Paper #109

10TH **I**NTERNATIONAL **C**OMMAND AND **C**ONTROL **R**ESEARCH AND **T**ECHNOLOGY **S**YMPOSIUM

THE **F**UTURE **O**F **C**2

Using assessment Methods and Tools to Understand Joint Battlespace Digitization (JBD)

Assessment, Tools, and Metrics

Author: N. M. Al-Duwaish* (PhD Student)

Supervisor: Prof. P. John (Director of Systems Engineering)

Engineering Systems Department, Cranfield University [RMCS],
Shrivenham, Swindon SN6 8LA, United Kingdom
Tel: +44(01793) 785497 / fax: +44(01793) 783192
E-mail: n.al-duwaish@cranfield.ac.uk

Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE **JUN 2005**	2. REPORT TYPE	3. DATES COVERED **00-00-2005 to 00-00-2005**
4. TITLE AND SUBTITLE **Using assessment Methods and Tools to Understand Joint Battlespace Digitization (JBD)**		5a. CONTRACT NUMBER 5b. GRANT NUMBER 5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)		5d. PROJECT NUMBER 5e. TASK NUMBER 5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **Engineering Systems Department,Cranfield University [RMCS],Shrivenham,Swindon SN6 8LA, UK, ,**		8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)		10. SPONSOR/MONITOR'S ACRONYM(S) 11. SPONSOR/MONITOR'S REPORT NUMBER(S)
12. DISTRIBUTION/AVAILABILITY STATEMENT **Approved for public release; distribution unlimited**		
13. SUPPLEMENTARY NOTES **The original document contains color images.**		
14. ABSTRACT		
15. SUBJECT TERMS		

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT **unclassified**	b. ABSTRACT **unclassified**	c. THIS PAGE **unclassified**		**48**	

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std Z39-18

Abstract

This paper reports the author's current research into an integrated approach to Joint Battlespace Digitisation (JBD) analysis. The work describes an approach to establishing a toolset that is useful to understand the JBD, existing policies on JBD lack clear directives in certain areas, which may inhibit its benefits and timely exploitation of military situations. There are several methods being developed that are potentially useful for analyzing JBD but several question arise:

- How do they relate to the overall needs of the JBD analyst?
- How do they integrate within an overall analytical approach?
- What methods can we employ for assessing the completeness of our analysis?

A new assessment is used to interact and share information between the various aspects of JBD analysis. This toolset is built around Strategy To Task (STT), which enables identification of requirements for JBD and to assess potential options, and System Dynamics (SD) to enable analysis of factors which contribute to mission effectiveness of JBD and to investigate the importance of these factors and also to enable the analysis of specific technical parameters leading to validation of STT assessment. Using different analysis elements is, illustrating the use of these methods tools in the study.

Introduction

The term digitisation is used to describe the process of applying modern technological advances to formulate a sound, secure and versatile integrated system of communication and action. Digitisation of the communication system of a battle space, endorses the total integration of information across the whole battle space in order to enhance the military capability. This greater information superiority management system enables one to conduct and coordinate Joint and Combined military operations more effectively and with precision. Digitisation of Battle space covers all aspects of command, control, computers, military intelligence, surveillance, target acquisition and reconnaissance, emanated from supreme command of the country to the theatre of operations as illustrated in figure 1. The battle space, on the other hand, encompasses the sea, air and land space, electronics engagement and ranges from strategic to the tactical levels including systems, responsible for acquiring, transmitting, processing or utilizing information to achieve desired objectives. It is an enduring capability system that increases tempo in battle. This is seen as the primary emergent property of interconnecting information and computing assets across the whole battle space. However, such extensive interconnection will result in high complexity and is unlikely to result in a single positive emergent property

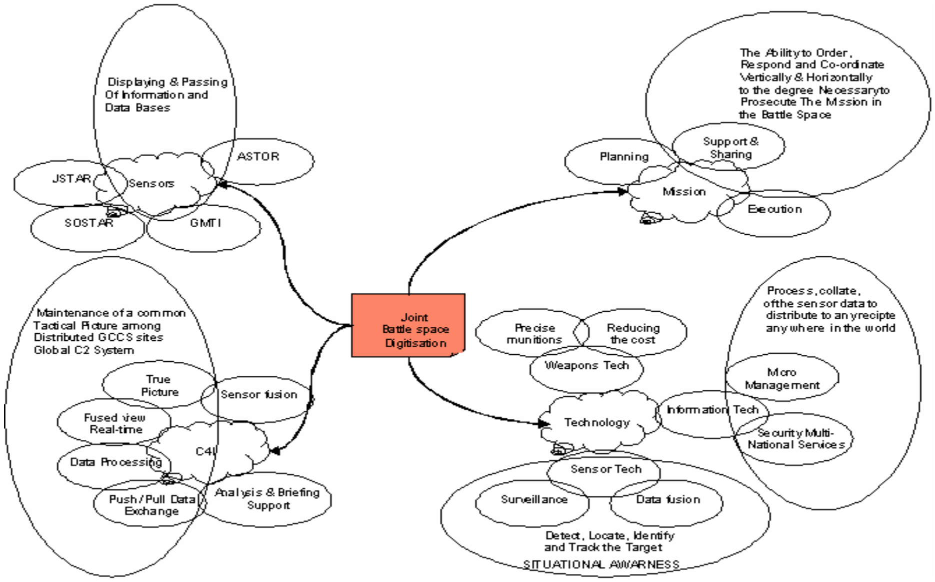


Figure 1: JBD Structure

Figure 2 shows many issues and challenges, which can affect the JBD. Command Structure: must be compatible with the information flow requirements and decision hierarchy (it must facilitate & support the same).

Technological change: Continued advances in technology offer prospects for major improvements in system capability. JBD must allow these advances to be exploited quickly within the constraints imposed by acquisition policy and procurement methods. Of particular importance, JBD must, as far as possible, embrace common commercial IT concepts to engender exploitation of mainstream commercial-off-the-shelf COTS components within Defence systems. Security and other constraints (e.g. military communications) will limit the potential for use of (COTS) technology.

Manpower and training demands: The growth in information requirements and thus of communications and information systems (CIS) to support them has a complex effect on required manpower levels and skills. On the one hand, automation of (for example) routine information handling, retrieval, storage or processing functions will reduce the manpower currently needed to fulfil these tasks, freeing military staff to concentrate on conducting operations. However, there is a concomitant increase in the demand for skilled manpower to acquire, manage and maintain (including in the field) the resulting systems. The continued pressure on manpower levels means that JBD must not demand (and ideally should reduce) manpower and training requirements for a given level of operational capability. To this end, it is vital that JBD is compatible with developing training environments like Synthetic Theater of War (STOW) and Joint Operational Interface Simulation Training (JOIST) so that it can contribute to, and benefit from, operational training.

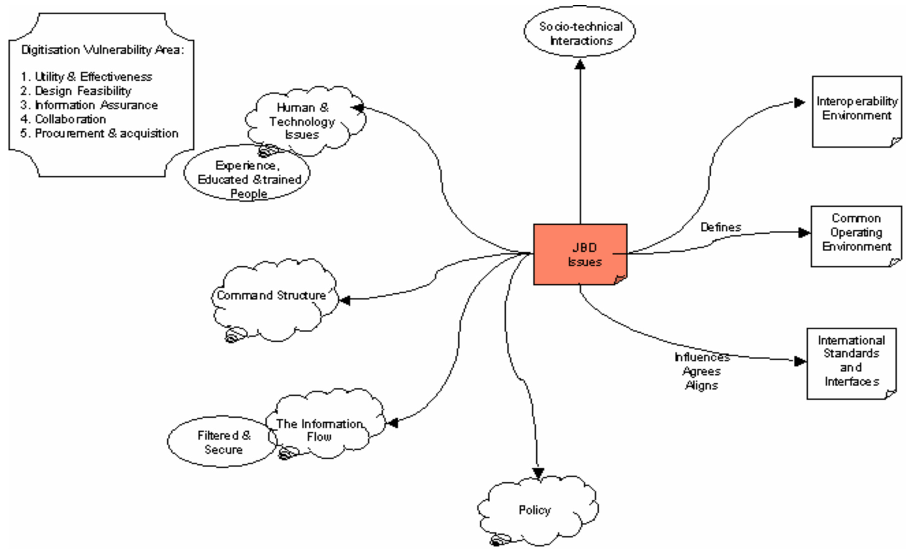


Figure 2: JBD Issues & challenges

Vision, Objectives, Success Factors and Metrics

It is important that the JBD design, which will evolve over several years, should keep in mind the high-level vision it is meant to realise, together with the derived objectives and the current view on priorities. These will be used to maintain the design principles and to focus effort on the areas of greatest concern. The success factors and metrics provide a basis against which to make situation and progress reports. The metrics must relate to the engineering design, i.e. they must be couched in engineering terms – Measures of Performance (MoPs). These in turn will have been derived from metrics couched in user (operational) terms – Measures of Effectiveness (MoEs).

In order to assist the understanding, management and application of these non-functional requirements, it is proposed that they should be logically grouped according to the nature of the constraints they impose and the reason for wishing to impose a constraint. A suggested top-level structure for such a grouping is:

- Resilience
- Security
- Control & Management
- Sustainability & Upgradability
- Usability & Flexibility

It is believed that all non-functional requirements can usefully be described under these top-level headings, but further work is required to confirm this and to determine any lower-level breakdown that would be beneficial.

Some of these design constraints will tend to reinforce or support each other, whilst others will tend to conflict. Such conflicts will inevitably lead to the need for trade-off analyses and design compromises. It is often the case that the greatest benefits from innovative design and implementation proposals can be gained in such areas of conflict.

Methods & tools

At this moment, there is no methodology or apparatus to verify the impact on the systems supporting the military operations, and there is a lack of linkage between high-level (System View) based parameters, such as performance parameters, interfaces, functionality index and so on, and lower level elements (Technical view) which actually form the physical implementation of JBD.

This link is critical only when a lower level simulation is carried out, that a clearer and more defined view of the impact of the options (e.g. AWACS or satellites) becomes available. Currently, no such things exist between the 3 views of JBDAF. Such a system is incapable of implementing the on-line, dynamic design, which has been spoken about earlier. Hence, the new system has an additional two tools, which will be explained in greater detail.

The first key tool is STT. This tool enables the identification of requirement for JBD and to assess potential options. The methodology utilized will be subsequently explained. The second tool is Vensim, which enables the analysis of factors, which contribute to mission effectiveness and investigate the importance of these factors. It links the operational and system views. In addition, it also links the system and technical views and analyses specific technical parameters, and validates the assessment carried out by STT.

Strategy to Task Technique

The Strategy to Task Technique developed by the RAND Corporation during the 1980's [1] in connection with their work on behalf of the US Air Force. It describes a framework, similar to that illustrated here, for cascading high-level objectives through a number of layers to a level appropriate to the individual problem being considered.

One way of implementing STT is to use Quality Function Deployment (QFD) an example matrix [2], which is illustrated here in Tables 1, 2, 3 and 4. In those examples our objectives are identified and are referred to as the WHATs. The various ways in which these objectives could be achieved are identified and are referred to as the HOWs. The relative importance of each objective is established and used as a weighting factor for subsequent calculation. The scores from a body of experts can then be included to illustrate the magnitude of the contribution of each HOW to the achievement of each WHAT. A formal marking scheme is typically used where:

- 9 represents a very high contribution
- 3 represents an important contribution
- 1 represents a high contribution
- 0 represents little or no contribution

For this paper the most frequently occurring score, gained from the responses to my analysis, for each WHAT/HOW combination was taken to populate the matrices. The raw technical importance is then calculated by simply adding the products of each WHAT/HOW combination. This score can then be normalised and is then used as the initial weightings for the subsequent layers of the cascade.

STT Applicability:

- Derivation of Capability Requirements
- Evaluation of doctrine to isolate capability requirements
- Full audit trail
- Weighting/Importance of Requirements
- Requirements have weightings at all levels
- Assessment of Equipment/Systems
- Assessment of all systems vs. requirements
- Assessment of importance of system elements vs. requirements
- Analysis of Doctrine
- Linkages down through hierarchy of publications
- Cross-comparison between publications

The first key tool is STT. This tool enables the identification of requirement for JBD and to assess potential options. The methodology utilized will be subsequently explained. The second tool is Vensim, which enables the analysis of factors, which contribute to mission effectiveness and

investigate the importance of these factors. It links the operational and system views. In addition, it also links the system and technical views and analyses specific technical parameters, and validates the assessment carried out by STT.

Now I shall look into the details of these two tools in the said order. As STT links the technical and operational views, it derives input from the former and provides input for the latter. The processing is carried out in a series of cascading tables. Each table carries out a prioritization and assessment procedure with the help of a set of assessment weighting factors. The output of one table is the input into the next table and the process continues.

Table 1 divides missions according to the objectives of Saudi strategic doctrine. According to this doctrine, the nature of the response to be taken is given relative importance. The weighting factors spans from 0 or no contribution, to 9, which is the maximum contribution. For example, for peacetime security purposes, information superiority is paramount. However, based on required operational readiness, full dimensional protection is relatively less important. Since there is no physical engagement, precision engagement is not a factor, and is not given a rating. Likewise, at the other end of the scale, a physical act of aggression against any Gulf Cooperation Council (GCC) member states has placed emphasis on factors like full dimension protection and Joint Command and Control among the armed services.

The next step would be to multiply each of the assigned weighting factors by the initial weight. The sum of these weighting factors for every possible response is tallied up as the Raw Technical Importance for each response in all possible mission types. The total tally is then normalized.

Table 1: STT at Strategy level

Very Important Contributor:	9									
Important Contributor:	3									
High Contributor:	1									
Low or Not a Contributor:										
Source Saudi Doctorine and	**JETL**	**Grand Strategic Level Tasks**								
		Responses from Saudi Doctrine								
Saudi Defence Missions	Initial Weight	Information Superiority	Interoperability	Dominant Maneuver	Precision Engagement	Focused Logistics	Full Dimension Protection	Joint Command & Control		
Peacetime Security	0.14286	9	3	1			3	1		
Defence Diplomacy	0.14286	1	1				1	1		
Support to Wider Saudi Interests	0.14286	1	1	3	1	1	1	1		
Peace Support	0.14286	1	3	3	1	1	3	3		
Regional Conflict outside GCC	0.14286	3	3	3	3	9	3	9		
Regional Conflict Inside GCC	0.14286	3	3	9	3	9	3	9		
Strategic Attack on GCC	0.14286	3	9	9	3	9	9	9		
Raw Technical Importance		3.0	3.3	4.0	1.6	4.1	3.3	4.7	24.0	Sum of Raw Technical Importance
Normalized Technical Importance		0.1250	0.1369	0.1667	0.0655	0.1726	0.1369	0.1964	1.0000	
Sum of Initial Weights	1.0000									

The next stage; as described in table 2 compares the responses stated earlier to individual tasks which can be carried out by each of the armed services. Once again the process of cross weighting is carried out. This table essentially demonstrates the importance of various tasks to ensure a particular doctrinal response. For example, to achieve information superiority over a potential adversary, it is important to have a dominant situational awareness (weighting factor 9) and effective area surveillance (weighting factor 9) but the ability to enforce economic sanctions or provide disaster relief is of no relevance (no weighting factor).

Once again the weighting factor are tallied up and normalized. This gives the importance of a certain task in order to support the responses in the peacetime as well as wartime according to Saudi defence doctrine. In a way, the armed services are made aware of the relative importance of the specific tasks they are to perform, and allows them to allocate resources appropriately.

Table 2: STT Cascade down to Tasks Level

Very Important Contributor:	9
Important Contributor:	3
High Contributor:	1
Low or Not a Contributor:	
Percent Filled	82.6%
Source	JBD Saudi Doctrine

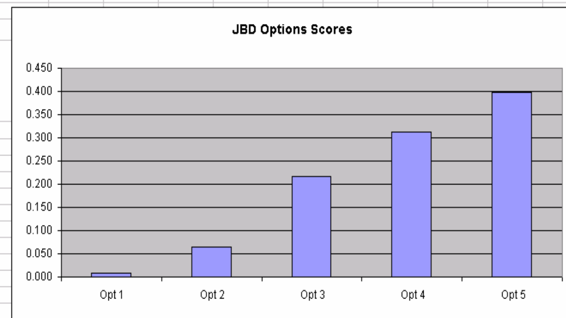
	Initial Weight	Situational Awareness	Own Force Location	Enemy Force Location	Force Protection	Interdiction of Enemy's Forces	Blockade	Containment	Exclusion Zones	Barrier Operations	Layered Defence	Enemy Force Intent	Strategic Air Lift	Tactical Air Lift	Sea Lift	Strategic Nuclear Deterrence	Presence
Information Superiority	0.1250	9	1	3								1				9	1
Interoperability	0.1369	9											1	1	1	3	3
Dominant Maneuver	0.1667	3	3	3	3	3	3	1	1	3	1	3	1	1	1	3	3
Precision Engagement	0.0655	3	3	9	3	3	9	3	3	3	3	3	1	1	1	3	3
Focused Logistics	0.1726	1	3	1	1	1	1			1		1	9	9	9		1
Full Dimension Protection	0.1369	3	3	3	9	1	3	1	1	1	1	3				3	3
Joint Command & Control	0.1964	9	3	3	1	3	1	1	1	1	1	3				9	3
Raw Technical Importance		5.4	2.3	2.6	2.3	1.6	1.9	0.7	0.7	1.2	0.7	2.0	1.9	1.9	1.9	4.4	2.4
Normalized Technical Importance		0.05	0.02	0.03	0.02	0.02	0.02	0.01	0.01	0.01	0.01	0.02	0.02	0.02	0.02	0.04	0.02
Sum of Initial Weights	0.4940																

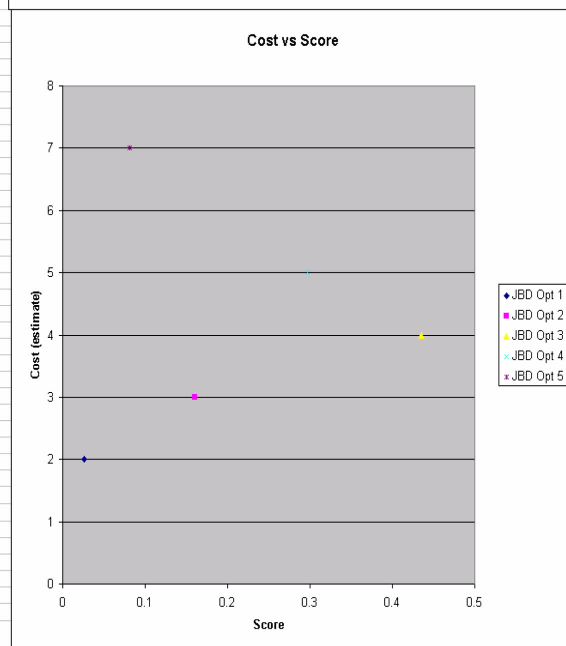
	Sympolic Use	Coercion	NonCombattant Evacuation Ope	Combat Operations vs Land	Combat Operations vs Air	Combat operations vs Navy	Combat Operations vs National	Amphibious Operations	Support to Joint Operations	Strategic Air Offensive	Counter Air	AntiSurface Force Land	AntiSurface Force Navy	Land Target Attack	Fire Support	Intelligence Gathering	Area Surveillance	Comms Provision	Logistic Support Provision	Protection of Joint Forces	Economic Sanctions	Disaster Relief	SAR	Amphibious Forces	Real-time Target Data	Target Identification	Peace Ops	
Information Superiority	1		1	3	3	3	3	1	3	3	3	3	3	3	9	9	9	3	1	1				1	1	3	1	95
Interoperability	3		1	3	3	3	3	3	3	3	3	3	3	3	3	3	9	9	1	1	1	1	1	1			1	86
Dominant Maneuver	3	1	1	3	3	3	3	3	3	3	9	3	3	3	3	3	3	9	3	3	1	1	1	3	3	3	1	117
Precision Engagement	1	3		3	3	3	3	3	3	3	9	3	3	3	9	1	3	9	1	9			1	3	3	3	1	140
Focused Logistics	1			1	1	1	1	1	3	1	1	1	1	1	3			1	9		3	1	1	1			1	72
Full Dimension Protection	1	1		1	3	1	1	3	3	9	9	3	3	3	3	3	1	3	1	9		3	3	3			1	106
Joint Command & Control	1		1	3	3	3	3	3	3	3	3	3	3	3	9	1	9	9	1	3		1	3	3	3	3	3	122
Raw Technical Importance	1.6	0.5	0.6	2.4	2.7	2.4	2.4	2.4	3.0	3.5	4.9	2.7	2.7	2.7	5.3	2.7	5.0	6.0	2.7	3.2	0.8	1.1	1.5	2.1	1.4	1.7	1.4	103.2 Sum of Raw Technical Importance
Normalized Technical Importance	0.02	0.00	0.01	0.02	0.03	0.02	0.02	0.02	0.03	0.03	0.05	0.03	0.03	0.03	0.05	0.03	0.05	0.06	0.03	0.03	0.01	0.01	0.01	0.02	0.01	0.02	0.01	1.0000

The next step would be to factor in cost and effectiveness of each of the options, which are part of the JBDAF. The options dictate the type of information available to the JBDAF, and vary on how much they cost and how effective they are. Table 3 shows how important each option is for a specified task. For example AWACS are extremely important for protecting or giving the air picture to the air force against hostile operation, but are of no consequence against land-based aggression.

Table 3: STT with different Systems options

Very Important Contributor:	9					
Important Contributor:	3					
High Contributor:	1					
Low or Not a Contributor:						
Percent Filled	#DIV/0!					
		JBD System Options				
	Initial Weight	Opt 1	Opt 2	Opt 3	Opt 4	Opt 5
Situational Awarness	0.0481	1	3	9	3	9
Own Force Location	0.0305				1	
Enemy Force Location	0.0337					
Force Protection	0.0337			9	9	
Interdiction of Enemy's Forces	0.0318					
Blockade	0.0102			3		
Containment	0.0160					
Exclusion Zones	0.0072		1			
Barrier Operations	0.0160		3			
Layered Defence	0.0160					
Enemy Force Intent	0.0115			3	9	
Strategic Air Lift	0.0195				9	
Tactical Air Lift	0.0104					
Sea Lift	0.0064		3			
Strategic Nuclear Deterrence	0.0217					
Presence	0.0265		3			
Sympolic Use	0.0265		3			
Coercion	0.0158		1			
NonCombattant Evacuation Operations	0.0195					
Combat Operations vs Land	0.0166					9
Combat Operations vs Air	0.0366					9
Combat operations vs Navy	0.0310					9
Combat Operations vs National Guard	0.0160					9
Amphibious Operations	0.0160					9
Support to Joint Operations	0.0299					9
Strategic Air Offensive	0.0337				3	
Counter Air	0.0299				3	
AntiSurface Force Land	0.0299				3	
AntiSurface Force Navy	0.0543				3	
Land Target Attack	0.0516				3	
Fire Support	0.0217				3	9
Intelligence Gathering	0.0559			9	9	9
Area Surveillance	0.0238					
Comms Provision	0.0307					
Logistic Support Provision	0.0086					
Protection of Joint Forces	0.0086					
Economic Sanctions	0.0134					
Disaster Relief	0.0193					
SAR	0.0064					
Amphibious Forces	0.0064			3		
Real-time Target Data	0.0064					
Peace Ops	0.0064					
Raw Technical Importance		0.0	0.4	1.3	1.9	2.4
Percent Technical Importance		0.008	0.064	0.216	0.313	0.399
Sum of Initial Weights	0.9543					
Cost (Relative estimate)		2	3	4	5	7
Risk (relative estimate)		1	2	3	4	5
		0.0261	0.1602	0.4354	0.2972	0.0811
		JBD Opt 1	JBD Opt 2	JBD Opt 3	JBD Opt 4	JBD Opt 5





The end of the exercise obtains an overview obtained of the contribution of each option (Table 4) towards the different defence missions spelt out in (Table 1). The impacts of these options are not entirely known until and unless they are modeled and simulated in a scenario depicting escalation of hostilities. This is done by the System Dynamic model (Vensim model), which is covered next.

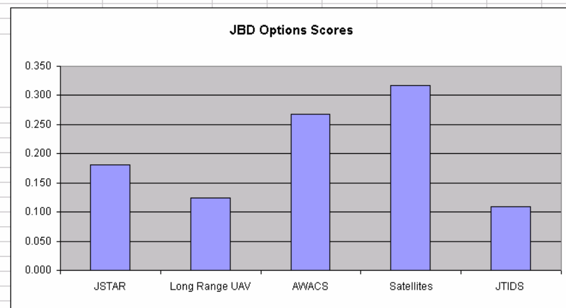
Table 4 clearly shows the most important piece of information required during peacetime, which is equipment acquisition. IT is a cost vs. score chart. The optimal choice of course would be the option, which would be in the most bottom right corner, which is high on the score scale but low on the cost scale. Such an option would be most cost effective, although in terms of score alone it might have a lower rating compared to a rival option.

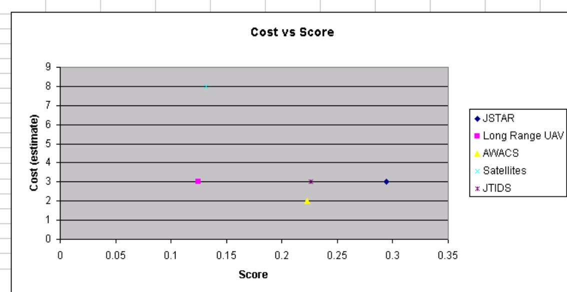
Table 4: STT with different Sub-Systems options

Very Important Contributor:	9	Directly equatable in the text
Important Contributor:	3	Mentioned in the text body
High Contributor:	1	Mentioned in the Sidebar Concepts/Enablers/Technologies (only)
Low or Not a Contributor:		Not mentioned at all
Percent Filled	#DIV/0!	

WHATS - OPERATIONS ADP Vol1 — JBD Options

LEVEL 1: *Strategy-to-Task Analysis*	Initial Weight	JSTAR	Long Range UAV	AWACS	Satellites	JTIDS
Situational Awarness	0.0481	3	3	9	9	3
Own Force Location	0.0305	3	3	3	3	1
Enemy Force Location	0.0337	3	1	3	3	1
Force Protection	0.0337	1	1	9	3	
Interdiction of Enemy's Forces	0.0318	3	3	3	3	3
Blockade	0.0102	3		3		
Containment	0.0160			1	1	
Exclusion Zones	0.0072	3	3	3	3	3
Barrier Operations	0.0160		3			
Layered Defence	0.0160	1	1	1	1	1
Enemy Force Intent	0.0115		1	3	9	
Strategic Air Lift	0.0195	1		3	3	
Tactical Air Lift	0.0265	1				1
Sea Lift	0.0217					
Strategic Nuclear Deterrence	0.0265			3	9	
Presence	0.0158	1	1	3	3	1
Sympolic Use	0.0195	3	3	3	3	3
Coercion	0.0166					
NonCombattant Evacuation Operations	0.0366	1	1	1	1	1
Combat Operations vs Land	0.0324	9	3		3	
Combat Operations vs Air	0.0310			9	3	1
Combat operations vs Navy	0.0160	1	1	3	3	
Combat Operations vs National Guard	0.0160	3		3	3	3
Amphibious Operations	0.0299	1	1	1	3	1
Support to Joint Operations	0.0337	9	3	9	9	3
Strategic Air Offensive	0.0299	1	1	9	9	3
Counter Air	0.0299		1	9	3	1
AntiSurface Force Land	0.0543	3	3	1	3	1
AntiSurface Force Navy	0.0516	3	1	1	3	3
Land Target Attack	0.0217	3	1		3	1
Fire Support	0.0559	1	1		3	1
Intelligence Gathering	0.0238	3	3	3	9	3
Area Surveillance	0.0307	3	3	3	3	
Comms Provision	0.0086			3	9	3
Logistic Support Provision	0.0086				1	
Protection of Joint Forces	0.0134	1	1	1	3	1
Economic Sanctions	0.0193					
Disaster Relief	0.0134				3	
SAR	0.0104					
Amphibious Forces	0.0064	1	1	1	3	1
Real-time Target Data	0.0064	1	1	3	9	1
Peace Ops	0.0064	1	1	1	3	1
Raw Technical Importance		2.0	1.4	3.0	3.6	1.2
Percent Technical Importance		0.182	0.124	0.268	0.318	0.109
Sum of Initial Weights	0.9872					
Cost (Relative estimate)		3	3	2	8	3
Risk (relative estimate)		2	3	4	5	1
		0.294	0.125	0.2231	0.1318	0.2262
		JSTAR	Long Range UAV	AWACS	Satellites	JTIDS





System Dynamic model (Vensim model)

The next tool to be added to JBD is the System Dynamic (Vensim model), which links the high-level systems and interconnections with the operational view. This ensures that there is greater transparency of tasks, doctrines, rules and concept for the personnel operating high-level systems. The Vensim model in figure 5 shows the communication between the JBD information sources and users. As we can see how is the relationship between them, and how it can effect each other with the positive and negative, hence we can realise the impact of some of those on JBD effectiveness, JBD cost effectiveness, JBD system cost and JBD information timeliness.

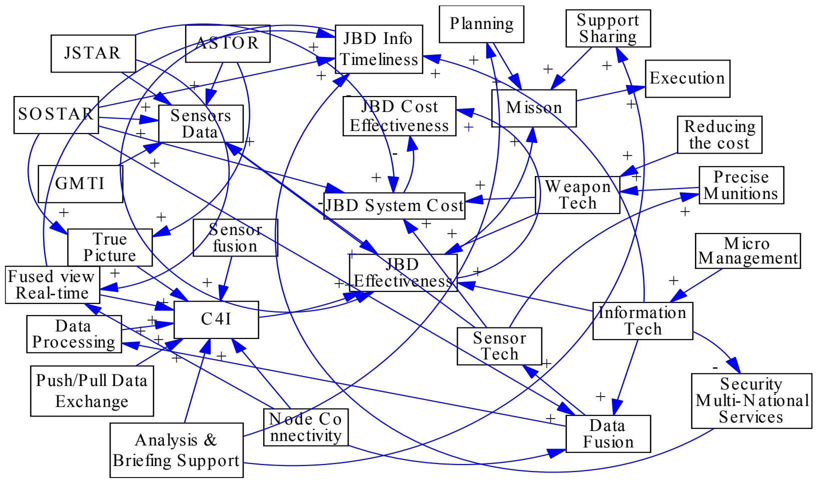


Figure 3: System Dynamic (SD) Communication Model for JBD Issues

Scenarios

The Vensim model in figure 6 simulates a scenario of possible escalation of conflict against Saudi Arabia or its GCC/Strategic partners. It attempts to incorporate all options in an escalating scenario that spans 28 days. Decisions and outcomes are based on weights and probabilities based on the STT study described earlier. The outcome of all the stages are depicted in the subsequent graphs which shown.

The simulations begin by specifying a number of hostile targets. Depending on the options in place, the targets are detected and prioritised. The effectiveness of JBD determines the threat assessment, this involves measuring target parameters, transmitting, prioritizing them to command sector. Based on situational awareness provided by JBD, the targets can choose to be eliminated. Even at an operational level, authorization of target engagement and eventual destruction is dependent upon the effectiveness of JBD this is because resources would be allocated based on the prior information provided by JBD. Hence, here the result of operational views input to JBD can be seen by the systems through simulation of the Vensim model

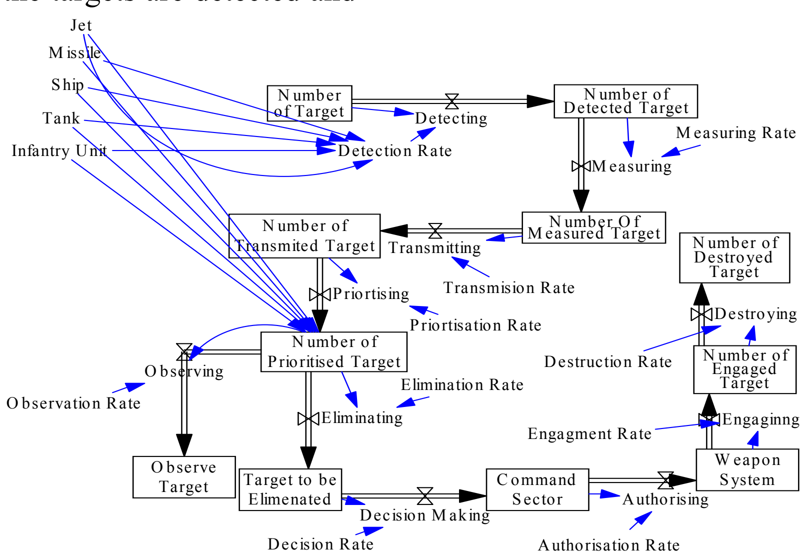


Figure 4: Escalated Hostility SD Vensim Model

The first case started from graph 1 up to graph 12 involves carrying out a sensitive study of a single asset. The exact performance of the asset is not available. However, the loop is able to demonstrate the effects of the asset having different performance capabilities. Each loop has 12 outputs, and the significance of each output will be explained in turn.

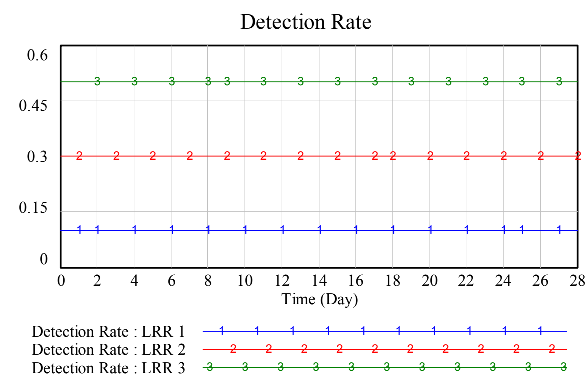
The first graph shows the three different detection rate capabilities of each asset. For example, the best capability of the LRR system is 0.5, followed by 0.3 and then 0.1. The indices refer to the whole system operating and not just a single unit of the system. The indices obtained from the sensitive study vary due to a number of possible reasons, be it the model of the equipment, technical issues, enemy countermeasures operating, etc.

The next step would be to examine the number of targets over a period of conflict of 28 days. There is a sharp increase in the number of targets initially. This is followed by gradual decline over the period of the conflict. The third graph shows the number of detected targets throughout the conflict. The greater the number of targets, the more the targets will be detected. Hence, the data for the third graph is obtained from the product of the data from the previous two graphs. Likewise, a higher capability index results in a higher rate of detection.

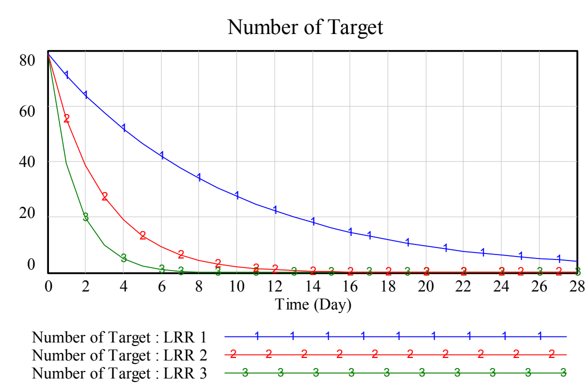
A second point to note is that the more effective the asset, the more skewed to the left the graph is when it comes to the graphs. This is because most hostile targets are dealt with early in the conflict. When the assets are less effective, dealing with the target is more gradual and more drawn out. It should not be misinterpreted to mean a greater effectiveness later in the conflict.

There are a few points to note with regards to the simulation case. It provides the analyst with the ability to assess the effects of a change in asset capability on the defence capability. For example, if the lines indicated by the legend for LRR 1 (blue) and LRR 2 (red) are close together, the increase is not significant, and vice versa. The option for LRR 2 is concerted to be the median case, or average between the best and worst case scenarios of LRR 1 and LRR 3 respectively. In addition, it is also important to note that the impact of an improved agent is felt right through the simulation process, from target detection, to engagement to destruction. This is because in the world of the digital battlespace, better asset performance results in better situational awareness. This translates into better performance across the board.

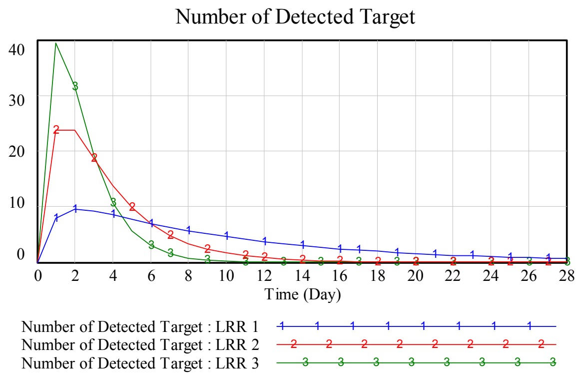
Note that the previous graphs are not cumulative graphs. It shows the actual number on any particular day of the conflict.



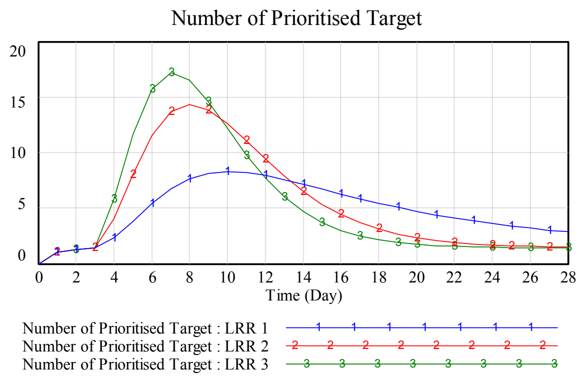
Graph 1: Detection Rate of the Sensors



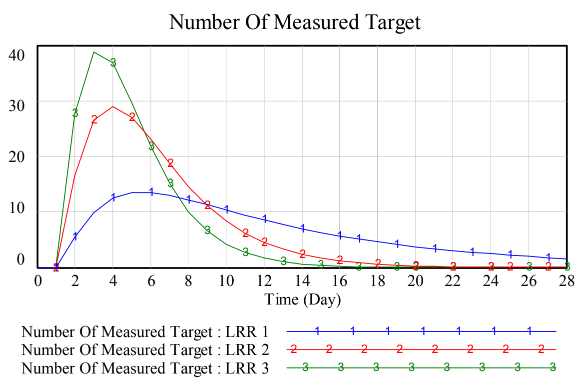
Graph 2: Number of Targets



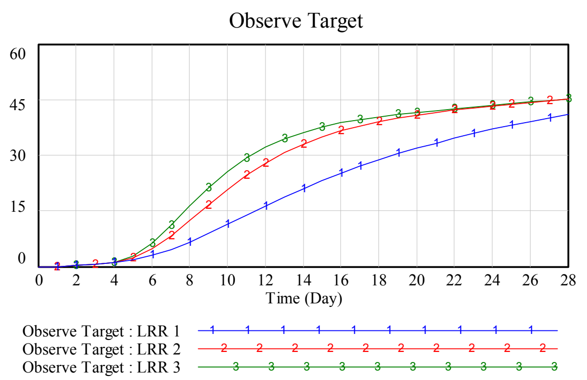
Graph 3: Number of Targets Detected each day



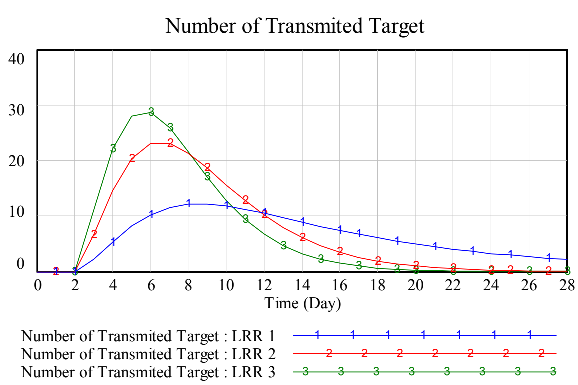
Graph 6: Number of Prioritised Targets



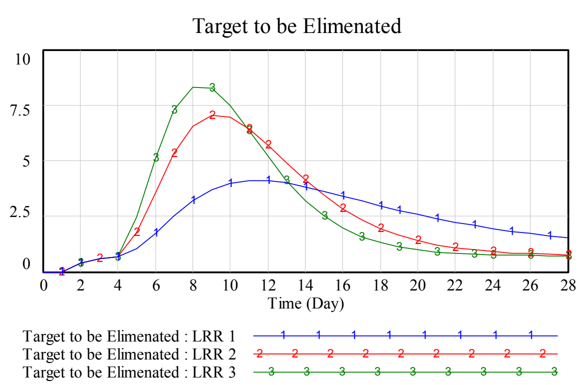
Graph 4: Number of Measured Targets



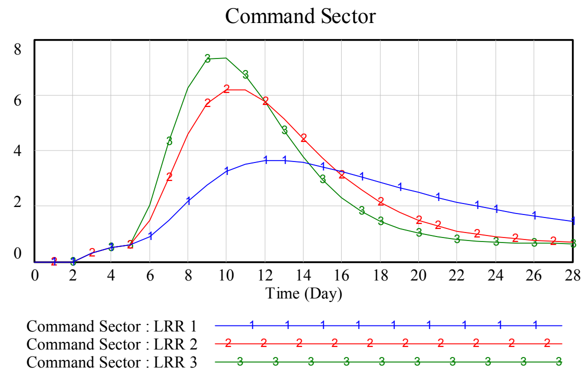
Graph 7: Number of Targets to be observed



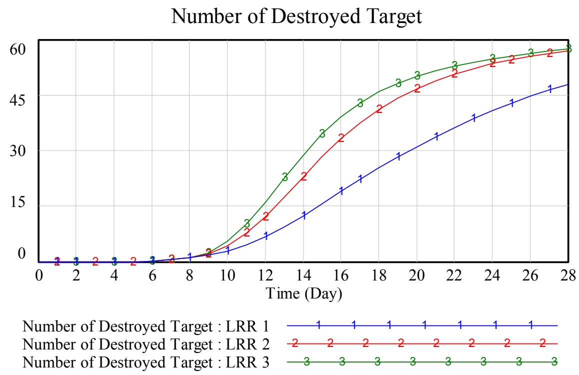
Graph 5: Number of Transmitted Targets



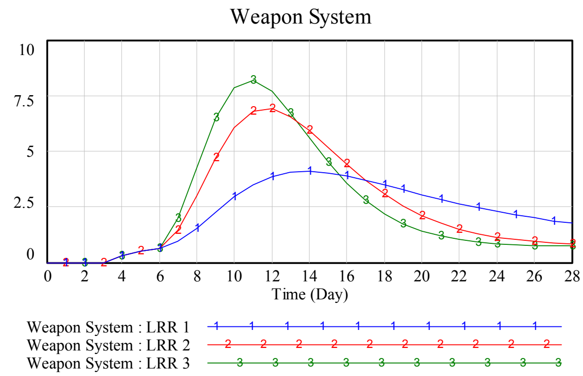
Graph 8: Number of Targets to be eliminated



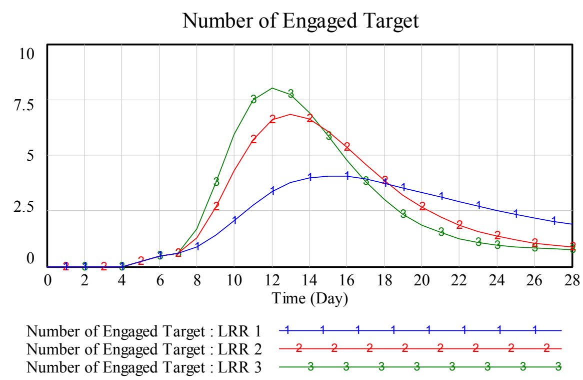
Graph 9: Command Sector



Graph 12: Total Number of Targets Destroyed



Graph 10: Weapon Systems in operation on the day

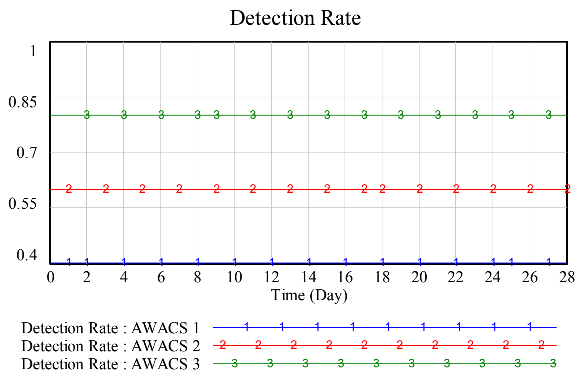


Graph 11: Number of Engaged Targets

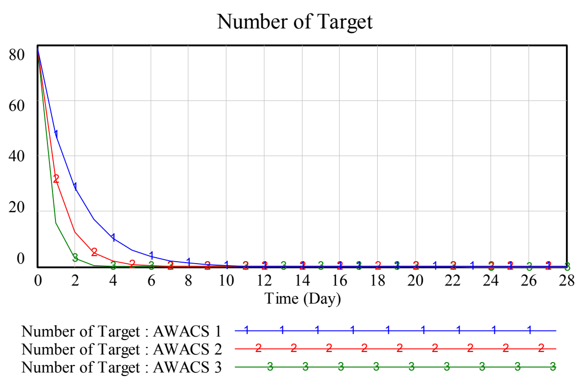
A second case started from graph 13 up to graph 24 is carried out for the AWACS system. The simulation and calculation procedures are identical to the case carried out for the LRR system, but the figures and the graph output are noticeable different.

In general, it is noticed that AWACS performance indices have a more significant spread than that of the LRR. AWACS performance can have a great variation in performance and are susceptible to various factors.

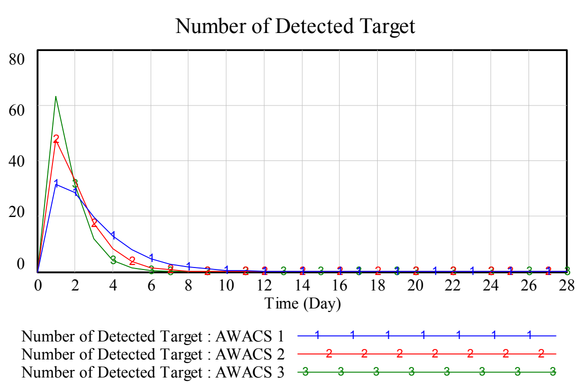
These factors however do not translate into vast variations in performance during the conflict. The graphs are very closely spaced, and for certain conditions even overlap. This is significant information when considering defence expenditure and investment. An increase in equipment capability should only be obtained if it translated into greater situational awareness and war-fighting capability. This is especially important when equipment upgrades and acquisitions are costly. To be cost effective, ideally a closely spaced graph on the performance index chart, i.e. graph 1 should translate into widely spaced graphs on the charts showing the number of engaged targets, target prioritisation and more importantly targets destroyed.



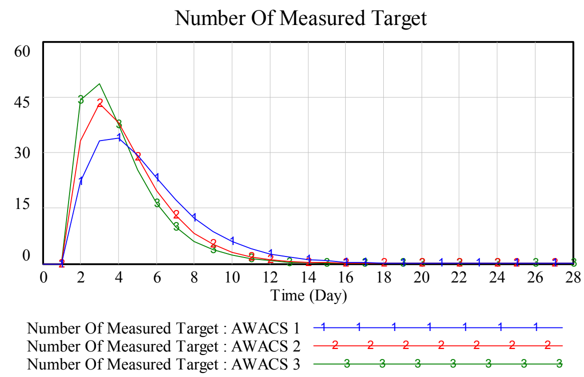
Graph 13: Detection Rate of the Sensors



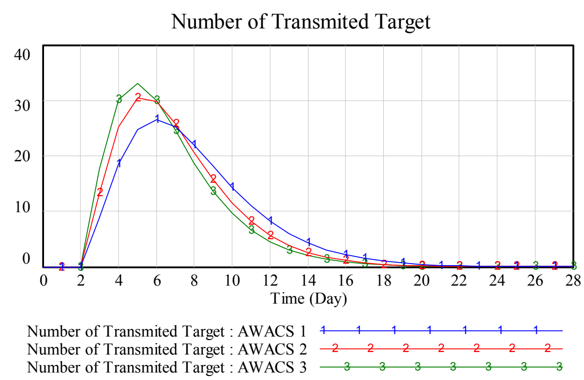
Graph 14: Number of Targets



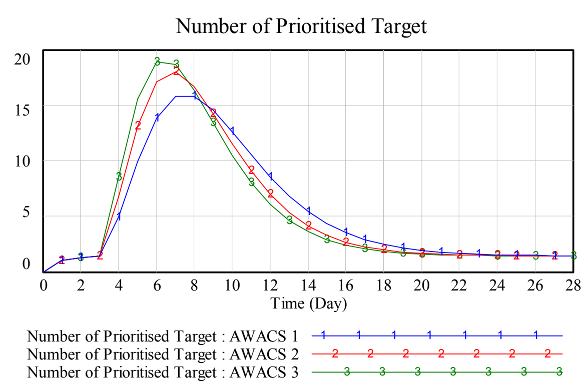
Graph 15: Number of Targets Detected each day



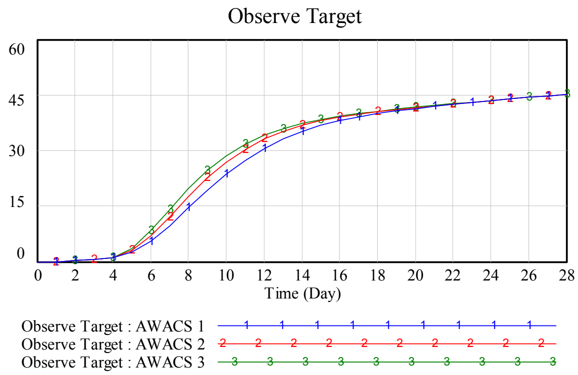
Graph 16: Number of Measured Targets



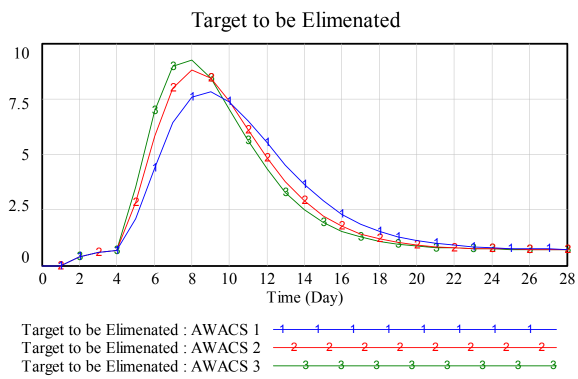
Graph 17: Number of Transmitted Targets



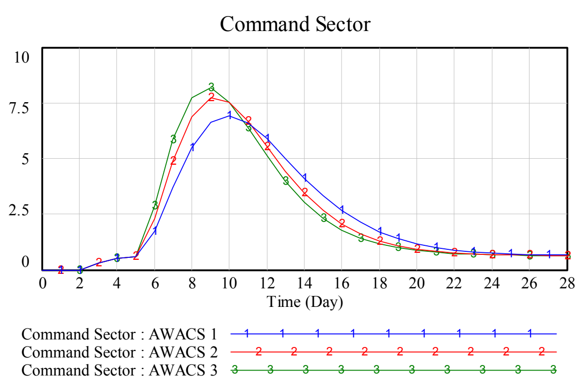
Graph 18: Total Number of Prioritised Targets



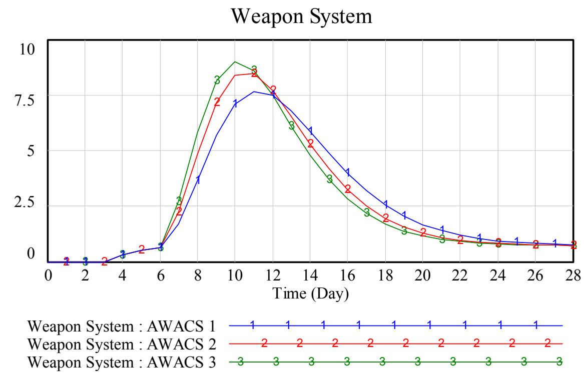
Graph 19: Number of Targets to be observed



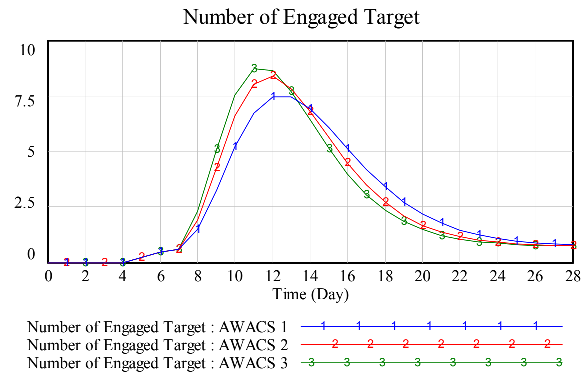
Graph 20: Number of Targets to be eliminated



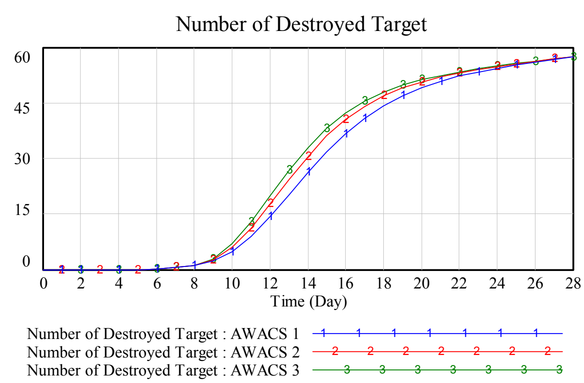
Graph 21: Command Sector



Graph 22: Weapon Systems in operation on the day



Graph 23: Number of Engaged Targets



Graph 24: Total Number of Targets Destroyed

The third case started from graph 25 up to graph 36 is carried out for the Satellite system. The simulation and calculation procedures are identical to the cases carried out for the LRR, AWACS systems, but the figures and the graph output are noticeable different.

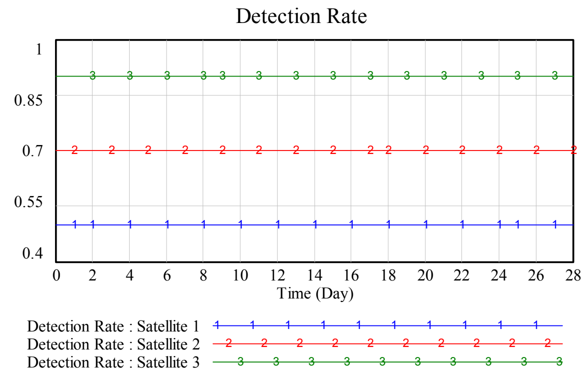
In general, it is noticed that satellite performance indices have a more significant spread than that of the LRR and AWACS. Satellite performance can have a great variation in performance and are susceptible to various factors.

The simulations begin by specifying a number of hostile targets. Depending on the options in place, the targets are detected and prioritised.

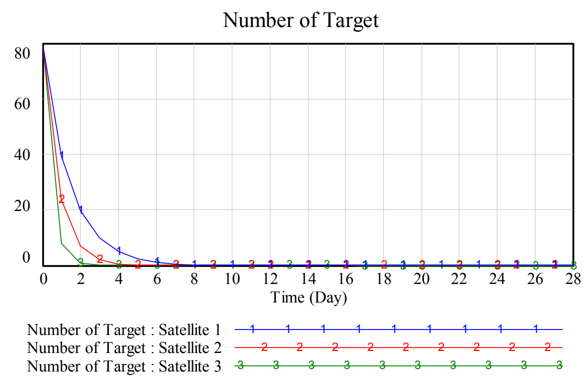
The effectiveness of JBD determines the threat assessment. This involves measuring target parameters, transmitting, and prioritizing them to command sector. Based on situational awareness provided by JBD, the targets can be choosing to be eliminated.

At the operational level, authorization of target engagement is shown. Eventual destruction is dependent upon the effectiveness of JBD this is because resources would be allocated based on the prior information provided by JBD. Hence, here the result of operational views input to JBD can be seen by the systems through simulation of the Vensim model.

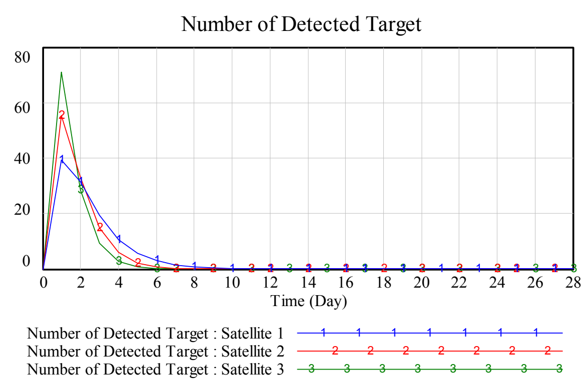
The graphs are very closely spaced, and for certain conditions even overlap. This is significant information when considering defence expenditure and investment. An increase in equipment capability should only be obtained if it translated into greater situational awareness and war-fighting capability. This is especially important when equipment upgrades and acquisitions are costly. To be cost effective, ideally a closely spaced graph on the performance index chart, i.e. graph 1 should translate into widely spaced graphs on the charts showing the number of engaged targets, target prioritisation and more importantly targets destroyed.



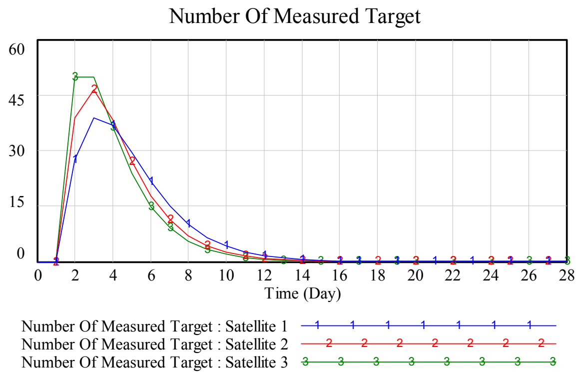
Graph 25: Detection Rate of the Sensors



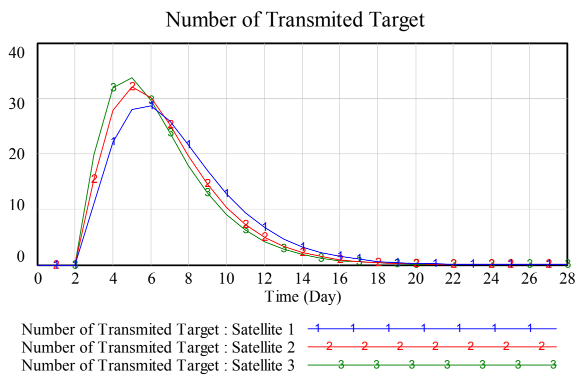
Graph 26: Number of Targets



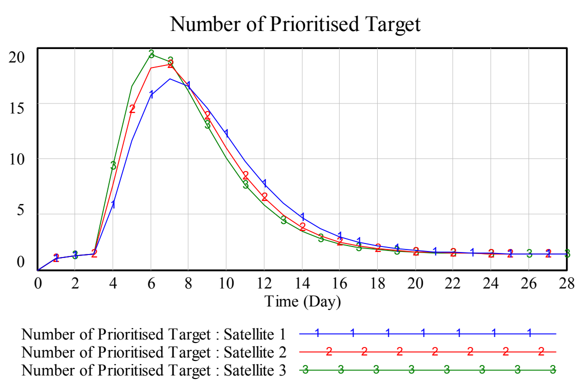
Graph 27: Number of Targets Detected each day



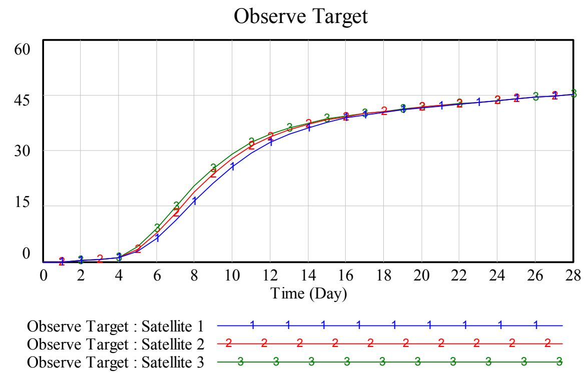
Graph 28: Number of Measured Targets



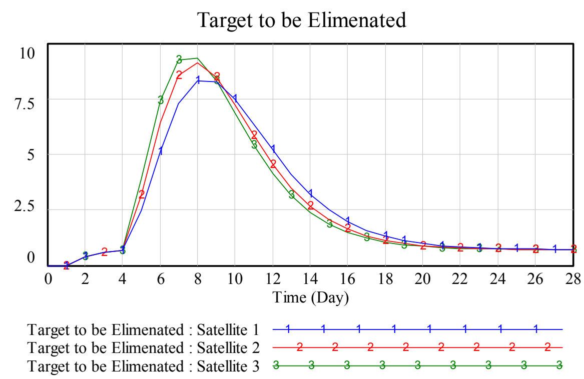
Graph 29: Number of Transmitted Targets



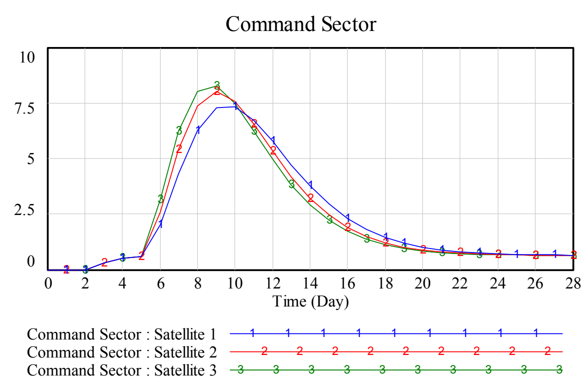
Graph 30: Total Number of Prioritised Targets



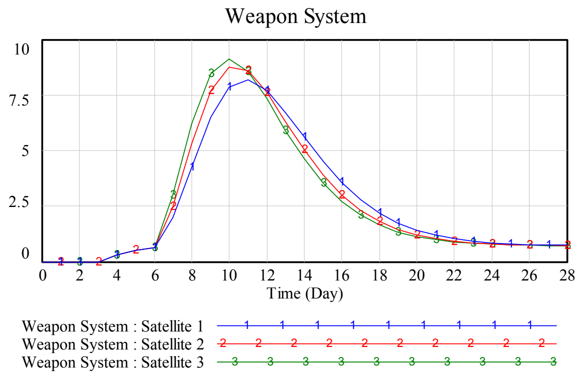
Graph 31: Number of Targets to be observed



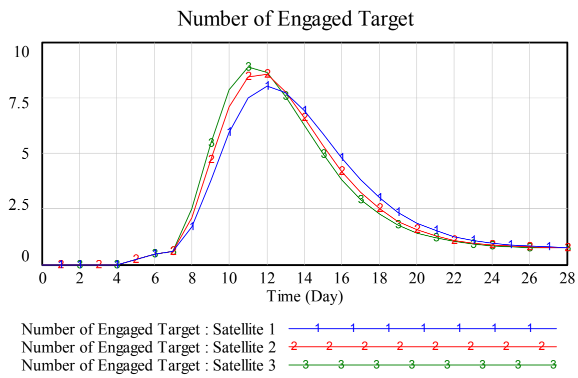
Graph 32: Number of Targets to be eliminated



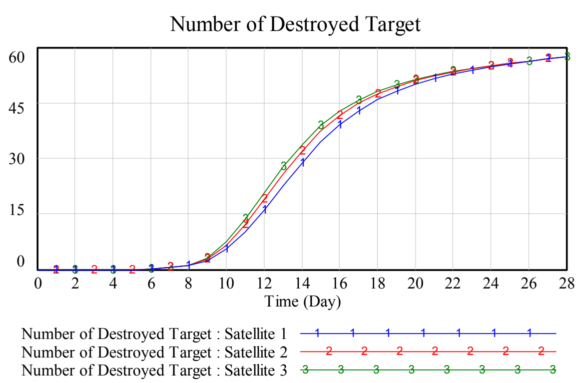
Graph 33: Command Sector



Graph 34: Weapon Systems in operation on the day



Graph 35: Number of Engaged Targets

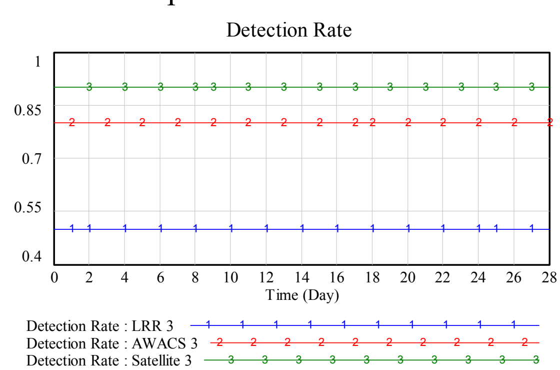


Graph 36: Total Number of Targets Destroyed

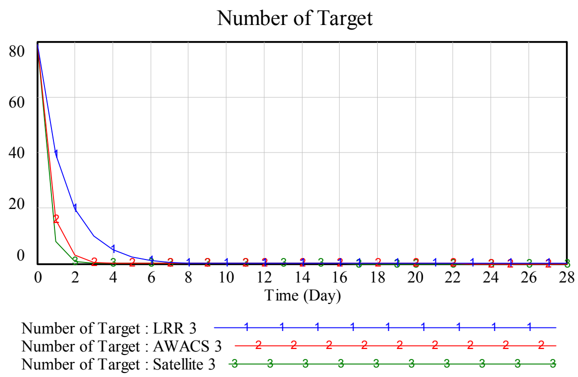
The next stage involves combining the assets to perform an integrated study. This involves the simultaneous study of all three assets under different performance indices to determine the outcome when simulated using the Vensim model. In these graphs from 37 up to 48, the highest performance indices of the assets are considered. The purpose of these simulations is to determine the effectiveness of assets competing for investment in improvement and upgrades.

A particular asset may have differing performance indices, but its effectiveness in the conflict, and indeed at different stages of the conflict may not be related to the simple indices. For example, the most obvious trend observed is that the satellite shows best performance, followed by the AWACS and then the LRR system. However, the novice reader may come to the false conclusion that LRR performance increases and supersedes the other two beyond 14 days of conflict. However, it must be emphasized that the scenario involves engaging an enemy, which has limits on its resources and combatants. Hence the greater effectiveness of the other two assets have ensured that most of the hostile targets have been destroyed in the opening days of the encounter, thereby demonstrating a very sharp drop in number of hostile targets in the beginning. The LRR however demonstrates a very gradual and long drawn out engagement, which translates into a longer time to overcome the hostile party.

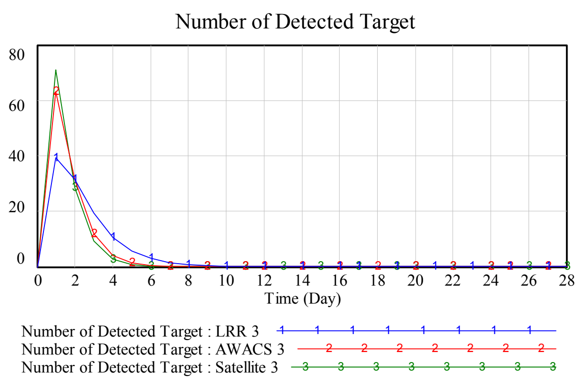
The previous cases examined the effectiveness of the assets in the digital battlespace in relation to the cost investment. The following case compare and contrast the same factors between assets. Only the results for the case combining LRR3, AWACS3, and satellite 3 are presented here.



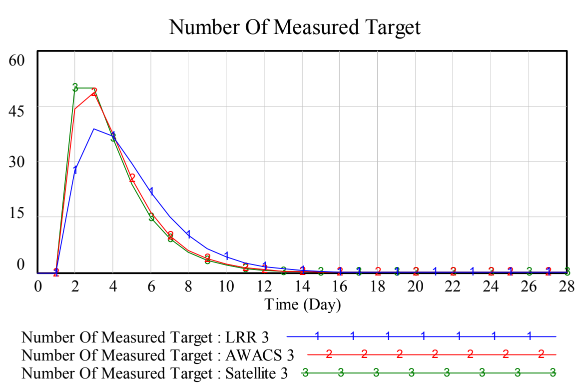
Graph 37: Detection Rate of the Sensors



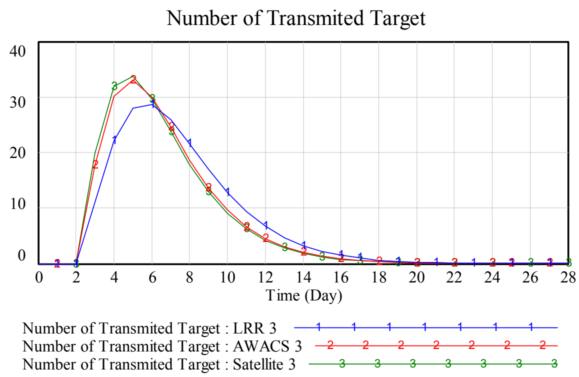
Graph 38: Number of Targets



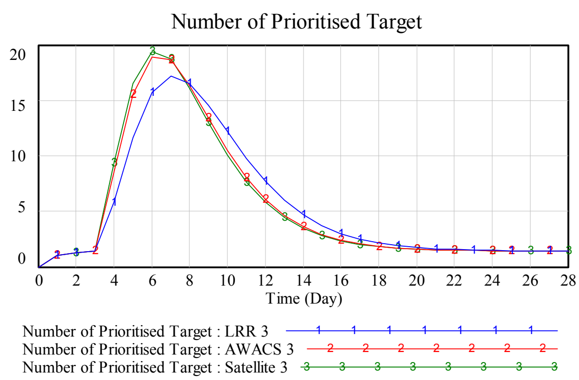
Graph 39: Number of Targets Detected each day



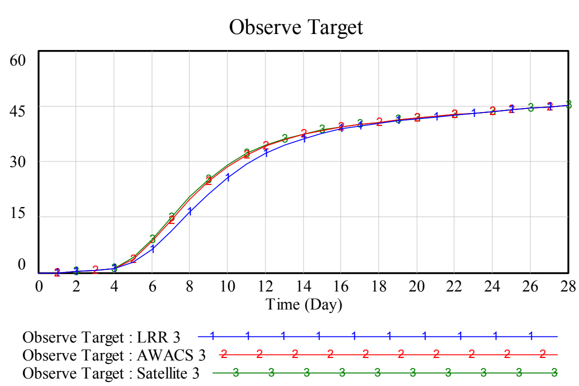
Graph 40: Number of Measured Targets



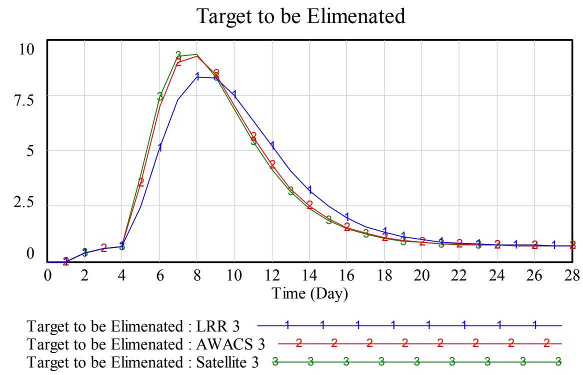
Graph 41: Number of Transmitted Targets



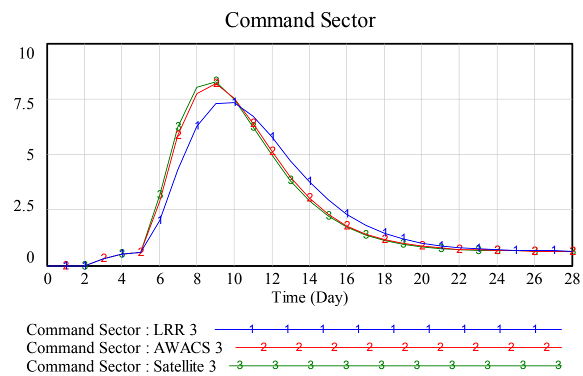
Graph 42: Total Number of Prioritised Targets



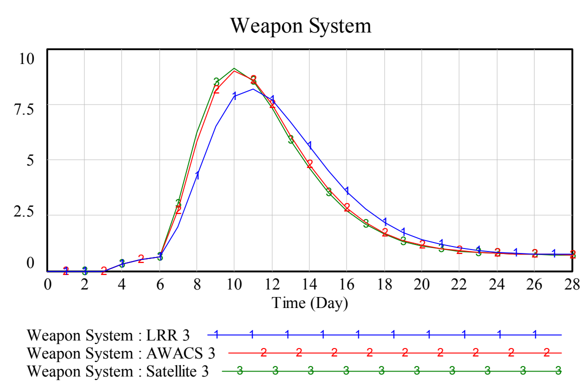
Graph 43: Number of Targets to be observed



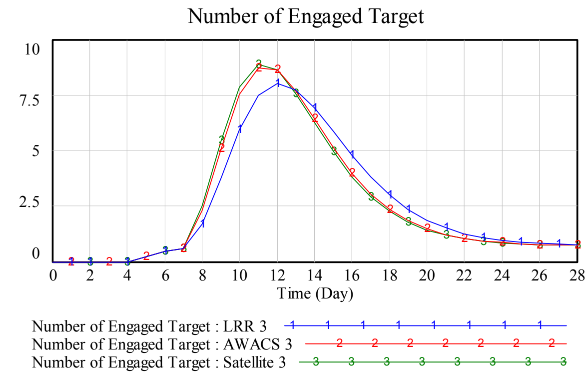
Graph 44: Number of Targets to be eliminated



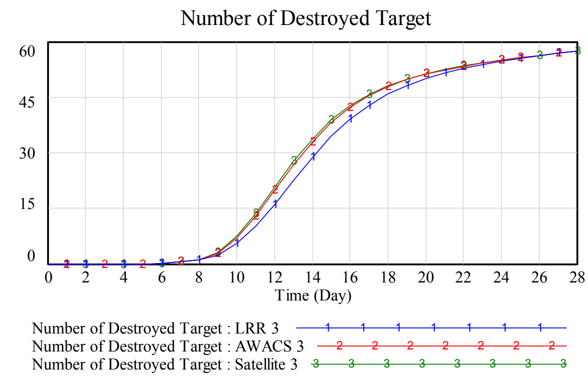
Graph 45: Command Sector



Graph 46: Weapon Systems in operation on the day



Graph 47: Number of Engaged Targets



Graph 48: Total Number of Targets Destroyed

This case is significant for two reasons. Firstly, it demonstrates the best performance of all three assets. In terms of the indices, there is a variation of 0.4 between the best and worst performance asset.

The second, and more significant point to note is the close bunch of all three graphs. This shows that the individual agents when showing their performance vary little. This is significant for the following reason. To achieve the maximum capability for each asset requires varying degrees of investment. For example, it might take one, extremely expensive satellite to achieve the required performance level. However, it might take two groups of a certain number of AWACS on two or more shifts to achieve a similar level of performance index. This information, when passed through the whole simulation and analysis system, is an important aid in resource planning activities.

Conclusion

The first key tool is STT. This tool enables the identification of requirement for JBD and to assess potential options. The methodology utilized will be subsequently explained. The second tool is Vensim, which enables the analysis of factors, which contribute to mission effectiveness and investigate the importance of these factors. It links the operational and system views. In addition, it also links the system and technical views and analyses specific technical parameters, and validates the assessment carried out by STT.

STT describe the link from strategic military task to the equipment bought and the system dynamic (Vensim) to describe the System of Systems (SoS) links at the programmatic level. Having a STT will underpin the JBD providing the consistency of approach to architectural modeling and provide a good means for change management of the architecture framework. STT identifies the gaps in system available to meet operational needs. The system dynamic model is to monitor the effects of programmatic changes to a system on the overall SoS. Hence, if a particular system got delayed, we know the impact on the performance, time and cost of other systems, which aids decision-making.

The analysis to date has indicated the benefits of different options for LRR, AWACS, and satellite systems and also possible combinations. The best combination according to the analysis is the last case described in this paper.

Acknowledgment

The author would like to acknowledge Mr Jeremy Smith the Head of Future Combat Systems Group within Engineering Systems Department at Cranfield Shrivenham.for his help in the preparation of the paper.

References

[1] G. Kent, *A Framework for Defense Planning*, RAND Corporation Report No R-3721-AF/OSD, August 1989.

[2] Michael R. Bathe and Jeremy D. Smith, *A Description of The Strategy to Task Technique and Example Applications,* Journal of Battlefield Technology, Vol 5 No 1, March 2002.

Biography

Naif Al-Duwaish was born in 1970. He received the BSs degree in Aero Science (with honors) in 1991 and MSc degree in Systems Engineering from Cranfield University in 2000. Since 1991 he serves in the Royal Saudi Air Force. He is currently working towards the PhD degree in Systems Engineering at Cranfield University, his current research interests in the Impact of Joint Battlespace Digitisation.

Professor Phil John is the Director of Cranfield University's Centre for Systems Engineering. Following his PhD at Imperial College, London he held a wide range of systems engineering and management roles, including Head of Systems Engineering for a major multinational company. He joined Cranfield University in 1999 as the Professor of Systems Engineering and leads the very active Centre for Systems Engineering. He is a member of several national bodies, including two National Advisory Committees. He was President of the UK Chapter of the International Council on Systems Engineering in 2003-04.

10th International Command & Contro
Research and Technology Symposium

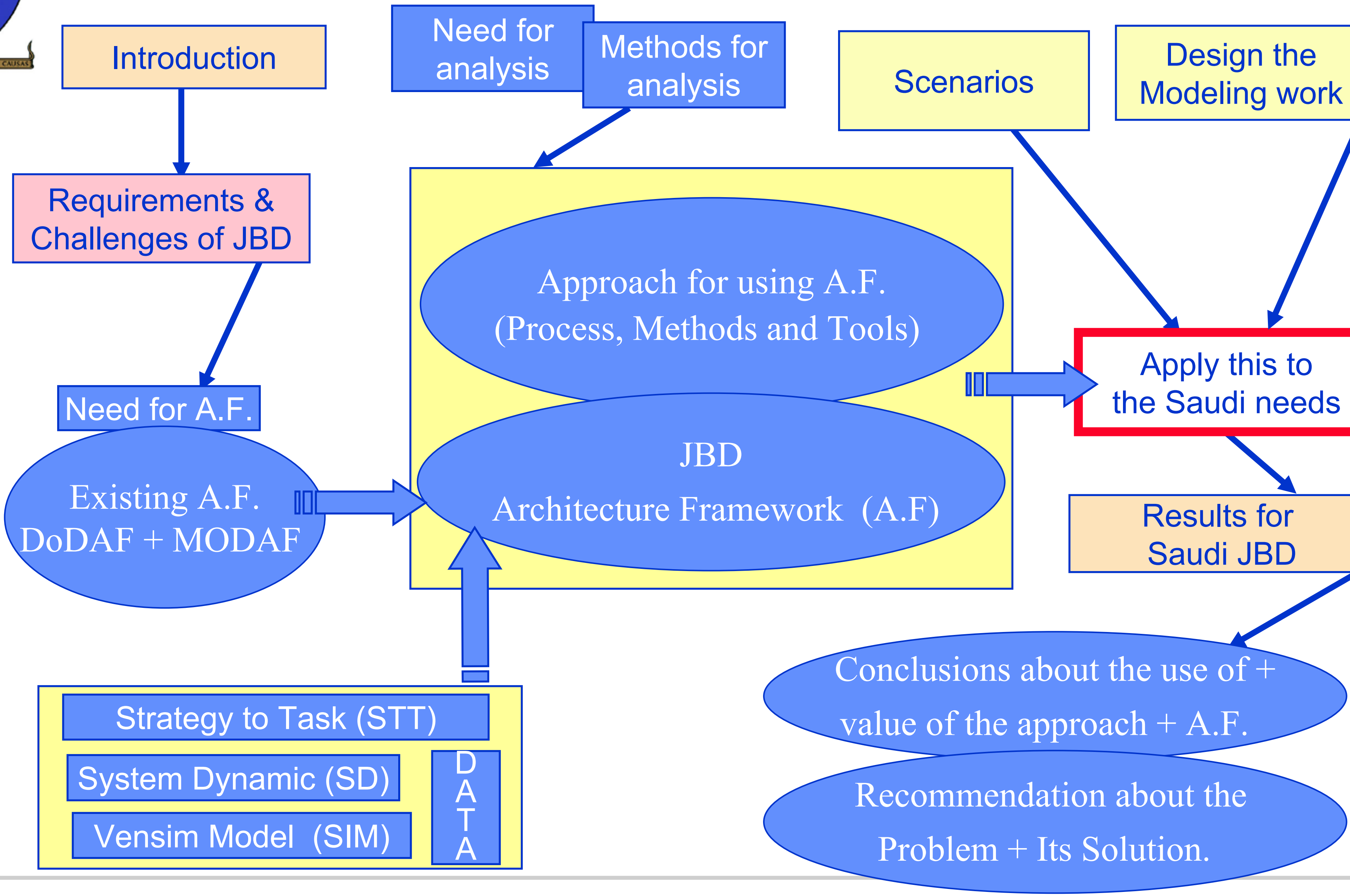
June 13 – 16, 2005
The Ritz-Carlton, McLean, Virginia

Naif M. Al-Duwaish

Engineering Systems Department
Cranfield University, Shrivenham, UK

Using Assessment Methods & Tools to Understand Joint Battle space Digitisation (JBD)

Scope of the Work



Introduction

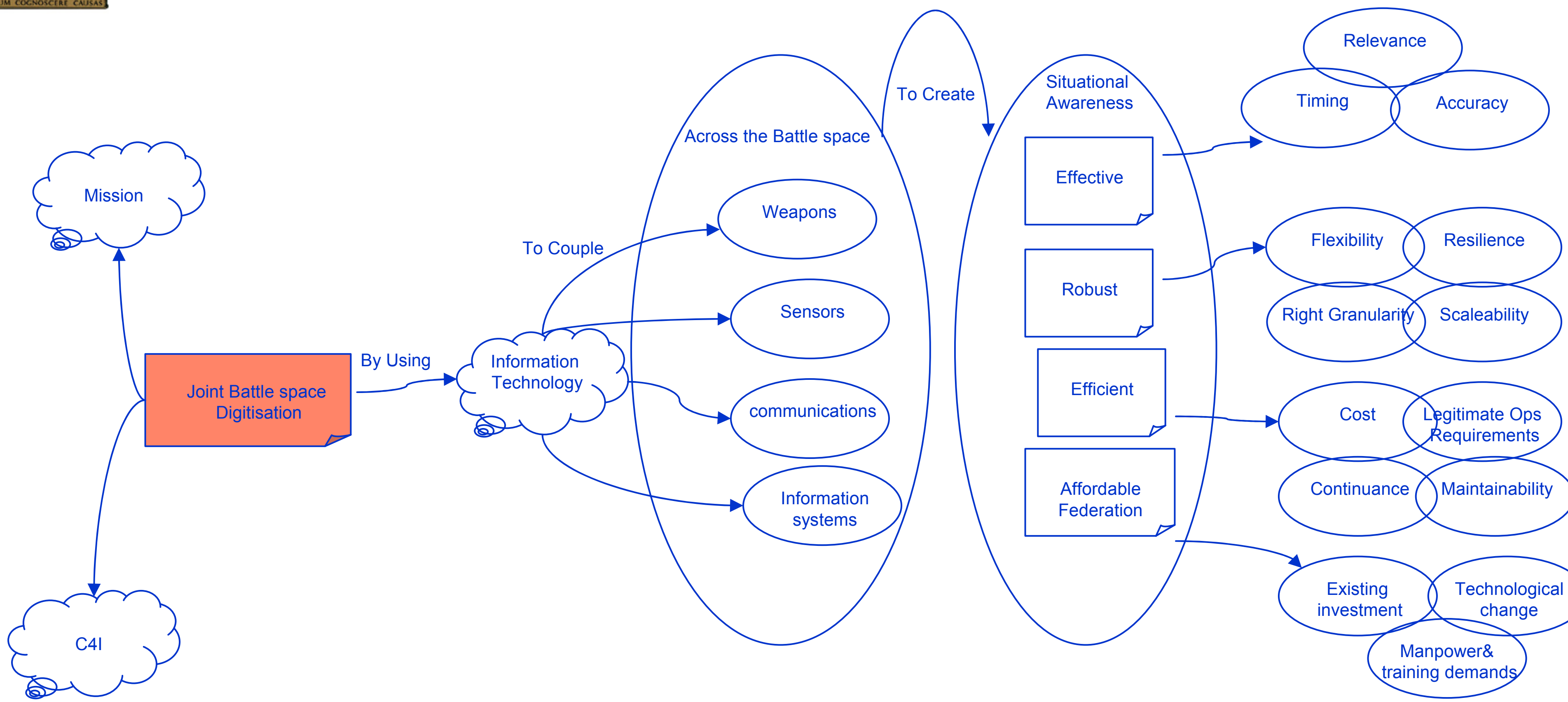
The system is increasing the complex and there is not a comprehensive methodology to aid the systems engineering or even the end user to analyse its characteristics.

Quick movement of land, sea and air forces are necessary in battle timely communication and processing of this information, and ensuring its availability to all level of decision making authorities plays a decisive role in success.

There are several methods being developed that are potentially useful for analyzing Joint Battlespace Digitisation (JBD) but they are not adequate to cope with complexity and emergent behavior of different level of complex systems

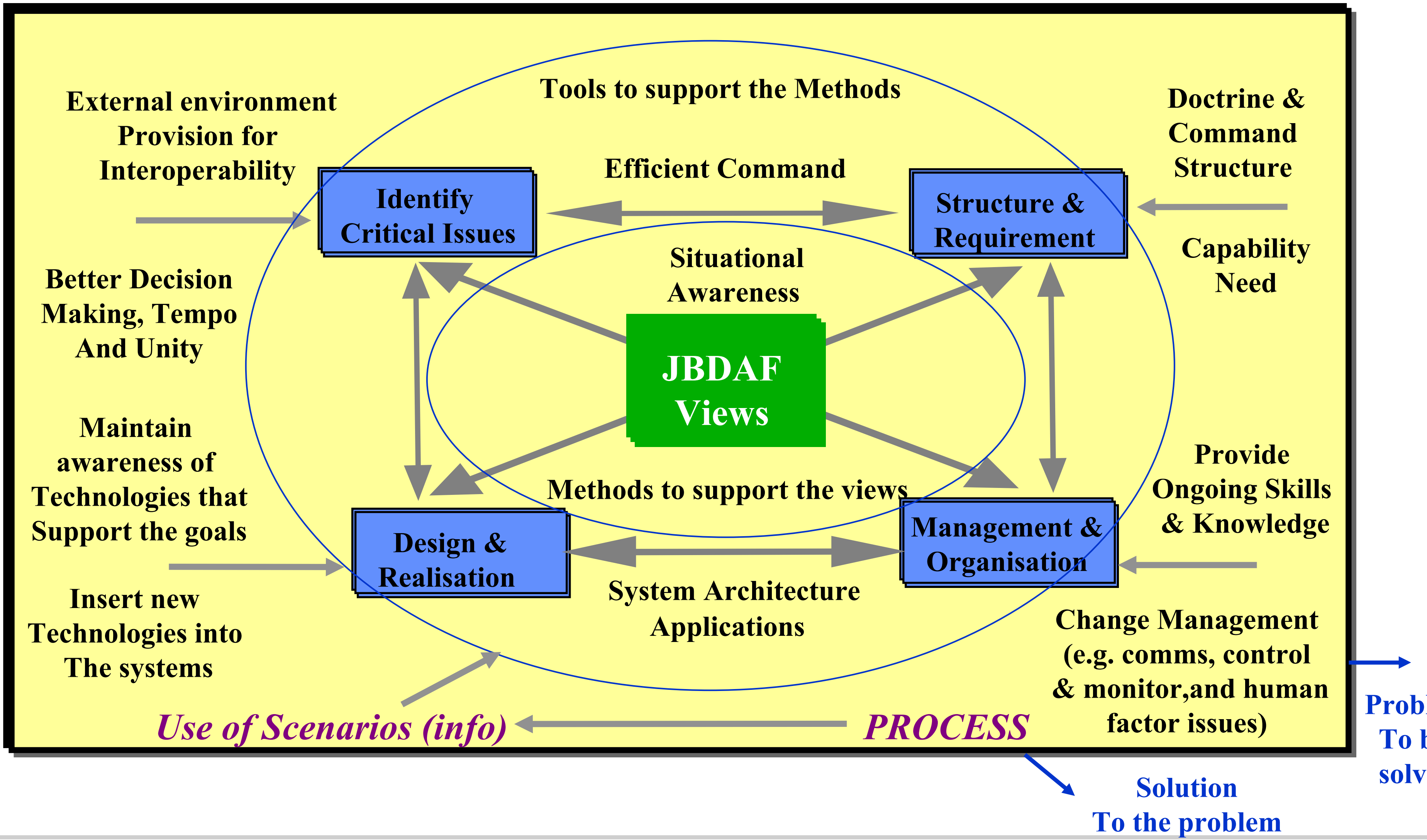
JBD Aim

The Joint Battlespace Digitisation (JBD) programme **aims** to enhance the operational effectiveness of Saudi Arabia forces in Joint and Combined operations by using modern information technology to couple weapons, sensors, communications and information systems (CIS) across the battlespace and thus to create an effective, robust, efficient and affordable federation of systems.

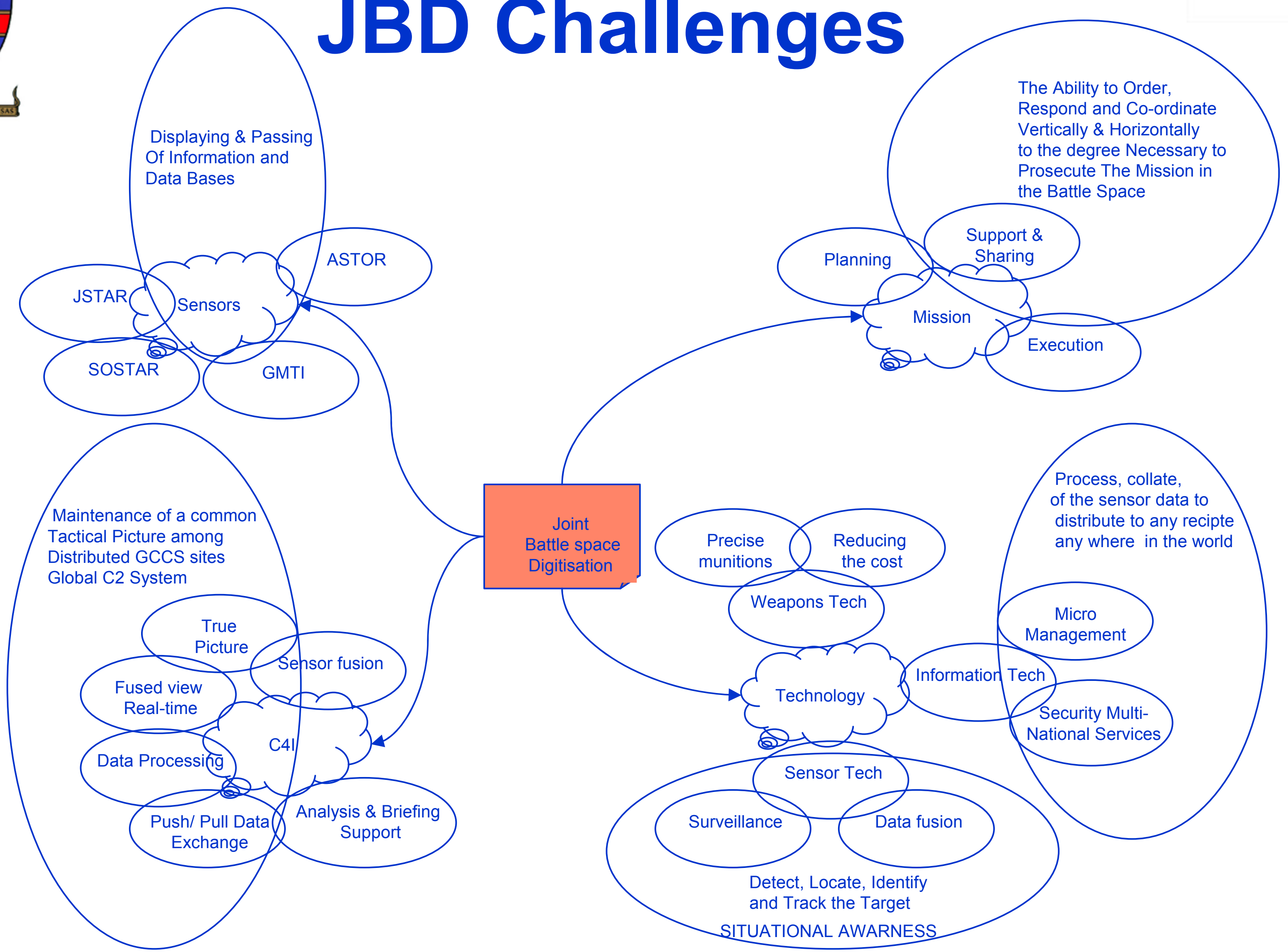

Mission
C4I
Joint Battle space Digitisation
By Using
Information Technology
To Couple
Across the Battle space
Weapons
Sensors
communications
Information systems
To Create
Situational Awareness
Effective
Robust
Efficient
Affordable Federation
Relevance
Timing
Accuracy
Flexibility
Resilience
Right Granularity
Scaleability
Cost
Legitimate Ops Requirements
Continuance
Maintainability
Existing investment
Technological change
Manpower& training demands

Cranfield UNIVERSITY

JBD Architecture Framework Process



JBD Challenges



Provision for Interoperability

– ensure compatibility of systems, processes or procedures.

Command micro-management

– deal with reduced command delegation, increased command chain and destruction from the overall picture/objectives.

Information reliance

– guard against reduced confidence/ reluctance in decision making missed point of opportunities due to required levels of information completeness.

Command Structure

– must be compatible with the information flow requirements and decision hierarchy (it must facilitate & support the same).

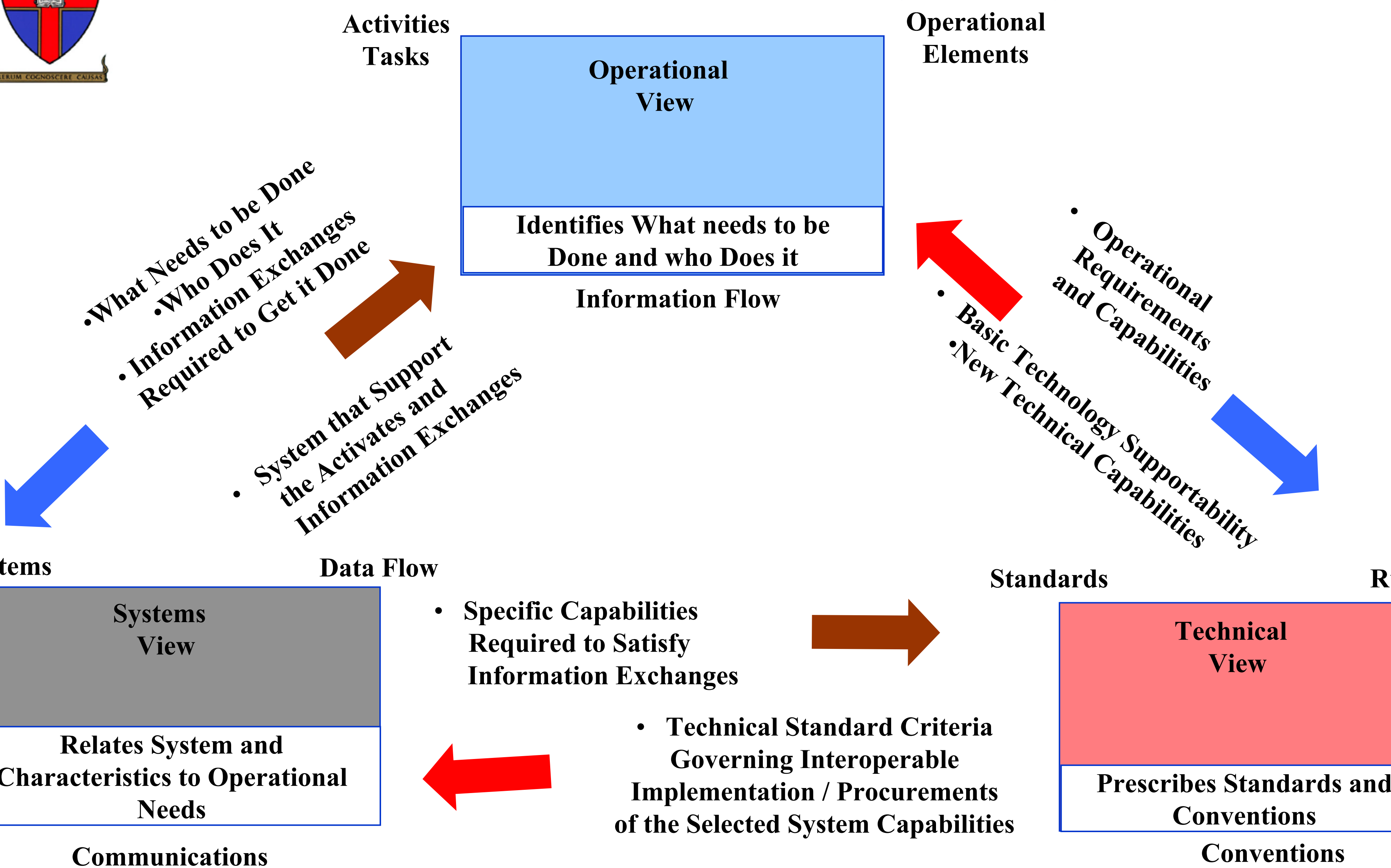
Recruitment & Training

– must personnel are matched with skills required (it must provide development & maintenance of the same).

Reduced Manning

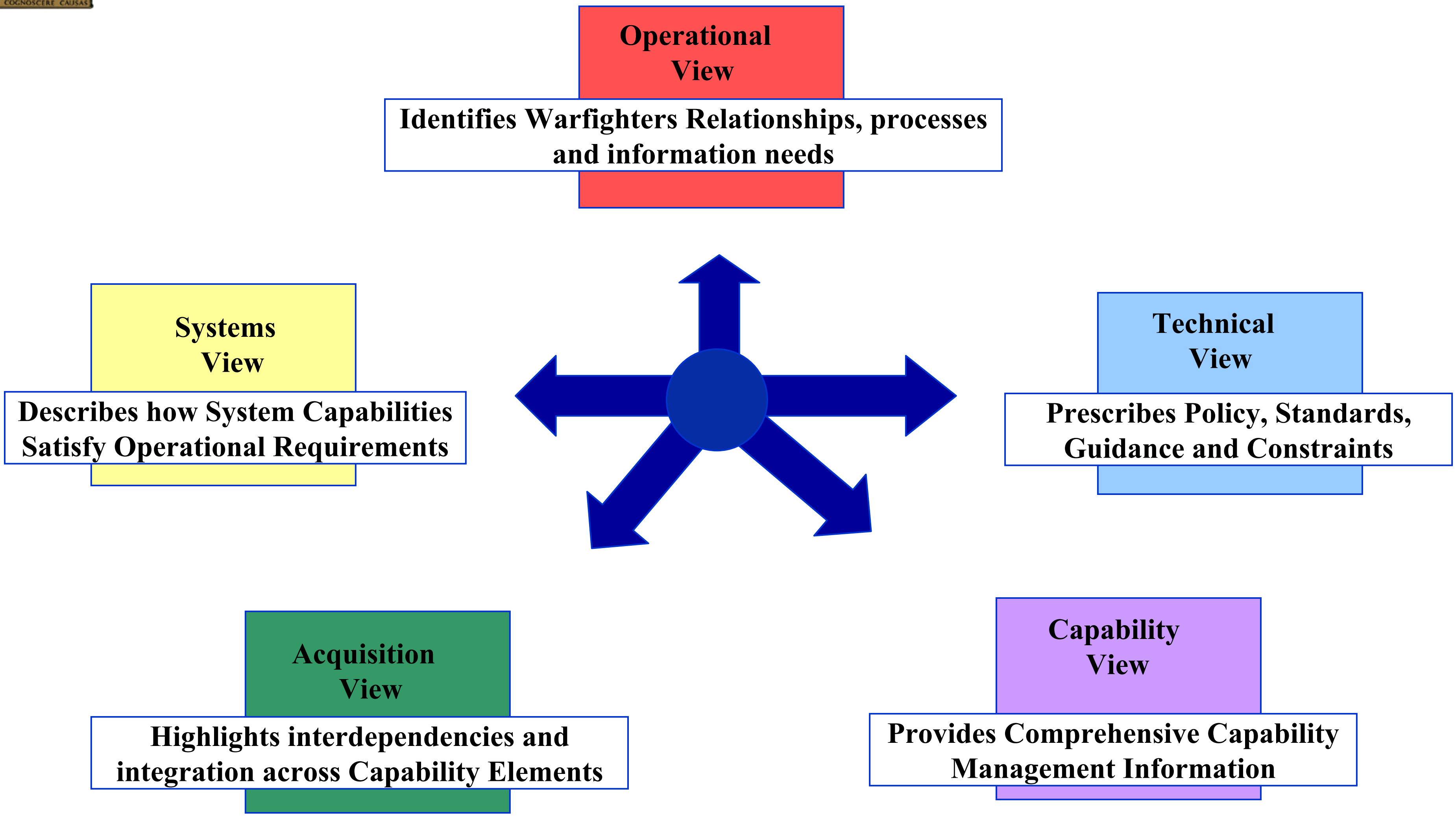
– deal with insufficient manpower for reversionary modes of operation.

DoD Architecture Framework (DoDAF)



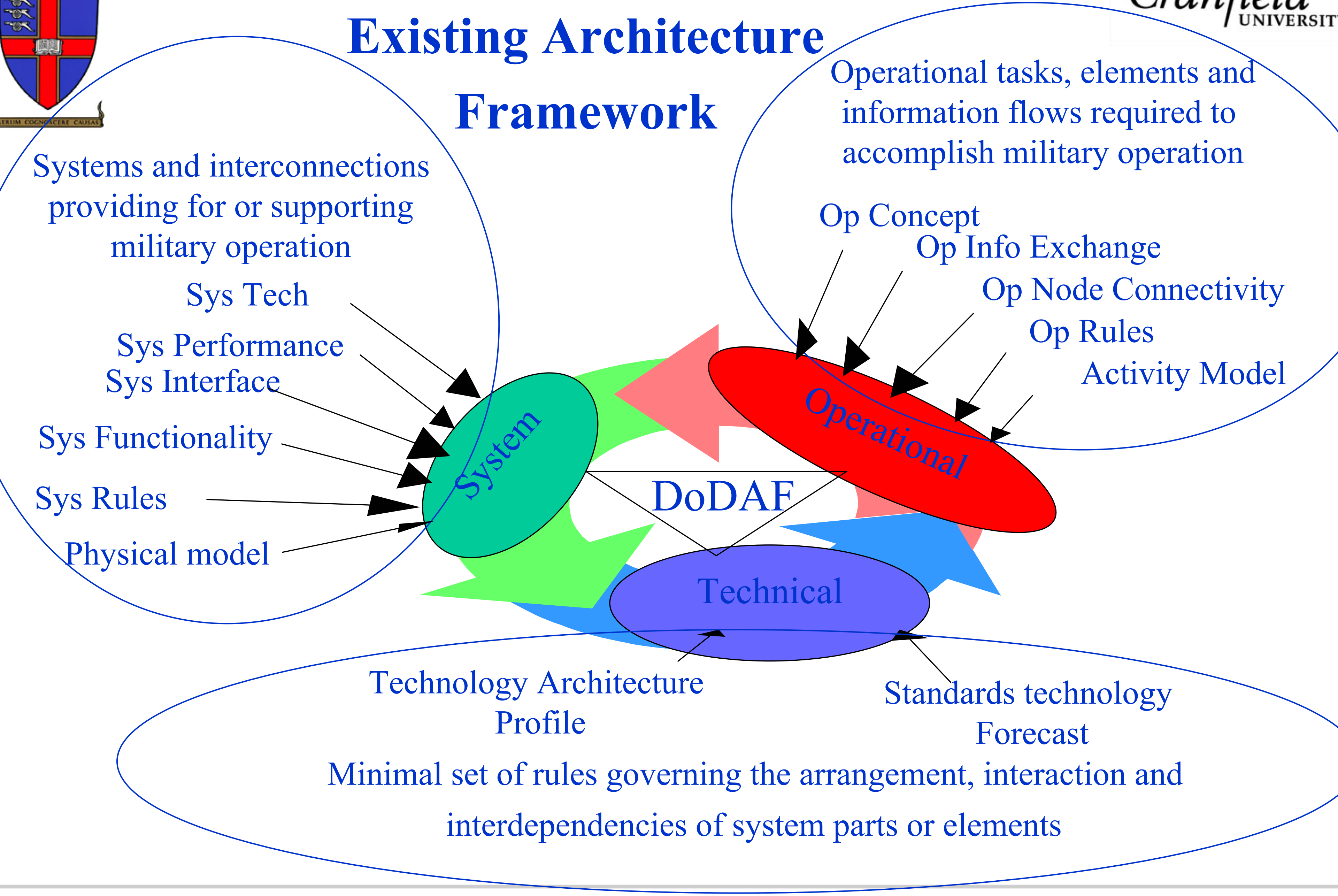
SOURCE: DoDAF- Overview Dr. Fatma Dandashi Oct 2003

MOD Architecture Framework (MODAF)

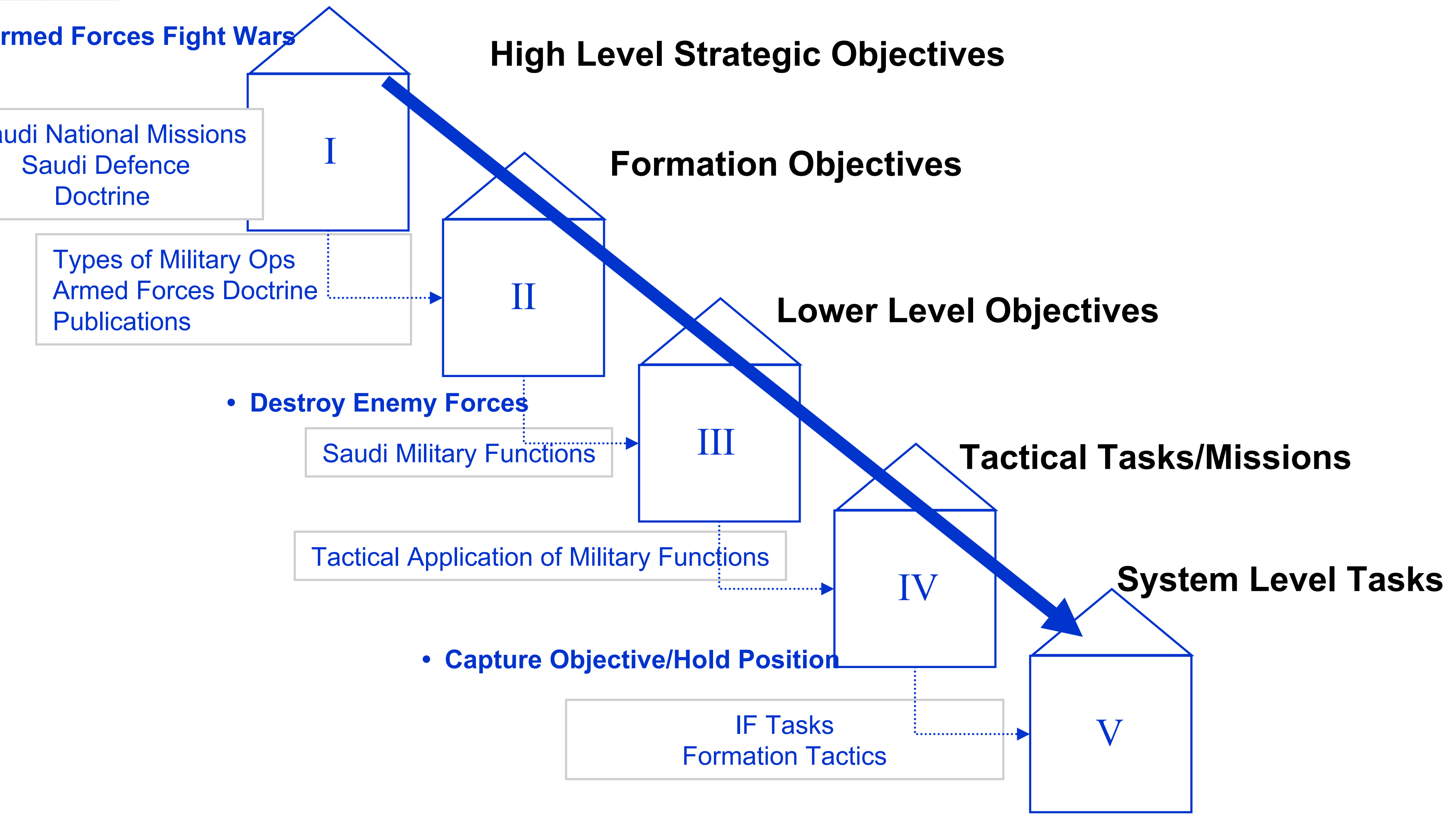


SOURCE: MODAF-M03-001, Draft 0.3 27 Sep 2004

Existing Architecture Framework



The STT structured cascading mechanism



The STT structured cascading mechanism

- **The process, starts from expressions of high-level requirements and cascades through several structured layers to arrive at the lower-level tasks.**

- **Each box is a Quality Function Deployment (QFD) matrix where a set of requirements is mapped against a set of responses generated from reviews of the source material.**

Cranfield UNIVERSITY

STT at Strategy level

Very Important Contributor:	9
Important Contributor:	3
High Contributor:	1
Low or Not a Contributor:	

Source Saudi Doctorine and **JETL** **Grand Strategic Level Tasks**

Responses from Saudi Doctrine

Saudi Defence Missions	Initial Weight	Information Superiority	Interoperability	Dominant Maneuver	Precision Engagement	Focused Logistics	Full Dimension Protection	Joint Command & Control		
Peacetime Security	0.14286	9	3	1			3	1		
Defence Diplomacy	0.14286	1	1				1	1		
Support to Wider Saudi Interests	0.14286	1	1	3	1	1	1	1		
Peace Support	0.14286	1	3	3	1	1	3	3		
Regional Conflict outside GCC	0.14286	3	3	3	3	9	3	9		
Regional Conflict Inside GCC	0.14286	3	3	9	3	9	3	9		
Strategic Attack on GCC	0.14286	3	9	9	3	9	9	9		
Raw Technical Importance		3.0	3.3	4.0	1.6	4.1	3.3	4.7	24.0	Sum of Raw Technical Importance
Normalized Technical Importance		0.1250	0.1369	0.1667	0.0655	0.1726	0.1369	0.1964	1.0000	
Sum of Initial Weights	1.0000									

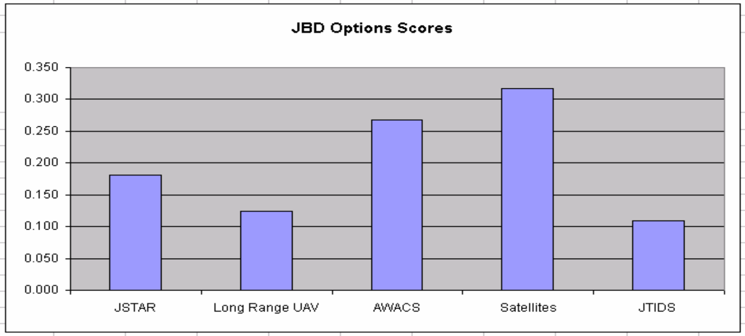
STT with different Sub-Systems options

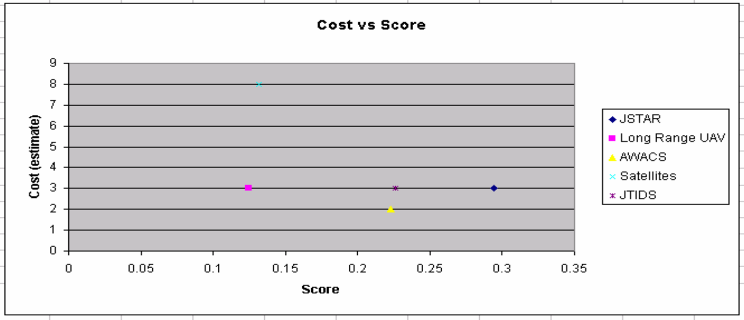
Very Important Contributor:	9	Directly equatable in the text
Important Contributor:	3	Mentioned in the text body
High Contributor:	1	Mentioned in the Sidebar Concepts/Enablers/Technologies (only)
Low or Not a Contributor:		Not mentioned at all

Percent Filled #DIV/0!

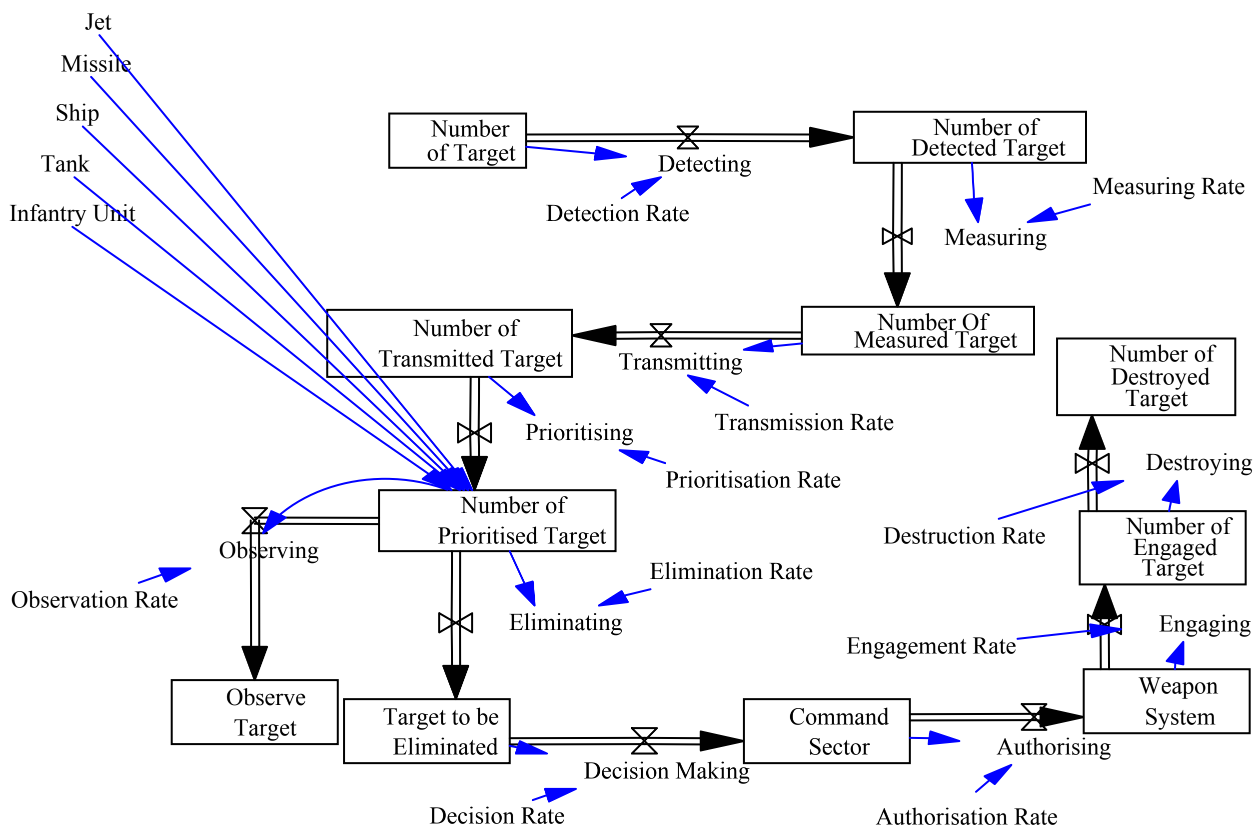
WHATS - OPERATIONS ADP Vol1 — JBD Options

LEVEL 1: *Strategy-to-Task Analysis*	Initial Weight	JSTAR	Long Range UAV	AWACS	Satellites	JTIDS
Situational Awarness	0.0481	3	3	9	9	3
Own Force Location	0.0305	3	3	3	3	1
Enemy Force Location	0.0337	3	1	3	3	1
Force Protection	0.0337	1	1	9	3	
Interdiction of Enemy's Forces	0.0318	3	3	3	3	3
Blockade	0.0102	3		3		
Containment	0.0160			1	1	
Exclusion Zones	0.0072	3	3	3	3	3
Barrier Operations	0.0160		3			
Layered Defence	0.0160	1	1	1	1	1
Enemy Force Intent	0.0115		1	3	9	
Strategic Air Lift	0.0195	1		3	3	
Tactical Air Lift	0.0265	1				1
Sea Lift	0.0217					
Strategic Nuclear Deterrence	0.0265			3	9	
Presence	0.0158	1	1	3	3	1
Sympolic Use	0.0195	3	3	3	3	3
Coercion	0.0166					
NonCombattant Evacuation Operations	0.0366	1	1	1	1	1
Combat Operations vs Land	0.0324	9	3		3	
Combat Operations vs Air	0.0310			9	3	1
Combat operations vs Navy	0.0160	1	1	3	3	
Combat Operations vs National Guard	0.0160	3		3	3	3
Amphibious Operations	0.0299	1	1	1	3	1
Support to Joint Operations	0.0337	9	3	9	9	3
Strategic Air Offensive	0.0299	1	1	9	9	3
Counter Air	0.0299		1	9	3	1
AntiSurface Force Land	0.0543	3	3	1	3	1
AntiSurface Force Navy	0.0516	3	1	1	3	3
Land Target Attack	0.0217	3	1		3	1
Fire Support	0.0559	1	1		3	1
Intelligence Gathering	0.0238	3	3	3	9	3
Area Surveillance	0.0307	3	3	3	3	
Comms Provision	0.0086			3	9	3
Logistic Support Provision	0.0086				1	
Protection of Joint Forces	0.0134	1	1	1	3	1
Economic Sanctions	0.0193					
Disaster Relief	0.0134				3	
SAR	0.0104					
Amphibious Forces	0.0064	1	1	1	3	1
Real-time Target Data	0.0064	1	1	3	9	1
Peace Ops	0.0064	1	1	1	3	1
Raw Technical Importance		2.0	1.4	3.0	3.6	1.2
Percent Technical Importance		0.182	0.124	0.268	0.318	0.109
Sum of Initial Weights	0.9872					
Cost (Relative estimate)		3	3	2	8	3
Risk (relative estimate)		2	3	4	5	1
		0.294	0.125	0.2231	0.1318	0.2262
		JSTAR	Long Range UAV	AWACS	Satellites	JTIDS



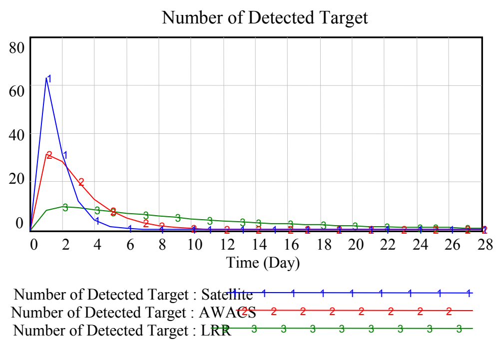


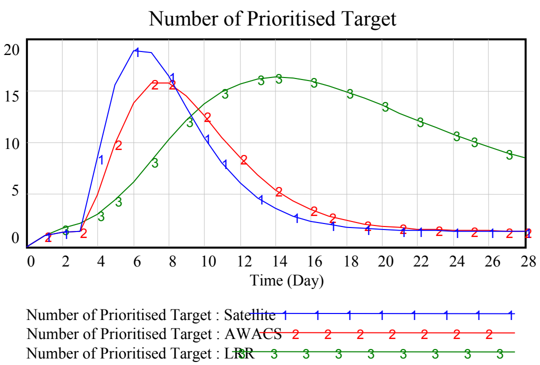
System Dynamic (Vensim Model)



Results from the Vensim Model

The Vensim model simulates a scenario of possible escalation of conflict It attempts to incorporate all options in an escalating scenario that spans 28 days.

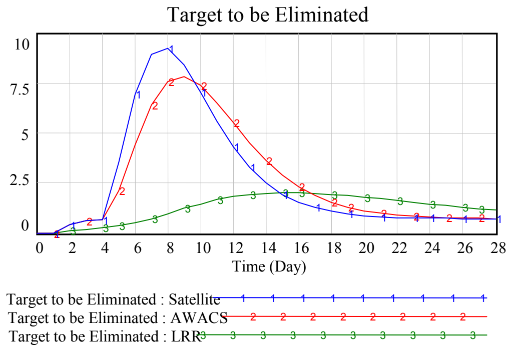


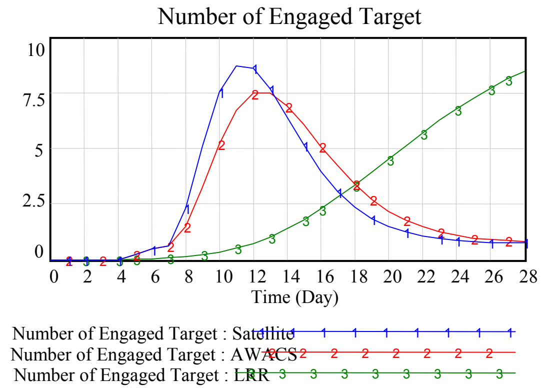


The simulations begin by specifying a number of hostile targets. Depending on the options in place, the targets are detected and prioritised as shown in graphs

Results from the Vensim Model (2)

The effectiveness of JBD determines the threat assessment. This involves measuring target parameters, transmitting, and prioritizing them to command sector.



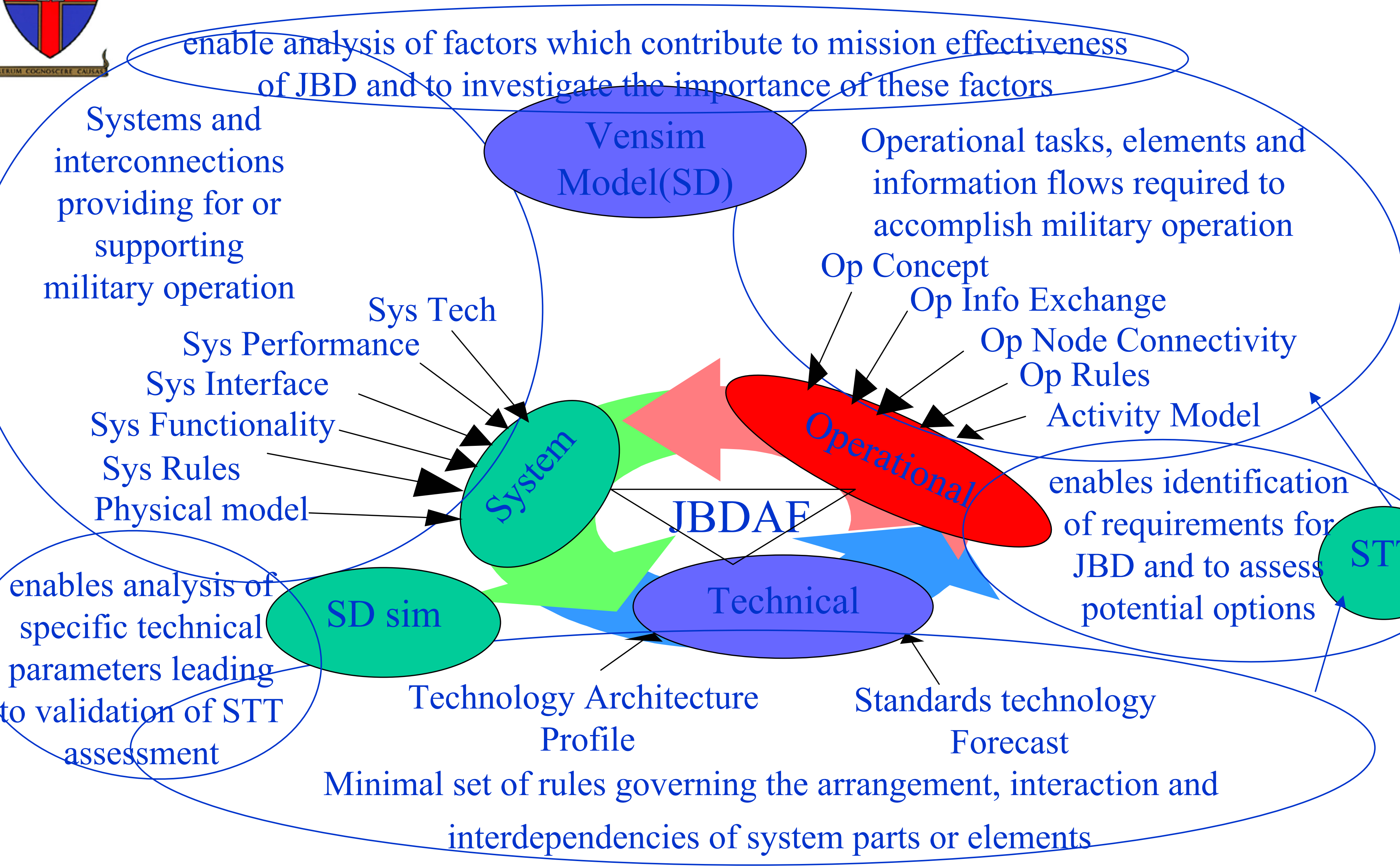


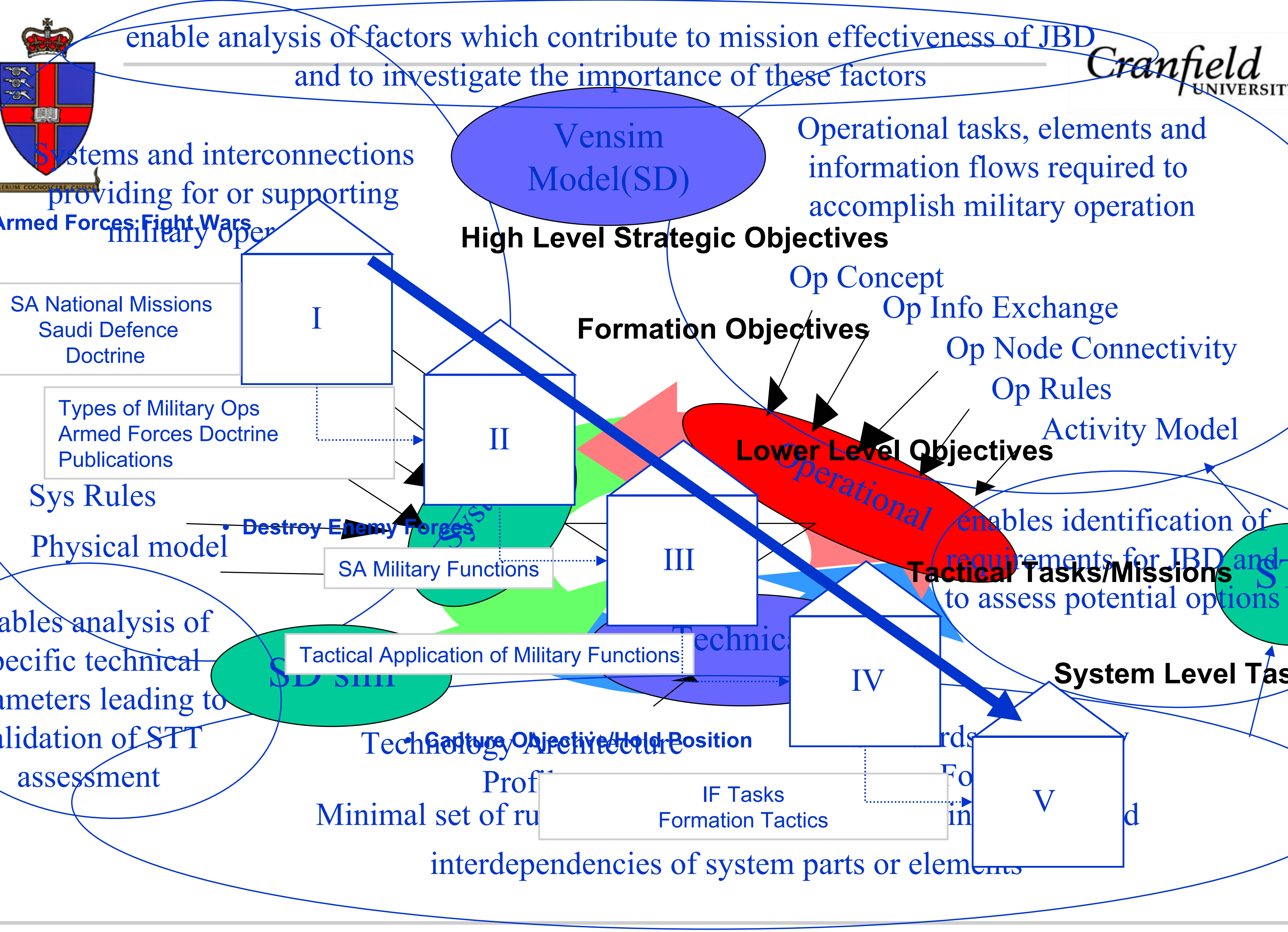
The targets can be chosen to be eliminated, at the operational level, authorization of target engagement as shown in Graphs. Eventual destruction is dependent upon the effectiveness of JBD

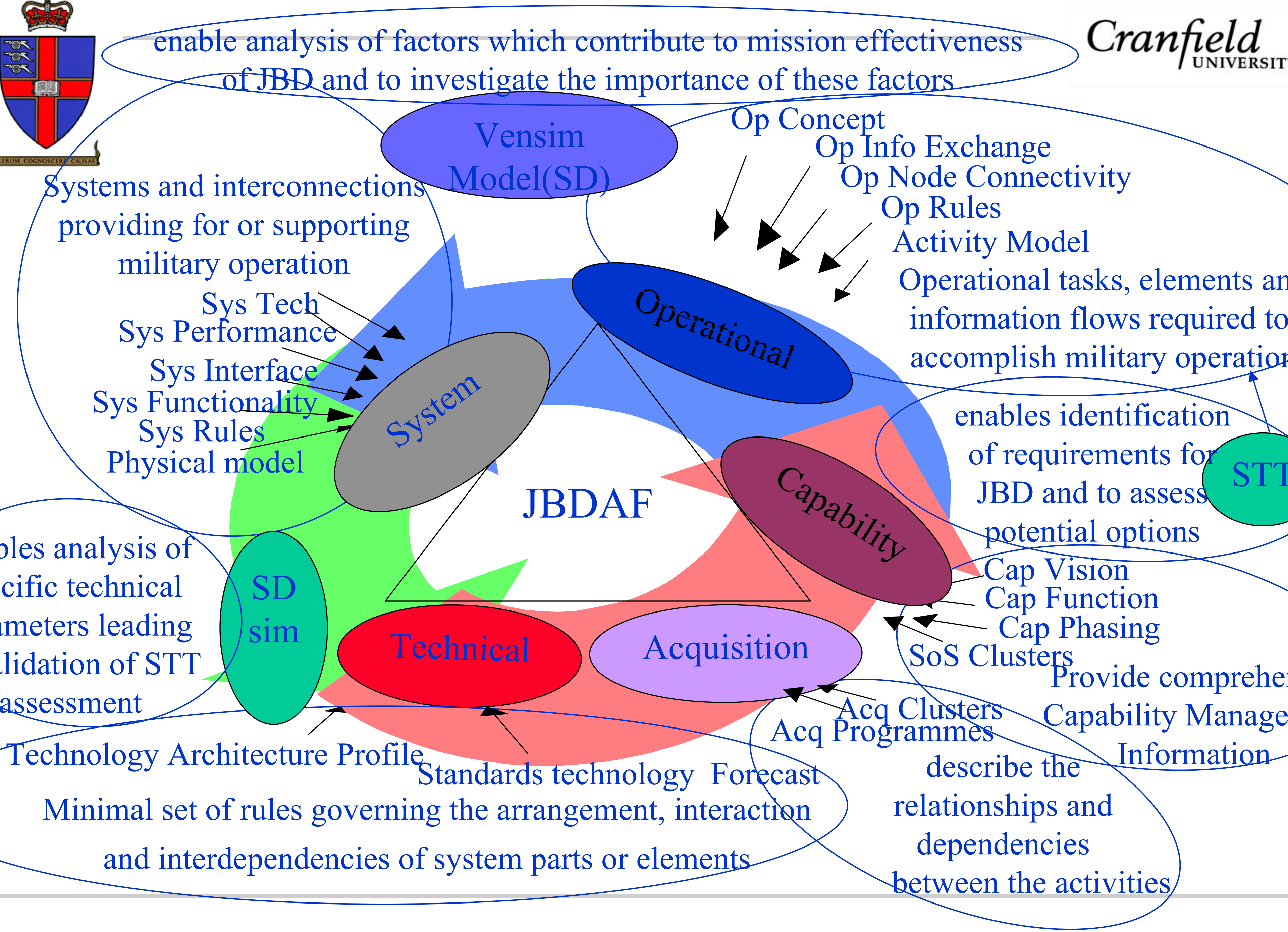
Evolution Area

Use of Architectures to measure mission effectiveness (capabilities and measure of effectiveness) by using JBDAF

JBD Architecture Framework (JBDAF)




enable analysis of factors which contribute to mission effectiveness of JBD
and to investigate the importance of these factors
Cranfield
UNIVERSIT
Vensim
Model(SD)
Operational tasks, elements and
information flows required to
accomplish military operation
Systems and interconnections
providing for or supporting
Armed Forces:Fight Wars
High Level Strategic Objectives
Op Concept
Op Info Exchange
Op Node Connectivity
Op Rules
Activity Model
SA National Missions
Saudi Defence
Doctrine
I
Formation Objectives
II
Types of Military Ops
Armed Forces Doctrine
Publications
Lower Level Objectives
Operational
Sys Rules
Destroy Enemy Forces
III
Physical model
SA Military Functions
enables identification of
requirements for JBD and
Tactical Tasks/Missions
to assess potential options
Tactical Application of Military Functions
Technica
IV
System Level Tas
SD sim
Capture Objective/Hold Position
Technology Architecture
Prof
Minimal set of ru
IF Tasks
Formation Tactics
V
interdependencies of system parts or elements



enable analysis of factors which contribute to mission effectiveness of JBD and to investigate the importance of these factors
Cranfield UNIVERSIT
Vensim Model(SD)
Op Concept
Op Info Exchange
Op Node Connectivity
Op Rules
Activity Model
Operational tasks, elements an information flows required to accomplish military operatio
Systems and interconnections providing for or supporting military operation
Sys Tech
Sys Performance
Sys Interface
Sys Functionality
Sys Rules
Physical model
Operational
System
JBDAF
Capability
enables identification of requirements for JBD and to assess potential options
STT
bles analysis of cific technical ameters leading lidation of STT assessment
SD sim
Technical
Acquisition
Cap Vision
Cap Function
Cap Phasing
SoS Clusters
Provide comprehe
Capability Manage
Information
Acq Clusters
Acq Programmes
describe the relationships and dependencies between the activities
Technology Architecture Profile
Standards technology Forecast
Minimal set of rules governing the arrangement, interaction and interdependencies of system parts or elements

Conclusion

- There are several significant shortfalls in MODA technical policy. The most significant of these relate to the policies for secure interconnection, message handling, messaging security, internetworking, data management and communications demand management.
- A key issue for JBD is how to pursue an evolutionary approach across a complex federation of systems in a competitive system acquisition regime.
- JBD capability is achieved by realising components of that capability in Component Systems.
- Actual JBD capability will become available to the user only as these enhancements to Component Systems are rolled out across the in-service platforms.

Conclusion (2)

- Use of the JBDAF provides the consistency and common language to enable the stakeholders (people involve in the JBD) to express the problem and to reach the solution.
- Having a STT will underpin the JBDAF providing the consistency of approach to architectural modeling and provide a good means for change management of the architecture framework. STT identifies the gaps in system available to meet operational needs.
- The system dynamic model is to monitor the effects of programmatic changes to a system on the overall SoS.
- we will know the impact on the performance, time and cost of other systems, which aids decision-making.