

Analysis of the Qualities Providing Robust Defence Systems

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Introduction and Background

- Systems Engineering topic
 - Prompted by conversations at INCOSE
 - Internal Work – Exploratory research
- Issue
 - Some enduring defence systems
 - provide capability quite different to original intent /requirement
 - Eg
 - » B52 bomber
 - » F15
 - » F4
 - » FV430 vehicle



Introduction and Background

- Why this longevity, flexibility and endurance?
 - Other systems do not endure
 - Eg contemporaries of the previous examples are
 - B58 Hustler,
 - Stalwart



- Drivers for the investigation/analysis
 - Future uncertainty
 - Predicted long service lives of new equipments
- Increasing demand for system robustness and flexibility
 - but little understanding of how this might be achieved.

Introduction and Background

- Initial work to investigate whether there appear to be any attributes or characteristics
 - resulting in a system or equipment which will provide robust, enduring defence capability.
- Initial application - military aircraft
 - explores various attributes and assesses combinations of these against varying roles.

Approach for Initial Study

- Air Domain
 - Phase 1 Simple Approach – Pathfinder
 - Simple mission requirements
 - Simple aircraft characterisation
 - Phase 2
 - More refined/detailed missions
 - Phase 3
 - Compare two outputs
 - Map onto real aircraft

Approach for Initial Study

- Phase 1
 - Define simple air missions
 - Initial Requirements
 - Identify simple characteristics of aircraft
 - Establish options for each characteristic
 - Assess utility of all combinations of these characteristics against all mission
 - Identify good options

Initial Missions

Baseline Reqts

- 1 Defend airbases from air attack
- 2 Shoot down 4 intruder a/c bombers
- 3 Intercept enemy at 200 miles range
- 4 Maintain CAP for 2 hours
- 5 Defeat 3 enemy fighter a/c
- 6 Long Range Deployment - Cross Atlantic

Aircraft Characteristics/Parameters

<i>Parameters</i>	<i>Levels</i>		
Crew Size	1	2	
# Engines	1	2	
Engine Power	L	H	
# Missiles	2	4	6
Radar Range	S	L	
Inflt Refuel	Y	N	
Wing Area	S	L	
Length	L	S	
Weight	H	L	

Aircraft Options

Concepts based on combinations of characteristics
- Filtered for feasibility

	# Engines	# Missiles	Radar Range	Wing Area	Weight
Concept					
1	1	2	S	S	L
2	1	2	S	L	L
3	1	2	L	S	L
4	1	2	L	L	L

Aircraft Options

Concept	# Engines	# Missiles	Radar Range	Wing Area	Weight
1	1	2	S	S	L
2	1	2	S	L	L
3	1	2	L	S	L
4	1	2	L	L	L
5	1	6	S	S	L
6	1	6	S	L	L
7	1	6	L	S	L
8	1	6	L	L	L
9	2	2	S	S	L
10	2	2	S	L	L
11	2	2	L	S	L
12	2	2	L	L	L
13	2	6	S	S	L
14	2	6	S	L	L
15	2	6	L	S	L
16	2	6	L	L	L
17	1	2	S	S	H
18	1	2	S	L	H
19	1	2	L	S	H
20	1	2	L	L	H
21	1	6	S	S	H
22	1	6	S	L	H
23	1	6	L	S	H
24	1	6	L	L	H
25	2	2	S	S	H
26	2	2	S	L	H
27	2	2	L	S	H
28	2	2	L	L	H
29	2	6	S	S	H
30	2	6	S	L	H
31	2	6	L	S	H
32	2	6	L	L	H

Score vs Mission

Score each concept vs the missions

1-5 scale

In house scoring with some SME comment

Req't	1	2	3	4	5	6	
	Def a/b	4 bombers	200 mls	CAP 2hrs	3 ftrs	X Atlantic	Score
	2	1	2	4	2	3	14
	2	1	2	4	3	3	15
	3	2	2	5	2	3	17
	3	2	2	5	3	3	18
	2	3	2	4	2	3	16

Score vs Mission

Concept							Def a/b	4 bombers	200 mls	CAP 2hrs	3 ftrs	X Atlantic	Score
1	1	2	S	S	L		2	1	2	4	2	3	14
2	1	2	S	L	L		2	1	2	4	3	3	15
3	1	2	L	S	L		3	2	2	5	2	3	17
4	1	2	L	L	L		3	2	2	5	3	3	18
5	1	6	S	S	L		2	3	2	4	2	3	16

Mapping

Concept	#Engines	#Missiles	Radar Range	Wing Area	Weight	Req't	1	2	3	4	5	6	Score
							Def a/b	4 bombers	200 mls	CAP 2hrs	3 ftrs	X Atlantic	
1	1	2	S	S	L		2	1	2	4	2	3	14
2	1	2	S	L	L		2	1	2	4	3	3	15
3	1	2	L	S	L		3	2	2	5	2	3	17
4	1	2	L	L	L		3	2	2	5	3	3	18
5	1	6	S	S	L		2	3	2	4	2	3	16
6	1	6	S	L	L		2	3	2	4	3	3	17
7	1	6	L	S	L		3	4	2	5	3	3	20
8	1	6	L	L	L	F16	3	4	2	5	4	3	21
9	2	2	S	S	L	Jaguar	2	1	2	4	3	4	16
10	2	2	S	L	L		2	1	2	4	4	4	17
11	2	2	L	S	L		3	2	2	5	3	4	19
12	2	2	L	L	L		3	2	2	5	4	4	20
13	2	6	S	S	L		3	3	2	4	3	4	19
14	2	6	S	L	L		3	3	2	4	4	4	20
15	2	6	L	S	L		4	4	2	5	4	4	23
16	2	6	L	L	L		4	4	2	5	5	4	24
17	1	2	S	S	H		2	1	2	4	1	3	13
18	1	2	S	L	H		2	1	2	4	2	3	14
19	1	2	L	S	H		3	2	2	5	1	3	16
20	1	2	L	L	H		3	2	2	5	2	3	17
21	1	6	S	S	H		2	3	2	4	1	3	15
22	1	6	S	L	H		2	3	2	4	2	3	16
23	1	6	L	S	H		3	4	2	5	2	3	19
24	1	6	L	L	H		3	4	2	5	3	3	20
25	2	2	S	S	H		2	1	2	4	2	4	15
26	2	2	S	L	H		2	1	2	4	3	4	16
27	2	2	L	S	H	Lightning	3	2	2	5	2	4	18
28	2	2	L	L	H		3	2	2	5	3	4	19
29	2	6	S	S	H		3	3	2	4	2	4	18
30	2	6	S	L	H		3	3	2	4	3	4	19
31	2	6	L	S	H	F3	4	4	2	5	3	4	22
32	2	6	L	L	H	F15/F14	4	4	2	5	4	4	23

Initial Concept vs Example Population

- Example

- Concepts 8 and 9 are consistent with F16 and Jaguar

8	1	6	L	L	L	F16
9	2	2	S	S	L	Jaguar



Approach for Initial Study

–Phase 2

- Generate more refined/detailed missions
- Three differing groups/roles
- Assess utility of all combinations again
 - In all three groups
- Identify good options

Refined Requirements/Scenarios

Suppression of Enemy Air Defence (SEAD)

Reqs

- 1 low level attack
- 2 bomb enemy SAM defences
- 3 Attack enemy radar
- 4 Sweep area (ahead of bomber mission/force)
- 5 Fly 300 mls into enemy airspace
- 6 Reduced /Stealthy signature

Refined Requirements/Scenarios

Air to Ground/CAS Missions

- Missile Truck

Reqs

- 1 Loiter over target area**
- 2 Communicate with ground forces**
- 3 Launch Air to Ground missiles**
- 4 300 mls Range**

Refined Requirements/Scenarios

Interdiction Strike (IDS)

Reqs

- 1 Reduced/Stealthy signature**
- 2 EW/Counter enemy radar**
- 3 Strike enemy targets**
- 4 Fly 300 miles**
- 5 Evade enemy fighters**

Refined Scenarios

Repts SEAD

- 1 low level attack
- 2 bomb en SAMs
- 3 Attack en radar
- 4 Sweep area for bomber force
- 5 Fly 300 mls into en airspace
- 6 Stealthy signature

Generated in-house

Repts AG Missile Truck

- 1 Loiter over target area
- 2 Comm with grd forces
- 3 Launch AG missiles
- 4 300 mls Rg

Repts IDS

- 1 Stealthy signature
- 2 Jam en radar
- 3 Attack en targets
- 4 Fly 300 miles
- 5 Evade en fighters

Analysis

Score each concept vs the missions

1-5 scale

In house scoring with some SME comment

Concept	low level	SAMs	radar	Sweep	Fly 300 m	Stealth	Score
1	3	3	2	2	3	3	16
2	4	4	2	3	3	2	18
3	3	3	2	2	3	3	16
4	4	4	2	3	3	2	18
5	3	3	3	2	3	3	17
6	4	4	3	3	3	2	19
7	3	3	3	3	3	3	18
8	4	4	3	4	3	2	20

Example Data - Concepts 1-8 vs SEAD

Analysis

Score each concept vs the missions

1-5 scale

In house scoring with some SME comment

Concept	low level	SAMs	radar	Sweep	Fly 300 m	Stealth	Score	Loiter	Comm	AG missil	Fly 300 m	Score	Stealthy s	Jam en r	Attack	300 miles	Evade	Score
1	3	3	2	2	3	3	16	2	3	3	3	11	3	2	3	3	2	13
2	4	4	2	3	3	2	18	2	3	4	3	12	2	2	4	3	2	13
3	3	3	2	2	3	3	16	2	3	3	3	11	3	2	3	3	2	13
4	4	4	2	3	3	2	18	2	3	4	3	12	2	2	4	3	2	13
5	3	3	3	2	3	3	17	2	3	3	3	11	3	2	3	3	3	14
6	4	4	3	3	3	2	19	2	3	4	3	12	2	2	4	3	3	14
7	3	3	3	3	3	3	18	2	3	3	3	11	3	2	3	3	3	14
8	4	4	3	4	3	2	20	2	3	4	3	12	2	2	4	3	3	14

SEAD

AG/CAS

IDS

Concepts 1-8

Complete Matrix

Concept	#Engines	#Missiles	Radar Range	Wing Area	Weight							SEAD				Truck					IDS			
						Concept	1 low level	2 SAMs	3 radar	4 Sweep	5 Fly 300 m	6 Stealth	Score	1 Loiter	2 Comm	3 AG missile	4 Fly 300 m	Score	1 Stealth	2 sJam		3 en rzAttack	4 300 miles	5 Evade
1	1	2	S	S	L	1	3	3	2	2	3	3	16	2	3	3	3	11	3	2	3	3	2	13
2	1	2	S	L	L	2	4	4	2	3	3	2	18	2	3	4	3	12	2	2	4	3	2	13
3	1	2	L	S	L	3	3	3	2	2	3	3	16	2	3	3	3	11	3	2	3	3	2	13
4	1	2	L	L	L	4	4	4	2	3	3	2	18	2	3	4	3	12	2	2	4	3	2	13
5	1	6	S	S	L	5	3	3	3	2	3	3	17	2	3	3	3	11	3	2	3	3	3	14
6	1	6	S	L	L	6	4	4	3	3	3	2	19	2	3	4	3	12	2	2	4	3	3	14
7	1	6	L	S	L	7	3	3	3	3	3	3	18	2	3	3	3	11	3	2	3	3	3	14
8	1	6	L	L	L	8	4	4	3	4	3	2	20	2	3	4	3	12	2	2	4	3	3	14
9	2	2	S	S	L	9	3	3	2	3	3	3	17	3	3	3	3	12	3	3	3	3	2	14
10	2	2	S	L	L	10	4	4	2	4	3	2	19	3	3	4	3	13	2	3	4	3	2	14
11	2	2	L	S	L	11	3	3	2	3	3	3	17	3	3	3	3	12	3	3	3	3	2	14
12	2	2	L	L	L	12	4	4	2	4	3	2	19	3	3	4	3	13	2	3	4	3	2	14
13	2	6	S	S	L	13	3	3	3	3	3	3	18	3	3	3	3	12	3	3	3	3	3	15
14	2	6	S	L	L	14	4	4	3	4	3	2	20	3	3	4	3	13	2	3	4	3	3	15
15	2	6	L	S	L	15	3	3	3	4	3	3	19	3	3	3	3	12	3	3	3	3	3	15
16	2	6	L	L	L	16	4	4	3	5	3	2	21	3	3	4	3	13	2	3	4	3	3	15
17	1	2	S	S	H	17	3	2	2	1	3	3	14	3	3	2	3	11	3	3	2	3	3	14
18	1	2	S	L	H	18	4	3	2	2	3	2	16	3	3	3	3	12	2	3	3	3	3	14
19	1	2	L	S	H	19	3	2	2	1	3	3	14	3	3	2	3	11	3	3	2	3	3	14
20	1	2	L	L	H	20	4	3	2	2	3	2	16	3	3	3	3	12	2	3	3	3	3	14
21	1	6	S	S	H	21	3	2	3	1	3	3	15	3	3	2	3	11	3	3	2	3	4	15
22	1	6	S	L	H	22	4	3	3	2	3	2	17	3	3	3	3	12	2	3	3	3	4	15
23	1	6	L	S	H	23	3	2	3	2	3	3	16	3	3	2	3	11	3	3	2	3	4	15
24	1	6	L	L	H	24	4	3	3	3	3	2	18	3	3	3	3	12	2	3	3	3	4	15
25	2	2	S	S	H	25	3	2	2	2	3	3	15	4	3	2	3	12	3	4	2	3	3	15
26	2	2	S	L	H	26	4	3	2	3	3	2	17	4	3	3	3	13	2	4	3	3	3	15
27	2	2	L	S	H	27	3	2	2	2	3	3	15	4	3	2	3	12	3	4	2	3	3	15
28	2	2	L	L	H	28	4	3	2	3	3	2	17	4	3	3	3	13	2	4	3	3	3	15
29	2	6	S	S	H	29	3	2	3	2	3	3	16	4	3	2	3	12	3	4	2	3	4	16
30	2	6	S	L	H	30	4	3	3	3	3	2	18	4	3	3	3	13	2	4	3	3	4	16
31	2	6	L	S	H	31	3	2	3	3	3	3	17	4	3	2	3	12	3	4	2	3	4	16
32	2	6	L	L	H	32	4	3	3	4	3	2	19	4	3	3	3	13	2	4	3	3	4	16

Initial scores

Score	Concept
14	1
15	2
17	3
18	4
16	5
17	6
20	7
21	8
16	9
17	10
19	11
20	12
19	13
20	14
23	15
24	16
13	17
14	18
16	19
17	20
15	21
16	22
19	23
20	24
15	25
16	26
18	27
19	28
18	29
19	30
22	31
23	32

Concept	#Engines	#Missiles	Radar Range	Wing Area	Weight	Score
7	1	6	L	S	L	20
8	1	6	L	L	L	21
11	2	2	L	S	L	19
12	2	2	L	L	L	20
13	2	6	S	S	L	19
14	2	6	S	L	L	20
15	2	6	L	S	L	23
16	2	6	L	L	L	24
23	1	6	L	S	H	19
24	1	6	L	L	H	20
28	2	2	L	L	H	19
29	2	6	S	S	H	18
30	2	6	S	L	H	19
31	2	6	L	S	H	22
32	2	6	L	L	H	23

Refined Analysis Scores

Concept	SEAD Score	Truck Score	IDS Score	
1	16	11	13	
2	18	12	13	
3	16	11	13	
4	18	12	13	
5	17	11	14	
6	19	12	14	
7	18	11	14	
8	20	12	14	
9	17	12	14	
10	19	13	14	Orange
11	17	12	14	White
12	19	13	14	Orange
13	18	12	15	White
14	20	13	15	Red
15	19	12	15	Orange
16	21	13	15	Red
17	14	11	14	
18	16	12	14	
19	14	11	14	
20	16	12	14	
21	15	11	15	
22	17	12	15	
23	16	11	15	
24	18	12	15	
25	15	12	15	
26	17	13	15	Orange
27	15	12	15	White
28	17	13	15	Orange
29	16	12	16	White
30	18	13	16	Orange
31	17	12	16	White
32	19	13	16	Red

	# Engines	# Missiles	Radar Range	Wing Area	Weight		SEAD	Truck	IDS	
Concept						Concept	Score	Score	Score	
1	1	2	S	S	L	1	16	11	13	
2	1	2	S	L	L	2	18	12	13	
3	1	2	L	S	L	3	16	11	13	
4	1	2	L	L	L	4	18	12	13	
5	1	6	S	S	L	5	17	11	14	
6	1	6	S	L	L	6	19	12	14	
7	1	6	L	S	L	7	18	11	14	
8	1	6	L	L	L	8	20	12	14	
9	2	2	S	S	L	9	17	12	14	
10	2	2	S	L	L	10	19	13	14	Orange
11	2	2	L	S	L	11	17	12	14	White
12	2	2	L	L	L	12	19	13	14	Orange
13	2	6	S	S	L	13	18	12	15	White
14	2	6	S	L	L	14	20	13	15	Red
15	2	6	L	S	L	15	19	12	15	Orange
16	2	6	L	L	L	16	21	13	15	Red
17	1	2	S	S	H	17	14	11	14	
18	1	2	S	L	H	18	16	12	14	
19	1	2	L	S	H	19	14	11	14	
20	1	2	L	L	H	20	16	12	14	
21	1	6	S	S	H	21	15	11	15	
22	1	6	S	L	H	22	17	12	15	
23	1	6	L	S	H	23	16	11	15	
24	1	6	L	L	H	24	18	12	15	
25	2	2	S	S	H	25	15	12	15	
26	2	2	S	L	H	26	17	13	15	Orange
27	2	2	L	S	H	27	15	12	15	White
28	2	2	L	L	H	28	17	13	15	Orange
29	2	6	S	S	H	29	16	12	16	White
30	2	6	S	L	H	30	18	13	16	Orange
31	2	6	L	S	H	31	17	12	16	White
32	2	6	L	L	H	32	19	13	16	Red

SEAD	Truck	IDS		Base		Concept	
16	11	13		14		1	
18	12	13		15		2	
16	11	13		17		3	
18	12	13		18		4	
17	11	14		16		5	
19	12	14		17		6	
18	11	14		20		7	
20	12	14		21		8	F16
17	12	14		16		9	Jaguar
19	13	14		17		10	
17	12	14		19		11	
19	13	14		20		12	
18	12	15		19		13	
20	13	15		20		14	
19	12	15		23		15	Gripen
21	13	15		24		16	Eurof
14	11	14		13		17	
16	12	14		14		18	
14	11	14		16		19	
16	12	14		17		20	
15	11	15		15		21	
17	12	15		16		22	
16	11	15		19		23	
18	12	15		20		24	
15	12	15		15		25	
17	13	15		16		26	
15	12	15		18		27	Lightning
17	13	15		19		28	
16	12	16		18		29	
18	13	16		19		30	
17	12	16		22		31	F3
19	13	16		23		32	F15/F14

Combined Results and Examples

Next Steps

- Analyse requirements for systems that have flexibility/robustness
 - B52, F15
- Commercial approach – IT
 - Process Requirements not technical
 - Leads to flexibility
- Investigate this wrt defence

Next Steps

- Commercial examples
 - IT
 - Transport
- Defence
 - Land Systems
 - Naval?
 - B52

Overall

- Rapid Analysis of Aircraft Robustness complete
- Two phased approach
 - Simple initial
 - (Still Simple) refinement
- Robust concepts identified
- Some indication of utility
- Extensions
 - Land Systems
 - Civilian Applications
 - IT systems – capability requirements
 - Transport