A Methodology for Modeling the Network-Centric Operations Value Chain

Ke-Bo Deng

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Outline

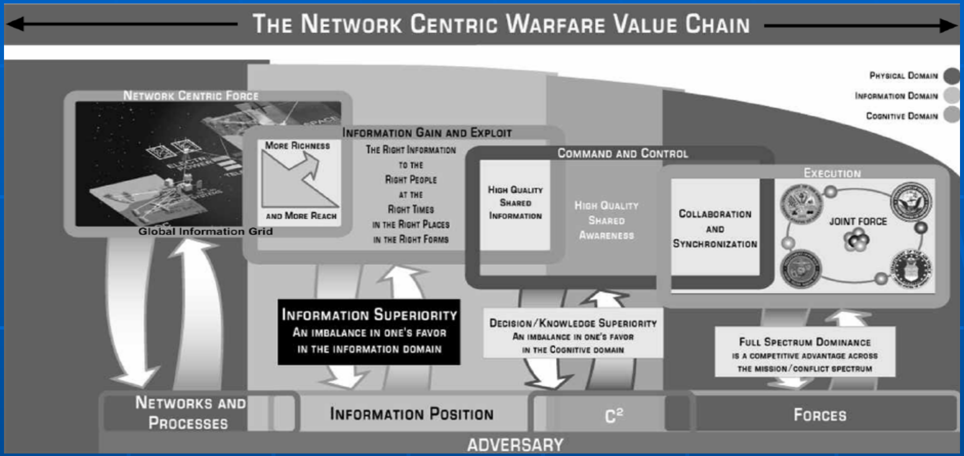
Network-Centric Operations Value Chain

—NCO-VC

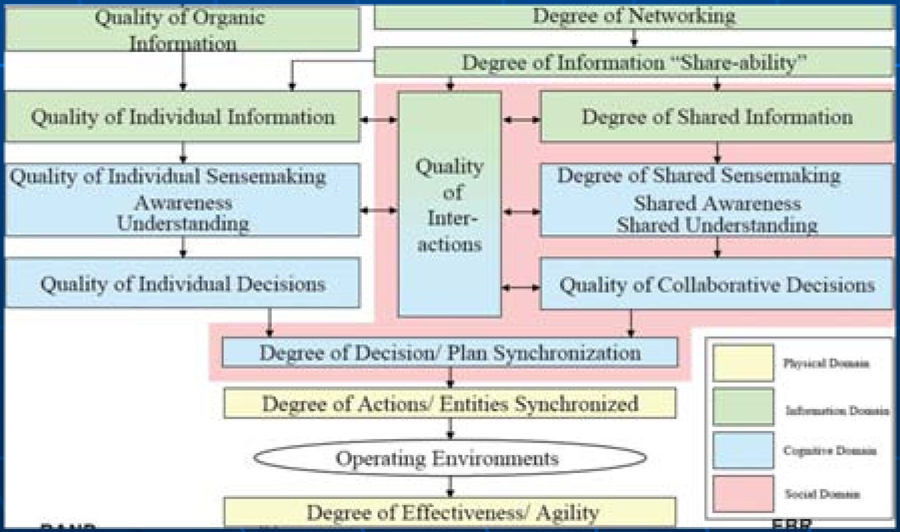
- **NCO-VC Concept**
- **NCO-VC Modeling Process**
- **NCO-VC Modeling with an Example**

NCO-VC Concept

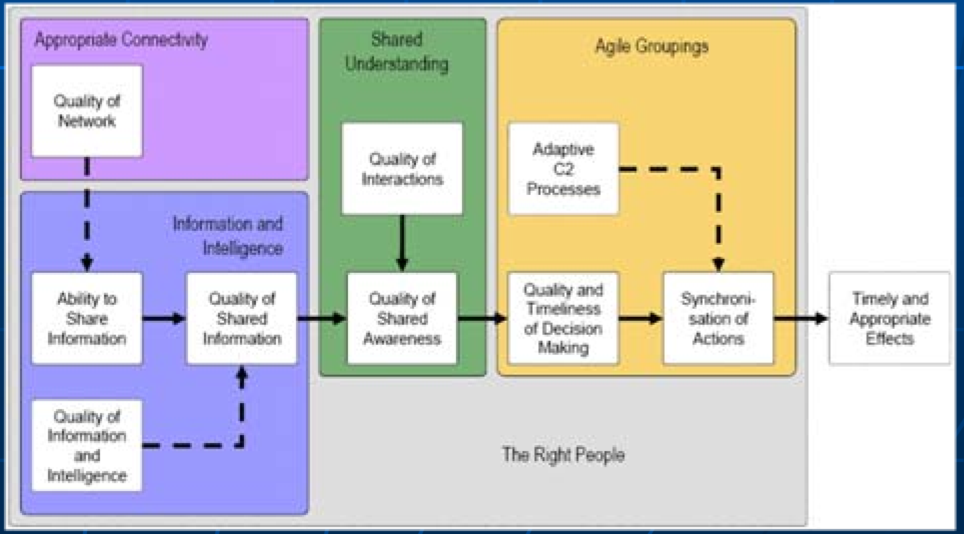
A hypothesis on the NCO is that improved networked force capability will add value and ultimately result in improved mission effectiveness, where the intervening steps can be viewed as the NCO value chain. NCO-VC cuts across the physical domain, information domain, cognitive domain.



—— 《Understanding Information Age Warfare》



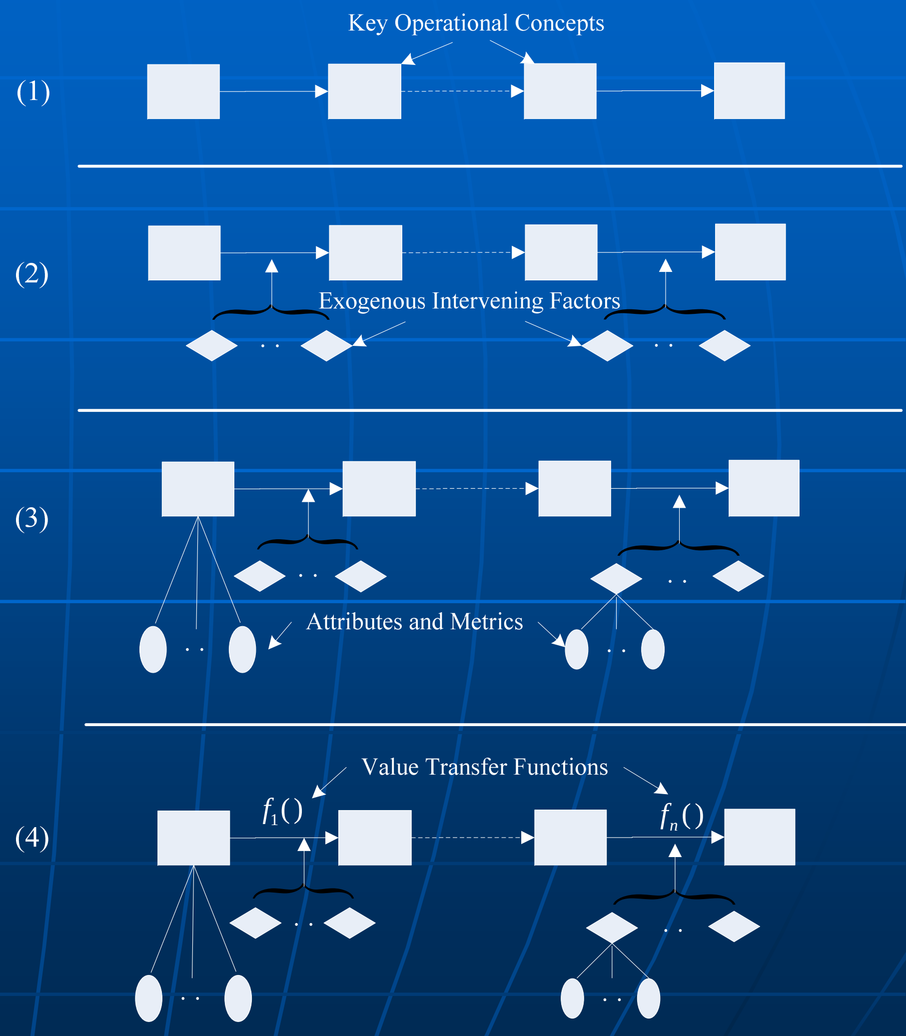
—— 《Network Centric Operations Conceptual Framework 》



—— 《Validating the Network Enabled Capability Benefits Chain》

NCO-VC Modeling Process

1) Identifying the key operational concepts and building the linkages among the key operational concepts according to the operation process;
2) Analyzing the exogenous factors that intervene the causality relationship between each linked pair of key operational concepts;
3) Defining the vector of attributes and metrics to access the key operational concept and related intervening factor respectively;
4) Formulating the value transfer functions between each linked pair of key operation concepts with the consideration of the related intervening factors.



NCO-VC Modeling with an Example

An air-defense operation case:

a) A set of sensors detect the threat objects penetrating into a specific spatial region;

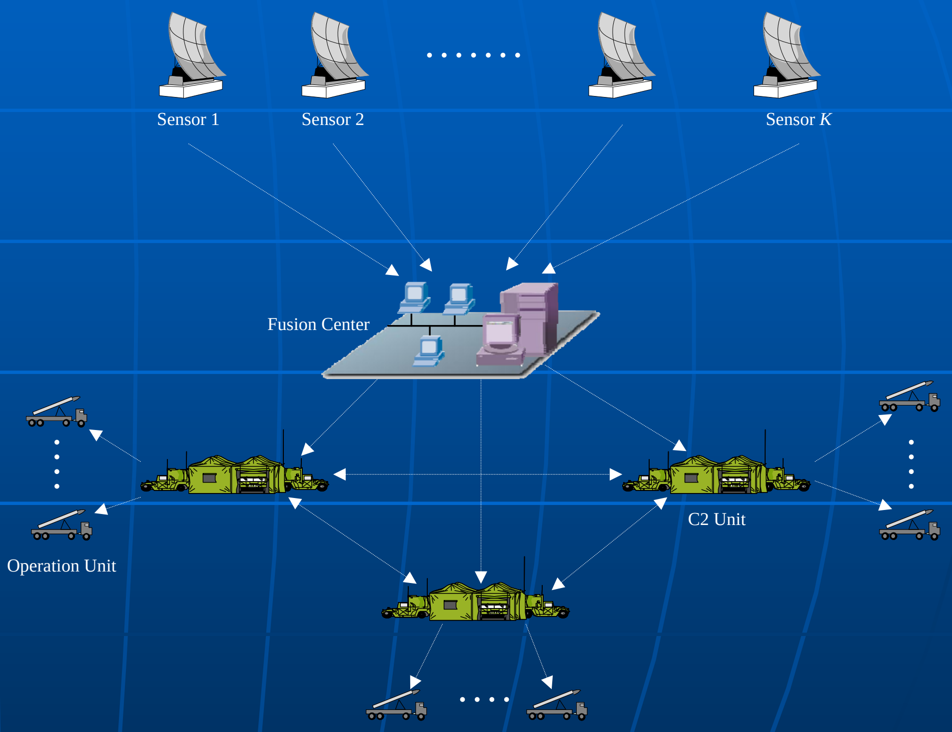
b) The sensors transmit their data to a central processing facility by the network to generate a single integrated air picture (SIAP);

c) The central processing facility transmits various versions of the fused SIAP to the C2 units by the communication networks;

d) The C2 units collaboratively interpret the received SIAP to achieve common battle-space realization;

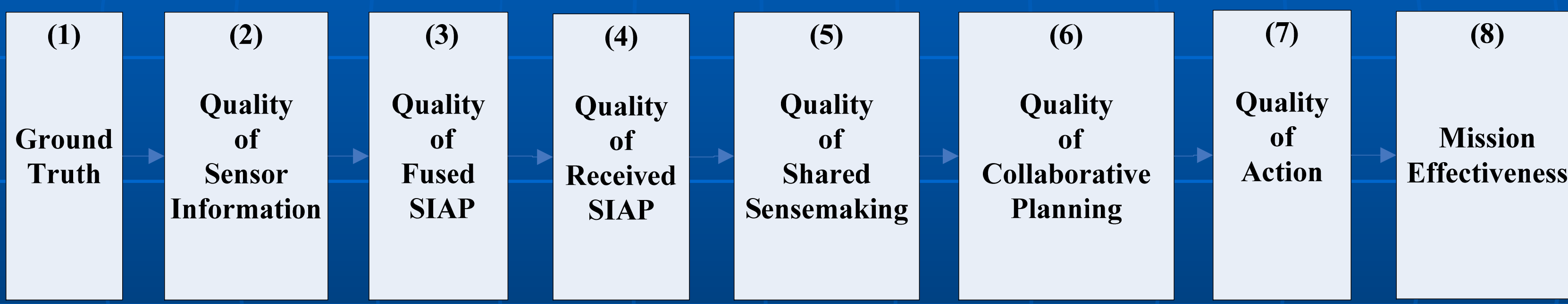
e) The C2 units collaboratively arrive at an agreed decision, devise the air-defense plans and send them to the operational units;

f) The operational units carry out the devised plans to intercept the incoming threat objects.



System organization

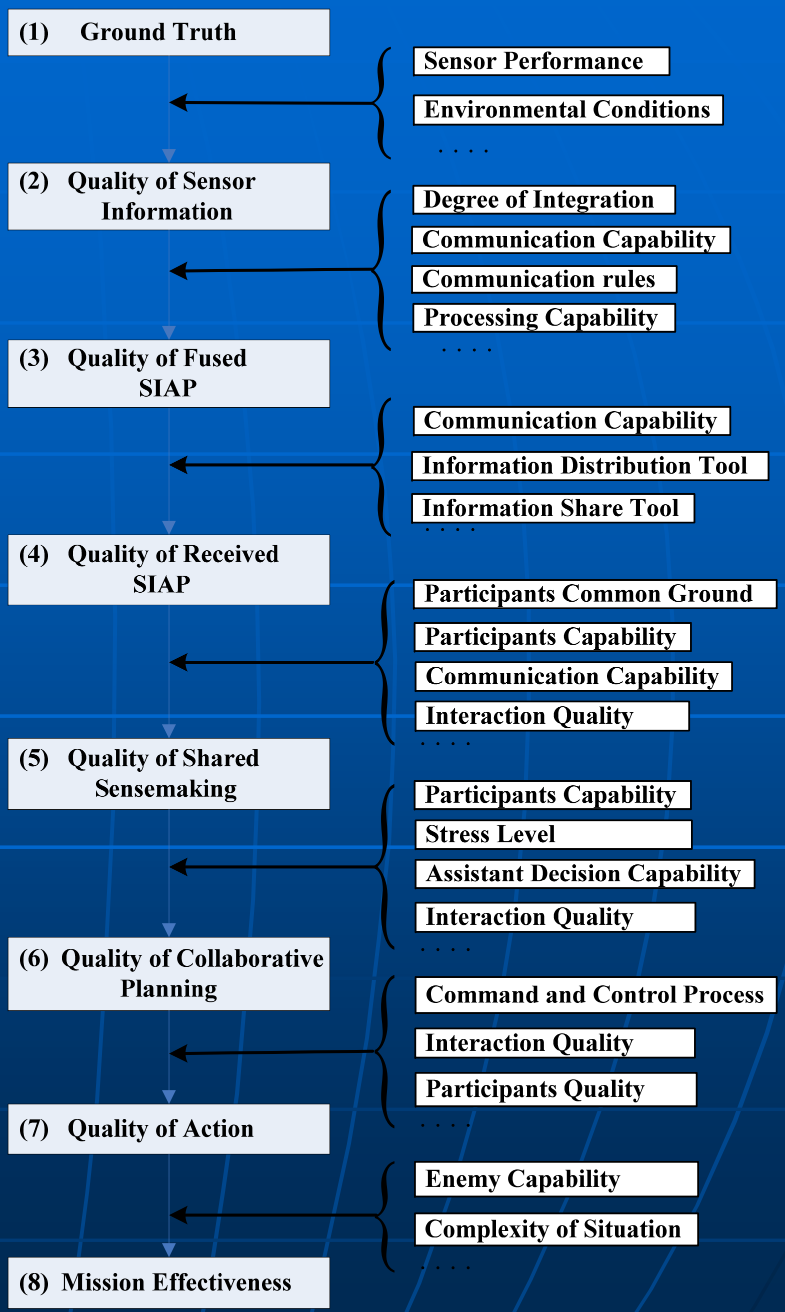
1) Identifying the key operational concepts



Key operational concepts in the air-defense operation case

2) Analyzing the exogenous intervening factors

To make a trade off between the simplicity and complexity, not all but the most important intervening factors could be taken into account.



Exogenous intervening factors in the air-defense operation case

3) Measuring the key concepts and intervening factors

The attributes measure different characteristics of the key concept and intervening factor in terms of quantity and quality.

Each attribute is actually measured by a metric or set of metrics that specifies in detail what data would be needed to measure the attribute.

Measures for the key concept of fused SIAP

Attribute	Metric
Completeness	The SIAP is complete when all objects are detected, tracked and reported.
Currency	The total time required to obtain a SIAP from the target detection.
Clarity	The SIAP is clear when it does not include ambiguous or spurious tracks.
Continuity	The SIAP is continuous when the track number does not change.
Kinematic Accuracy	The SIAP is kinematically accurate when the position and velocity of each assigned track agree with that of the associated object.
Correctness	The ID is correct when all tracked objects are in the correct ID state.
……	……

Measures for the communication capability

Attribute	Metric
QoS	Vector of performance metrics, including average bandwidth provided, packet delay, delay jitter and data loss.
Reach	Degree to which force entities can connect and communicate in desired access modes, information formats and applications.
Assurance	Extent to which network provides services facilitating the assurance of information in the areas of privacy, availability, integrity and authenticity.
Availability	The percentage of time all authorized users have access to the network.
Redundancy	Multiple ways to get at the same information or to get from point A to point B in a network.
Reliability	An attribute of any network that consistently produces the same results, preferably meeting or exceeding its specifications.
……	……

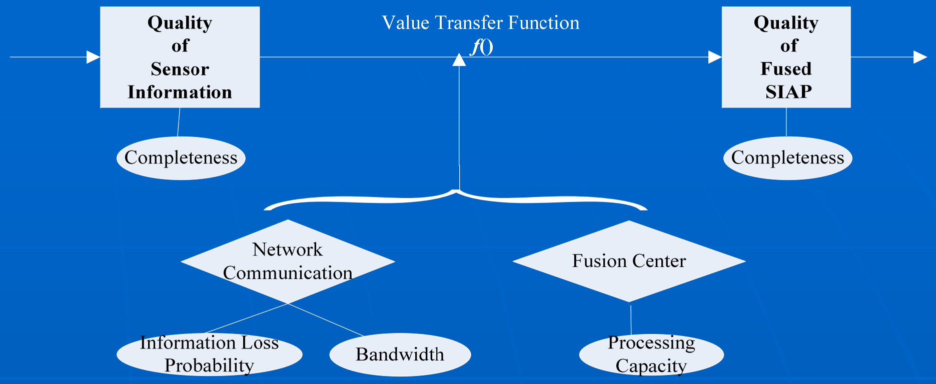
4) Formulating the value transfer functions

The transfer functions are determined by the intervening factors and transform the attributes of the key concepts, i.e. map the attributes of a key concept to the attributes of its successive key concept in the NCO-VC.

By the form of mathematical formula, the transfer functions clearly define what exogenous factors, which attributes of the factors, and how the attributes of the intervening factors play roles in the attribute transform.

Example

- **Concerned value transfer function:**
  ※ the one between the key concepts of sensor information and SIAP
- **Concerned measure of key concept :**
  ※ completeness
  — the percentage of real tracks included in the sensor information or SIAP.
- **Concerned intervening factors:**
  ※ network communication
  ※ fusion center
- **Concerned attributes of the intervening factors:**
  ※ network communication _ bandwidth
  — the maximum information network could transmit
  ※ network communication _ information loss probability
  — the percentage of lost information in the total sent information
  ※ fusion center _ processing capacity
  — the maximum information fusion center could processing



SIAP completeness can be approximated:

$$C_{SIAP} = \frac{\bigcup_{i=1}^{K} A_{Sen(i)}}{A_0} \cdot \sum_{i=1}^{K} W_i \cdot C_{Sen(i)} \cdot \sum_{i=1}^{K} W_i \cdot h\left(N_{Sen(i)}, N_{Net(i)}\right) \cdot \left(1 - P_{Net(i)}\right) \cdot g\left(N_{Sen}, N_{Fus}\right)$$

$A_{Sen(i)}$: the coverage area of sensor *i*

A_0 : the entire concerned area

W_i : a weight accounting for the relative size of the sensor coverage

$C_{Sen(i)}$: the completeness of sensor *i* information

$N_{Sen(i)}$: the number of the targets sensor *i* reports

$N_{Net(i)}$: the maximum number of the targets communication line *i* could transmit

$P_{Net(i)}$: the information loss probability of communication line *i*

N_{Sen} : the number of targets all the sensor report,

N_{Fus} : the processing capacity of the fusion facility

$$W_i = \frac{A_{Sen}(i)}{\bigcup_{i=1}^{K} A_{Sen}(i)}$$

$$h\left(N_{Sen(i)}, N_{Net(i)}\right) = \begin{cases} 1 & N_{Sen(i)} \le N_{Net(i)} \\ \dfrac{N_{Net(i)}}{N_{Sen(i)}} & N_{Sen(i)} > N_{Net(i)} \end{cases}$$

$$g\left(N_{Sen}, N_{Fus}\right) = \begin{cases} 1 & N_{Sen} \le N_{Fus} \\ \dfrac{N_{Fus}}{N_{Sen}} & N_{Sen} > N_{Fus} \end{cases}$$

****Note:**

Value transfer function formulation is the most important and intricate step in the modeling of NCO-VC.

Above mentioned example is simple and ideal.

As taking the personnel behavior into account, it is often extremely difficult, even impossible to formulate a reasonable transfer function using the analytics, and then we should turn to the human-in-the-loop simulations.

Conclusions

- A systematic NCO-VC model will be the focus of analysis and experimentation, not only help us to understand the benefits accumulation process within NCO, but also recognize the factors having the greatest payoff and the conditions under which the benefits will accrue.
- We have outlined a methodology for modeling the NCO-VC.
- However, it should be noted that this research just gets under way and many details remain to be explored.
- As more evidence regarding NCO is collected from studies, simulations, experiments and actual operations, the NCO-VC model could be further tested, enriched and improved.

Thanks!