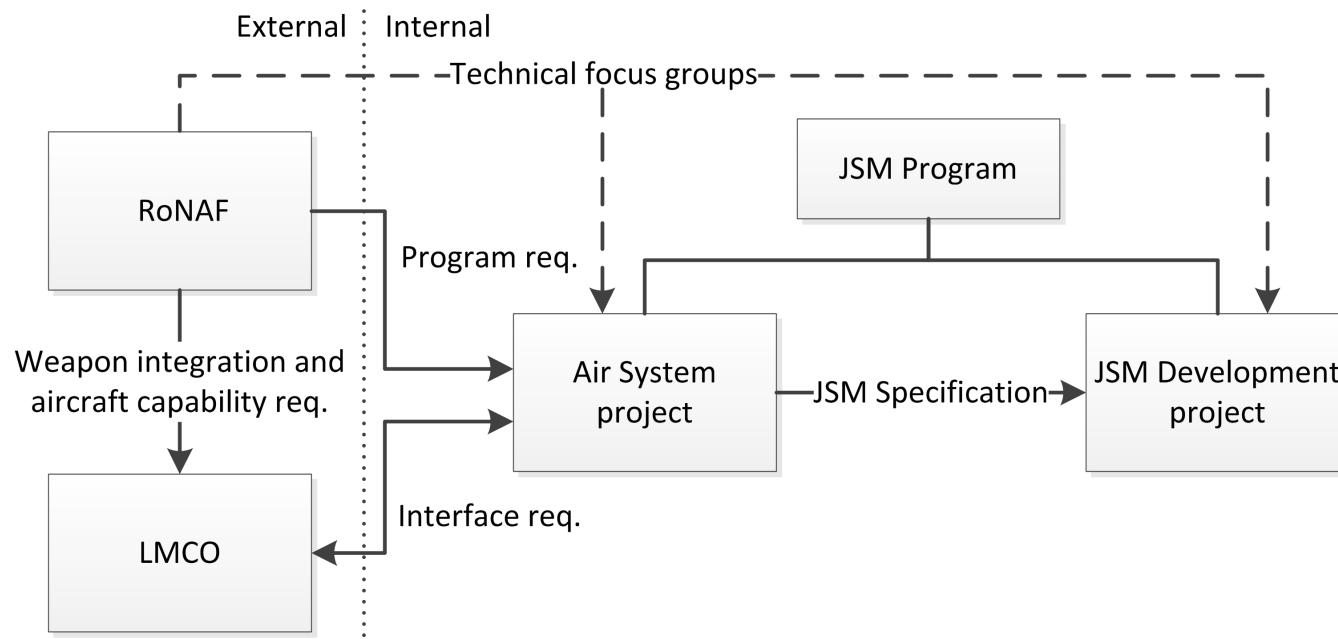
Problem

- Obtain a deeper understanding of the needs and priorities behind the system requirements than those found in the requirements documents

- Apply Quality Function Deployment as a method to communicate the goals and priorities of the system and subsystems between the customer and engineering disciplines

- QFD increases the decisiveness and confidence in priorities, especially when facing trade-off decisions, thereby increasing the effectiveness of the organization and product value

- <u>Align</u> SE with customer

Needs analysis

«requirement»
Mission flexibility

«requirement»
A long range, high precision, air launched missile to engage high value, highly defended, open water, littoral and land targets.

«requirement»
Constraining the aircraft and pilot as little as possible
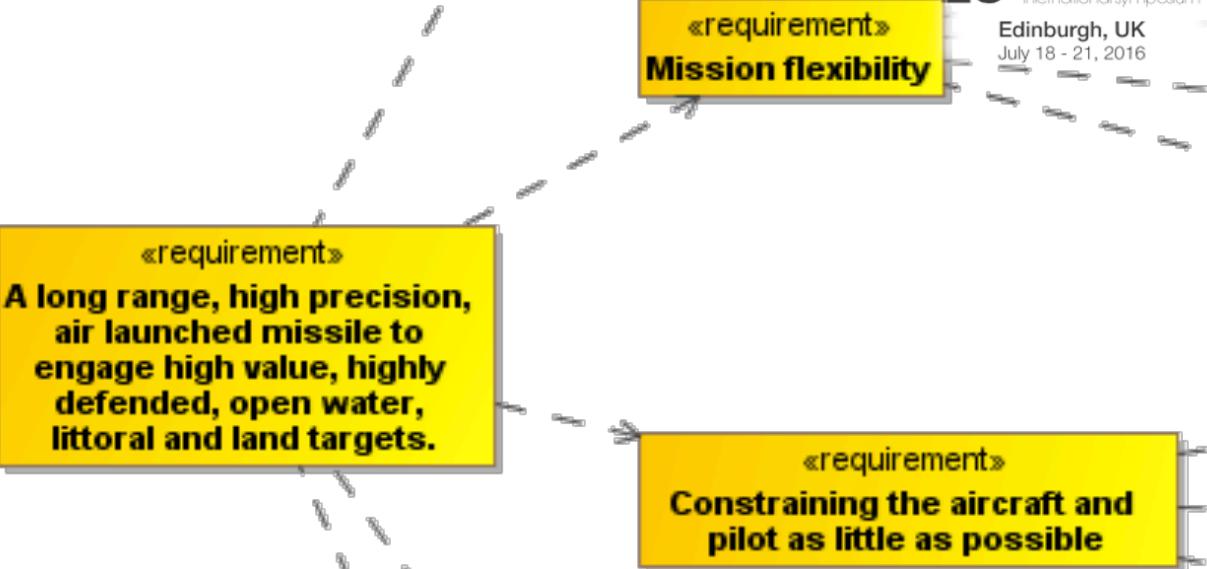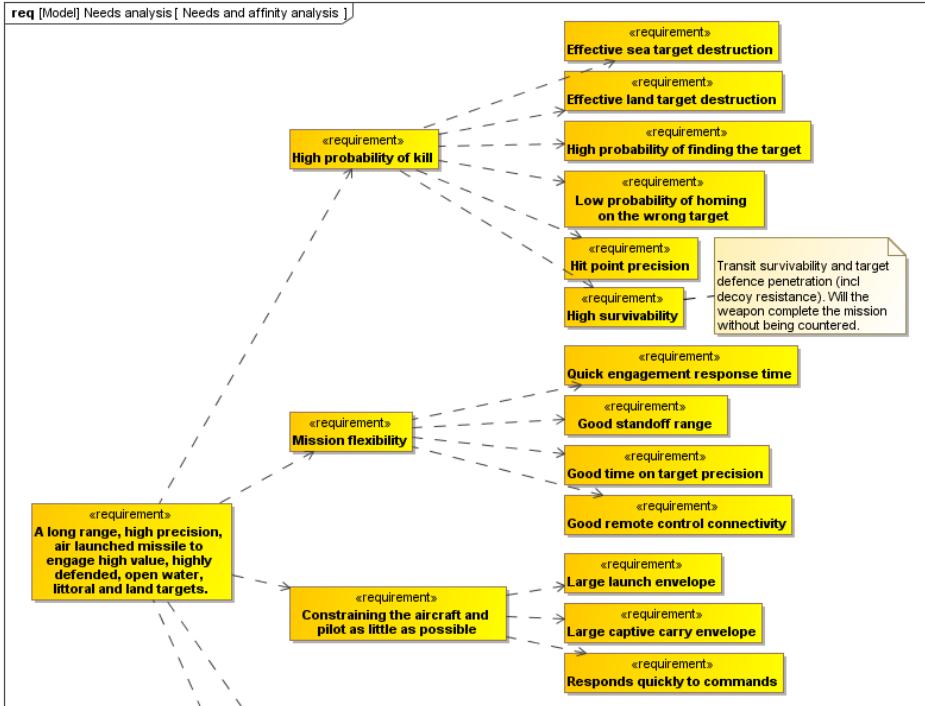
Needs analysis – 1

Needs analysis – 2
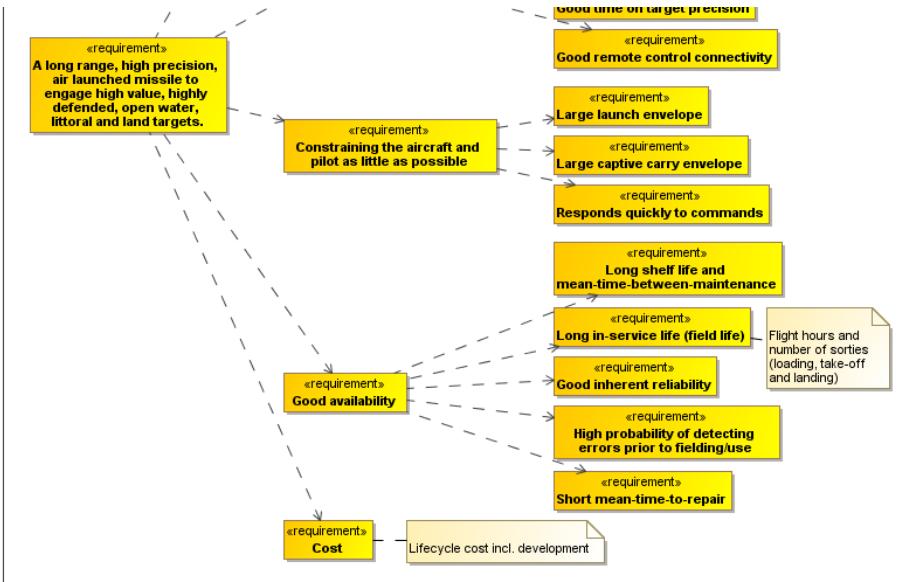
Analytical Hierarchy Process – measuring customer priorities

Instant feedback on impossible priorities

Top level objectives   Consistency rating = 0,07

	High probability of kill	Mission flexibility	Constraining aircraft/pilot as little as possible	Good availability	Cost
High probability of kill	1	7	3	3	5
Mission flexibility	1/7	1	1/3	1	3
Constraining aircraft/pilot as little as possible	1/3	3	1	3	3
Good availability	1/3	1	1/3	1	1
Cost	1/5	1/3	1/3	1	1
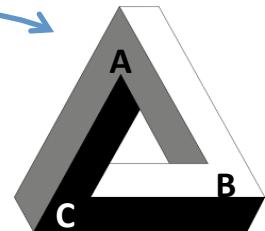
1 = equally important
7, 1/7 = highly preferred
3, 1/3 = moderately preferred

Top level objectives Consistency rating = 0,05

	High probability of kill	Mission flexibility	Constraining aircraft/pilot as little as possible	Good availability	Cost
High probability of kill	1	3	5	5	3
Mission flexibility	1/3	1	5	3	3
Constraining aircraft/pilot as little as possible	1/5	1/5	1	1	1/3
Good availability	1/5	1/3	1	1	1
Cost	1/3	1/3	3	1	1

High probability of kill Consistency rating = 0,08

	Effective sea target destruction	Effective land target destruction	High probability of finding target	Low probability of homing on the wrong target	Hit point precision	High survivability
Effective sea target destruction	1	3	1/3	1/7	1	1/3
Effective land target destruction	1/3	1	1/3	1/9	1	1/3
High probability of finding target	3	3	1	1/5	5	3
Low probability of homing on the wrong target	7	9	5	1	5	5
Hit point precision	1	1	1/5	1/5	1	1/5
High survivability	3	3	1/3	1/5	5	1

Mission flexibility Consistency rating = 0,09

	Quick engagement response time	Good standoff range	Good time on target precision	Good remote control connectivity
Quick engagement response time	1	1/3	1/3	5
Good standoff range	3	1	1/3	7
Good time on target precision	3	3	1	7
Good Link 16 remote control connectivity	1/5	1/7	1/7	1

Constraining the aircraft and pilot as little as possible Consistency rating = 0,12

	Large launch envelope	Large captive carry envelope	Responds quickly to commands
Large launch envelope	1	1/3	1
Large captive carry envelope	3	1	1
Responds quickly to commands	1	1	1

Good availability Consistency rating = 0,10

	Long shelf life and MTBM	Long in-service life	Good inherent reliability	High probability of detecting errors prior to fielding/use	Short MTTR
Long shelf life and MTBM	1	1/3	1/3	3	5
Long in-service life	3	1	3	3	5
Good inherent reliability	3	1/3	1	3	3
High probability of detecting errors prior to fielding/use	1/3	1/3	1/3	1	3
Short MTTR	1/5	1/5	1/3	1/3	1

Priority weights for JSM performance and qualities

A long range, high precision, air launched missile to engage high value, highly defended, open water littoral and land targets.

Priority weights

0,45 High probability of kill

		Priority weights
0,07	Effective sea target destruction	0,032
0,04	Effective land target destruction	0,020
0,20	High probability of finding target	0,088
0,49	Low probability of homing on the wrong target	0,219
0,05	Hit point precision	0,024
0,15	High survivability	0,066

0,27 Mission flexibility

0,16	Quick engagement response time	0,043
0,29	Good standoff range	0,078
0,50	Good time on target precision	0,133
0,05	Good remote control connectivity	0,013

0,07 Constraining the aircraft and pilot as little as possible

0,23	Large launch envelope	0,015
0,45	Large captive carry envelope	0,030
0,32	Responds quickly to commands	0,022

0,09 Good availability

0,19	Long shelf life and MTBM	0,017
0,41	Long in-service life	0,036
0,24	Good inherent reliability	0,022
0,11	High probability of detecting errors prior to fielding/use	0,009
0,06	Short MTTR	0,005

0,13 Cost 0,128

- Questionnaire mirroring the hierarchical needs structure

- Reduced number of judgments from 171 to 44

- The final priority weights were gathered from 31 participants

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Measure of alignment
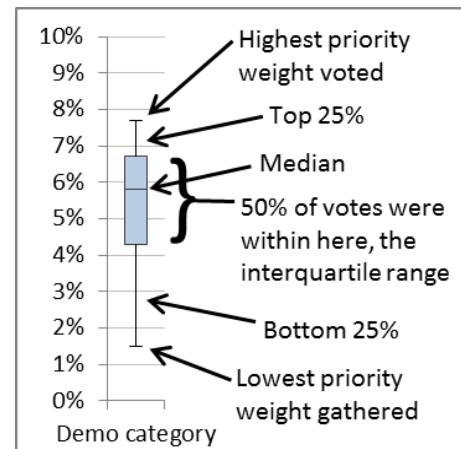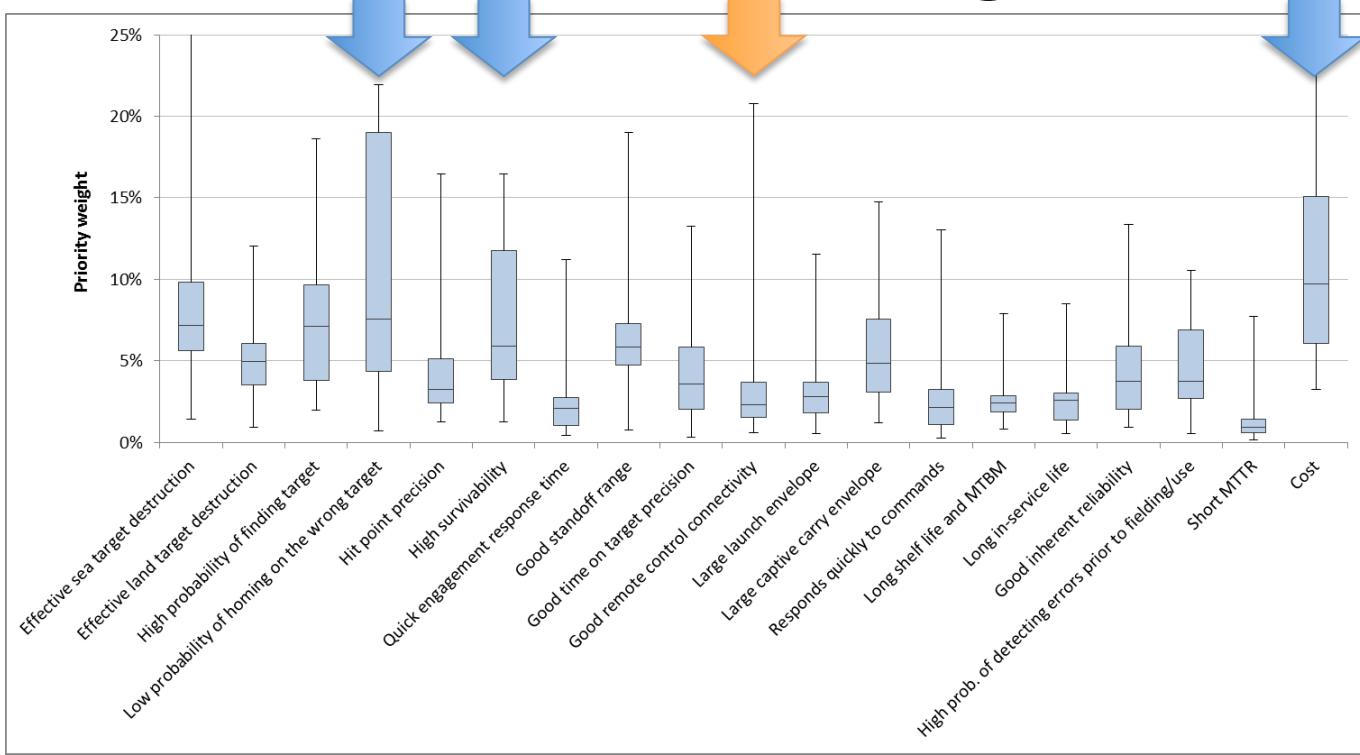
Box-chart explanation

Perception of priority
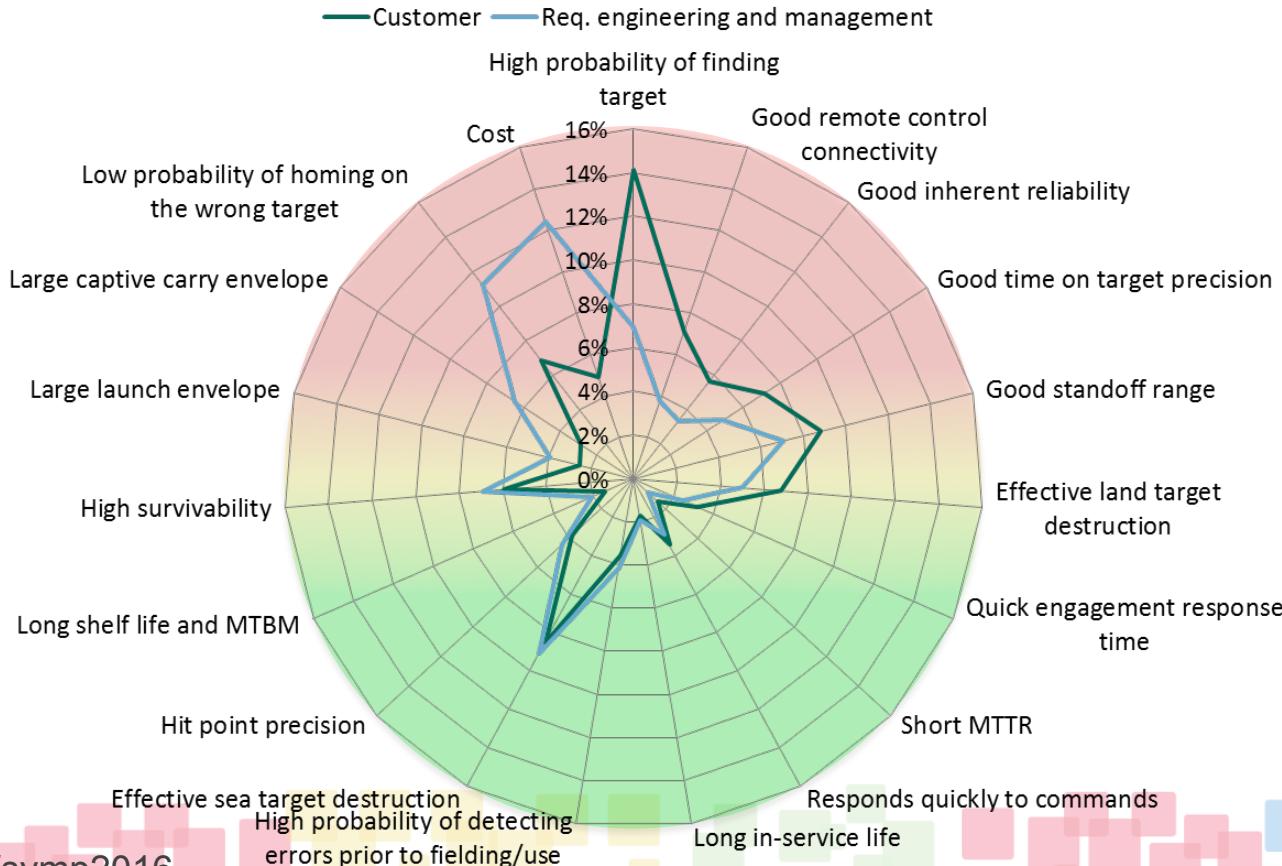
Examples of problem areas subject to tradeoff

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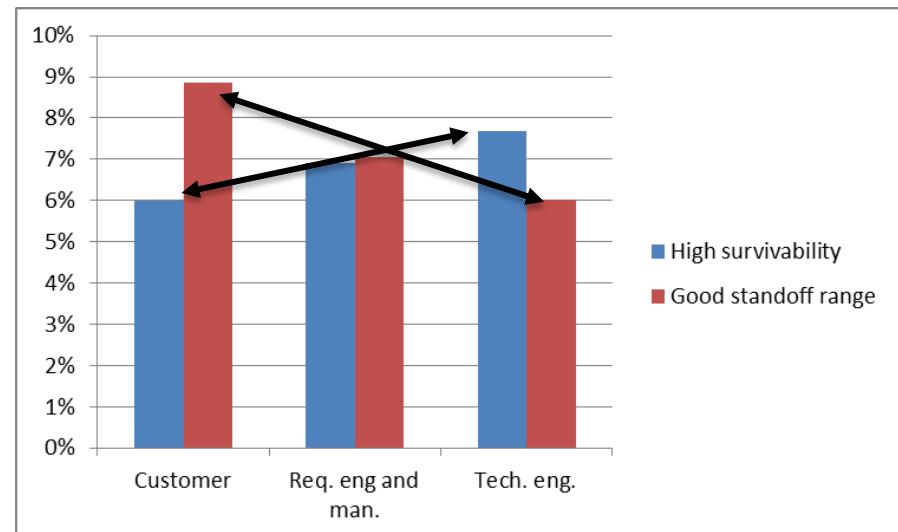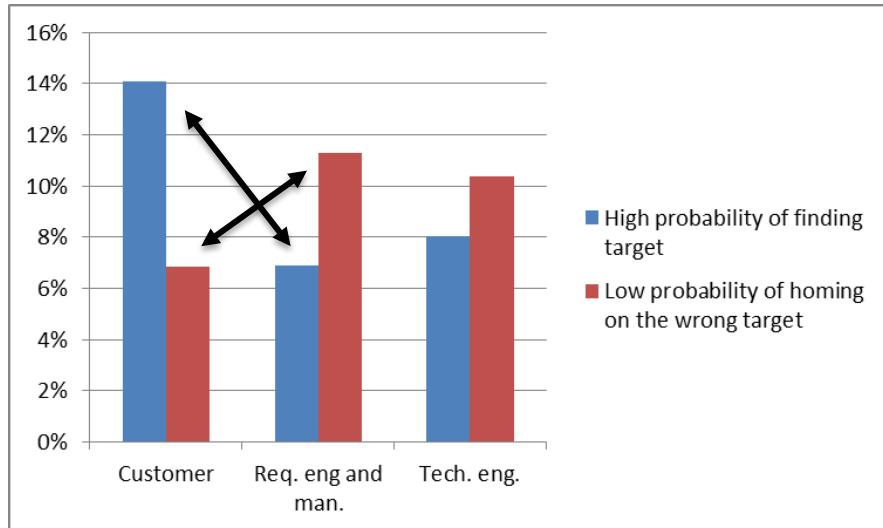
Emerging process

1. Sit down with the customer representatives and agree on the needs hierarchy, being clear about the definition of each need.

2. Let each representative fill out the AHP based questionnaire individually. It is important to help the individuals in the defense organization portray their own views, which otherwise may be held back in the presence of higher ranking officers.

3. Sit down again and discuss the findings, why do some believe one element is more important than others and so on, until all can agree on a common way forward.

Communicating with engineering

- House of Quality is used to translate the needs' priorities of the customer into requirement priorities

- The result is priority weights for 63 quantifiable system characteristics

House of quality

- Input;

  – needs w/mean of AHP evaluation results

Row number	Demanded Quality (a.k.a. "Customer Requirements" or "Whats")	Weight / Importance	Relative Weight
1	Flexibility - Quick engagement response time	0,0318	10,19 %
2	Flexibility - Good standoff range	0,0885	28,41 %
3	Flexibility - Good time on target precision	0,0714	22,89 %
4	Flexibility - Good Link 16 remote control connectivity	0,0707	22,69 %
5	Cost	0,0493	15,82 %
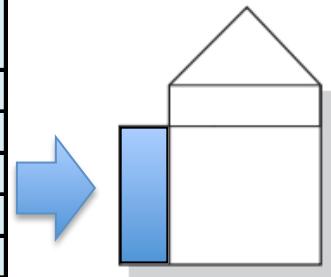
  – Quality characteristics with correlation to needs (derived from interviews)

Resulting importance of characteristic

Customer needs

System quality characteristics

Column Number	1	2	3	4	5
Strongest Relationship In Column	●	●	●	●	○
Relative Weight	10,19 %	28,41 %	22,89 %	22,69 %	15,82 %

Demanded Quality (a.k.a. "Customer Requirements" or "Whats")

Quality Characteristics (a.k.a. "System Requirments" or "Hows")

Row Number	Strongest Relationship In R	Requirement Weight	Relative Weight	Difficulty (0=Easy, 10=Extr	Minimize (▼), Maximize (▲)	Target or Limit value		Flexibility - Quick response time	Flexibility - Good range	get precision	mote control contr	Cost
1	●	322	11,17 %		▼	< x sec [SSS-JSM-X46]	Flight time precision relative to estimation	○	○			
2	○	116	4,01 %		▼	< x m [SSS-JSM-X5/X60]	Sea Skim altitude less than				○	○
3	●	2 0	7,64 %		▲	Complexity	Route planner connectivity planning				●	▽
4	●	325	11,28 %		▼	< x nm deviation	Route	○		▽		▽
5	●	204	7,09 %		▲	> x %	Link 1				●	
6	●	204	7,09 %		▲						●	
7	●	204	7,09 %		▲						●	
8	○	133	4,61 %		▲	>= x ft [SSS-JSM-546]	Maxim			○		○
9	●	256	8,87 %		▲	>= x nm [SSS-JSM-1370/X45]	Minim			●		
10	●	256	8,87 %		▲	>= x nm [SSS-JSM-X44]	Minimum weapon range from max launch altitude			●		
11	●	3 7	12,06 %		▲	>= x Mach	Air speed	●	●			
12	●	237	8,21 %		▲	max-min Mach	Velocity envelope (throttling capability)	○		●		
13	○	58	2,00 %		▼	sec [SSS-JSM-1416/137/276]	Retarget/generate missile plan command response time	▽				○

Relationships	
Strong	●
Moderate	○
Weak	▽
None	
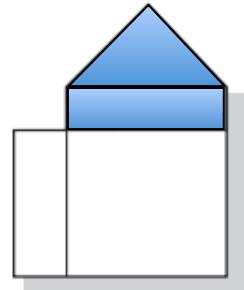
Column number	1	2	3	4	5	6	7	8	9	10	11	12	13
Quality Charateristics (a.k.a "Functional Requirements" or "Hows") / Row number	Flight time precision relative to estimation	Sea Skim altitude less than	Route planner connectivity planning	Route planner range estimator precision	Link 16 antenna efficiency	Link 16 tranceiver sensitivity	Link 16 output power	Maximum launch altitude	Minimum weapon range at sea altitude	Minimum weapon range from max launch altitude	Air speed	Velocity envelope (throttling capability)	Retarget/generate missile plan command respo
1 Flight time precision relative to estimation													
2 Sea Skim altitude less than													
3 Route planner connectivity planning													
4 Route planner range estimator precision													
5 Link 16 antenna efficiency													
6 Link 16 tranceiver sensitivity													
7 Link 16 output power						-							
8 Maximum launch altitude													
9 Minimum weapon range at sea altitude													
10 Minimum weapon range from max launch altitude								+					
11 Air speed								-	- -	- -			
12 Velocity envelope (throttling capability)	++			-							+		
13 Retarget/generate missile plan command response time													

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Evaluation of the HoQ

- Good communication tool internally, especially for discussions related to the importance of characteristics in relation to objectives

- Missing neccessary information to perform efficient trade-off decisions

The Kano Diagram
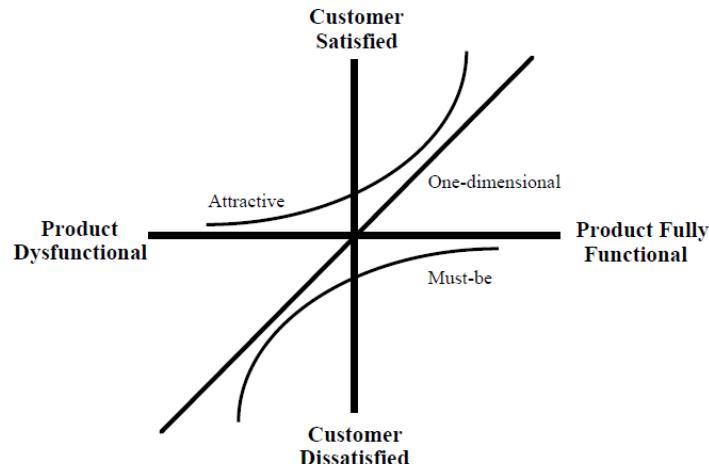
Brochure

Survivability (launch platform and missile)
- Stand-off Range
- Low Observable
- Mission Profile
- End Game Profile

Target Selectivity
- Target Detection & Identification
- Autonomous Target Recognition (ATR)
- Target Discrimination (in cluttered invironment)
- ROE Compatible

Lethality
- Precision Aimpoint
- Warhead Effect
- Collateral Damage Mitigation

Mission Flexibility
- Multi Target Capable
- Multiple Operational Domains

Service Suitability
- Multi Platform Capable
- Net Ready
- Minimum Maintenance
- Aircraft Carrier Suitable