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System-of-Systems Situational Awareness Effectiveness Using AHP

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Objective

The objective of this work is to use AHP with technical and cognitive elements to evaluate system-of-systems concepts to facilitate (performance evaluation) the situation awareness.

Background

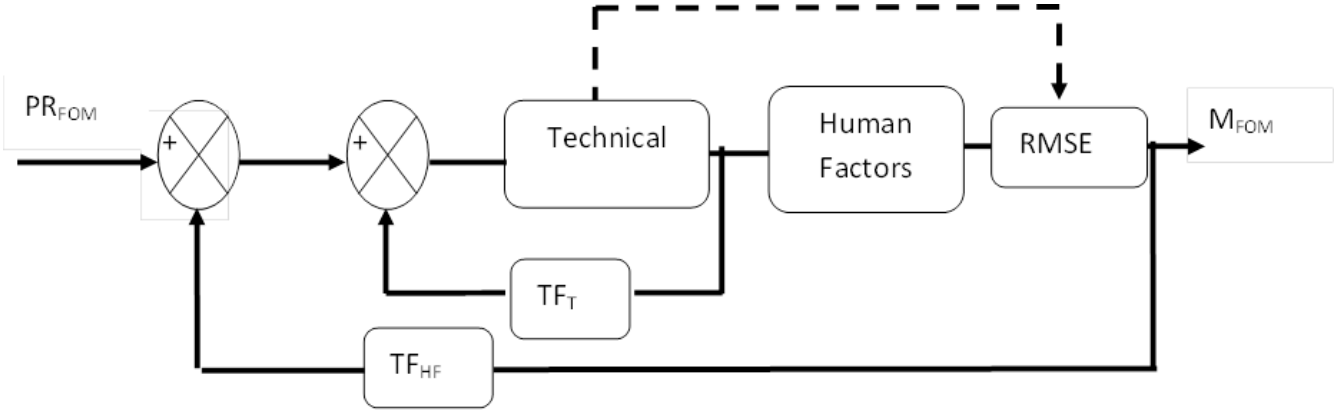
Situational awareness (SA):

- involves a complex interplay between a collection of sensors, network architectures and exploitation capability.

System-of-Systems concept design and evaluation:

- Technical
  - How system-of-systems technologies, processes and framework impact SA
- Human Factors
  - How the data produced by system-of-systems will impact human operation to facilitate SA .

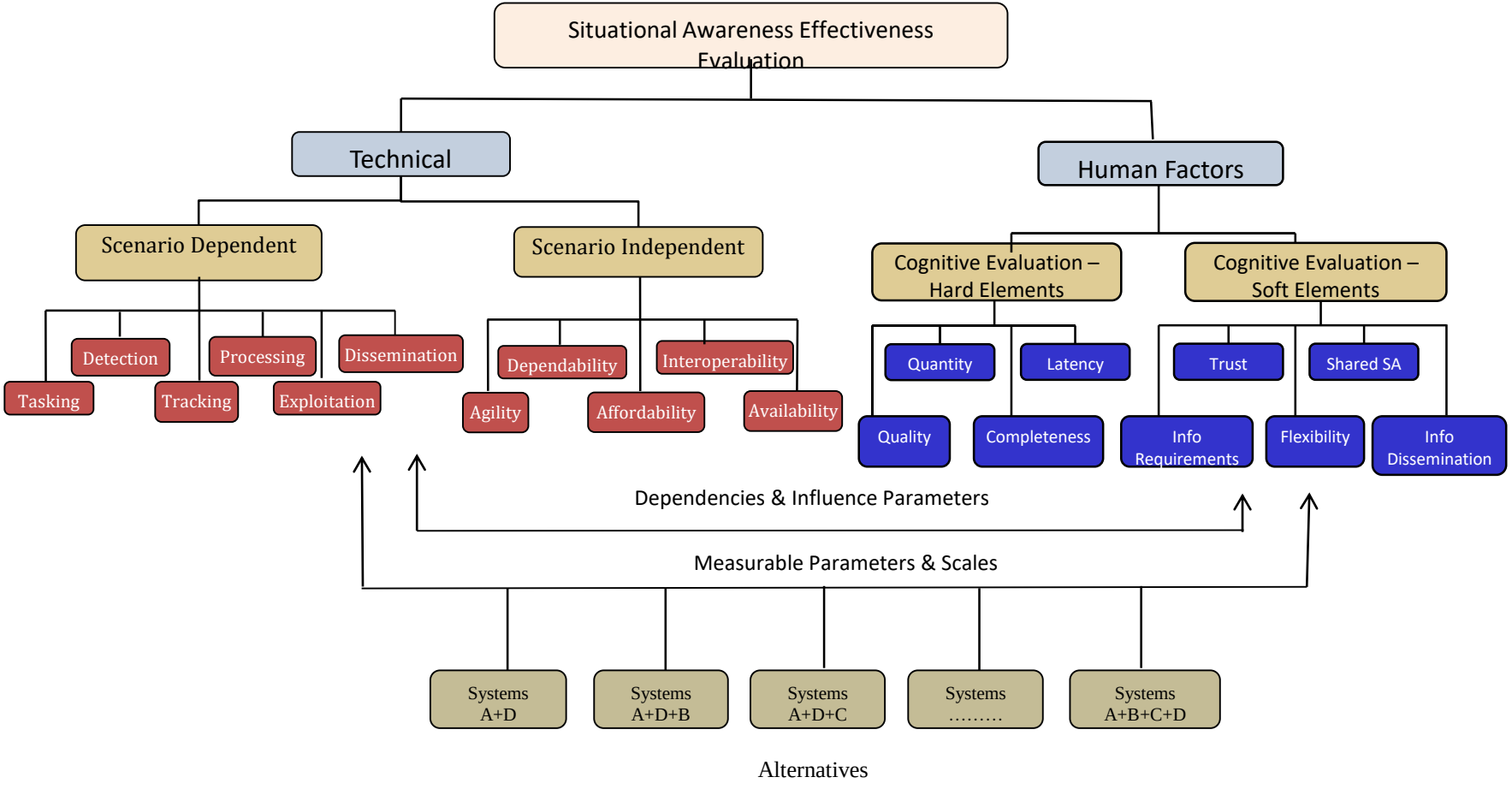
Evaluation Process



Where:

- PR_{FOM} = Performance Requirements FOM
- FOM = Figures of Merits
- M_{FOM} = Measured FOM
- TF_T = Transfer Function (Technical)
- TF_{HF} = Transfer Function (Human Factor)
- RMSE = Root Mean Square Error

Situational Awareness Effectiveness Evaluation Influence Diagram



Technical Criteria

Scenario Dependent:	
Tasking	response time, revisit time, and coverage percentage in
Detection	number of detections, detection gaps and probability of detection
Tracking	track life time, number of tracks, and inclusion of track correlation
Processing	time required, computational power and parallel processing
Exploitation	number of products produced, and the time required to be integrated adequately
Dissemination	size of the product, synchronization of data and bandwidth from the service provider to consumer

Scenario Independent:	
Agility	responsiveness, manoeuvrability, flexibility and robustness
Dependability	comprise the sensing capability, resolution, reliability and quality
Affordability	acquisition, operations, life cycle maintenance, management costs and staff training requirements
Interoperability	compatibility, accuracy, and accessibility
Availability	survivability, resiliency and durability

Human Factors Criteria

Cognitive- Hard Elements (pertain to operators' perception)	
Quality	refers to the resolution
Quantity	the amount of information that the operators receive
Latency	Associate with the amount of time it takes to receive information after it has been requested
Completeness	focus on the extent to which gaps in information occur as a result of combining data

Cognitive- Soft Elements (pertain to meta-cognitive aspects of the decision-making process.)	
Info Requirements	involved in the operation addresses whether the concept can facilitate the way the participating groups organize themselves
Trust	denotes a certain degree of dependence on the human or technology to deliver or provide a reliable and expected output
Flexibility	utilize different combinations of SOS concepts at any given time, assesses the concept's responsiveness to unscheduled
Shared SA	ensure synchronization of effort to make possible the achievement of the goals
Info Dissemination	allow evaluators to determine the extent to which operators have to push or pull information to make decisions individually or in a team

Comparison matrix for technical and human factor criteria

Technical

Scenario Dependent	Tasking	Detection	Tracking	Processing	Exploitation	Dissemination
Tasking	1	0.5	0.33	0.33	0.14	1.0
Detection	2.0	1.0	0.50	0.50	0.20	2.0
Tracking	3.0	2.0	1.00	1.00	0.50	3.0
Processing	3.0	2.0	1.00	1.00	0.50	3.0
Exploitation	7.0	5.0	2.00	2.00	1.00	7.0
Dissemination	1.0	0.5	0.33	0.33	0.14	1.0

Scenario Independent	Agility	Dependability	Affordability	Interoperability	Availability
Agility	1.0	2.0	1.0	1.0	0.5
Dependability	0.5	1.0	0.5	0.5	0.5
Affordability	1.0	2.0	1.0	2.0	1.0
Interoperability	1.0	2.0	0.5	1.0	2.0
Availability	2.0	2.0	1.0	0.5	1.0

Human Factor

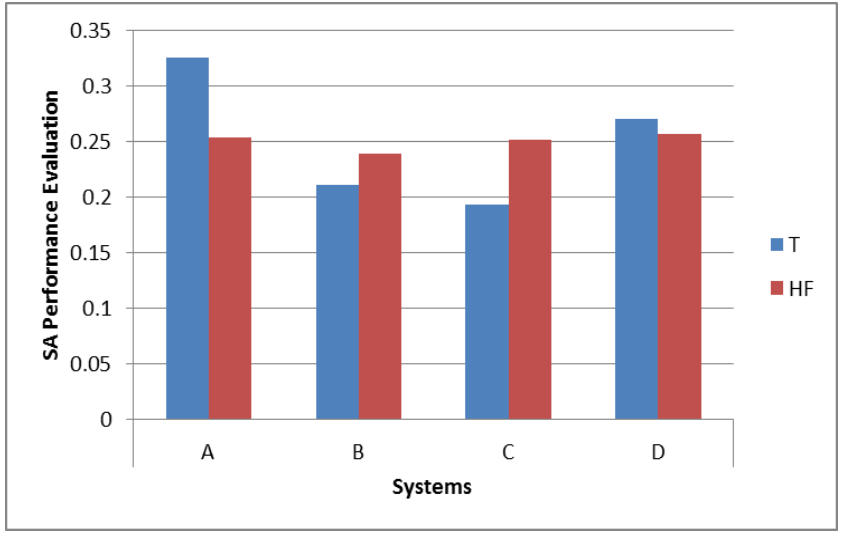
Cognitive Evaluation- Hard Elements	Quality	Quantity	Latency	Completeness
Quality	1.0	2.0	1.0	2.0
Quantity	0.5	1.0	2.0	0.5
Latency	1.0	0.5	1.0	0.5
Completeness	0.5	2.0	2.0	1.0

Cognitive Evaluation- Soft Elements	Info Requirements	Trust	Flexibility	Shared SA	Info Dissemination
Info Requirements	1.0	1.0	2.0	1.0	2.0
Trust	1.0	1.0	2.0	2.0	4.0
Flexibility	0.5	0.5	1.0	2.0	1.0
Shared SA	1.0	0.5	0.5	1.0	2.0
Info Dissemination	0.5	0.25	1.0	0.5	1.0

The weights of each criteria and sub-criteria

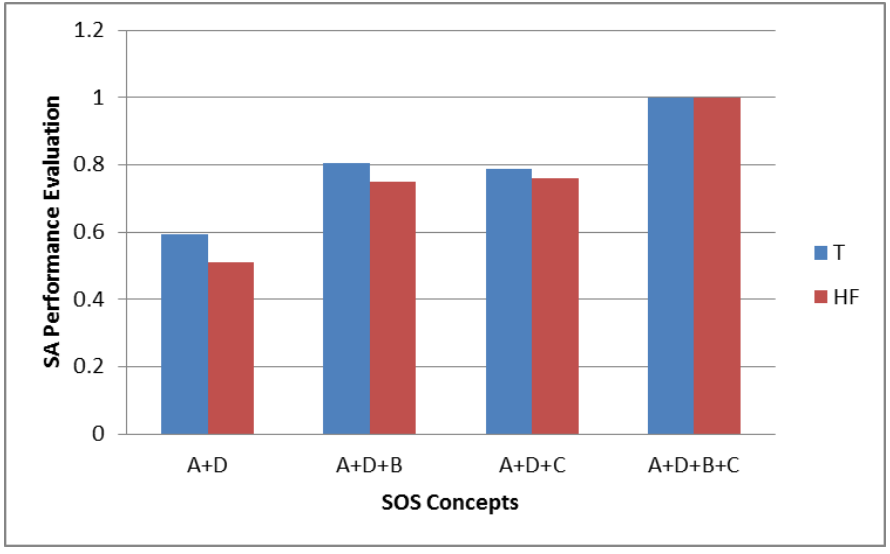
Criteria	Sub-Criteria	Weights	Measured level-Criteria	Weights
Technical	Scenario Dependent	.6	Tasking	0.058
			Detection	0.100
			Tracking	0.187
			Processing	0.187
			Exploitation	0.410
			Dissemination	0.058
	Scenario Independent	.4	Agility	0.191
			Dependability	0.105
			Affordability	0.251
			Interoperability	0.226
			Availability	0.227
Human Factor	Cognitive Evaluation-Hard Elements	.5	Quality	0.341
			Quantity	0.202
			Latency	0.179
			Completeness	0.278
	Cognitive Evaluation-Soft Elements	.5	Info Requirements	0.244
			Trust	0.315
			Flexibility	0.168
			Shared SA	0.167
			Info Dissemination	0.107

Results and Analysis



System level evaluation (T for Technical, HF for Human Factor), (RMSE: 0.0488)

System-of-Systems level evaluation (RMSE: .0538)



Conclusions

- Initial correlation between technical and HF performance evaluation
- Applied AHP in such system-of-systems application (Multi-stage evaluation using AHP)
- Improved concept development
- For follow on work:
  - Improve mapping between the technical and HF criteria
  - Improve the process
  - Evaluate with additional cases

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