



# Human Network Systems: Analysis & Operations

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Computational Methods/Tools Conference**

**19 March 2008**

*The views expressed in this presentation are those of the author and do not reflect the official policy or position of the United States Air Force, Department of Defense, or the United States Government.*

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***Integrity - Service - Excellence***



# Overview



- Background
- BIA R&D Methodology
- Structure & Function
- Required Skill Mix
- Some AFIT Work



# 4<sup>th</sup> Generation Warfare<sup>1</sup>

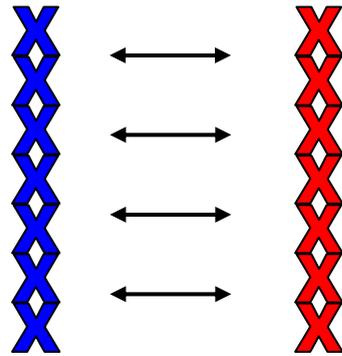


Modeling and Analysis of Resolve and Morale for the 'Long War' Michael J Artelli, Major, USAF, AFIT / DS / ENS / 07-02



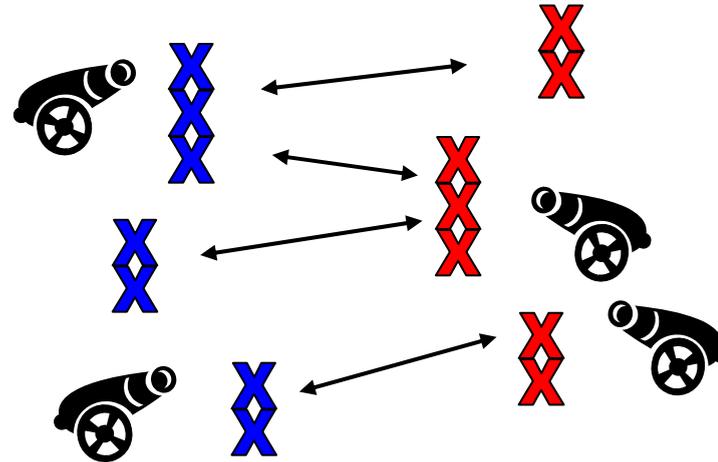
## 1<sup>st</sup> Gen Warfare

- Smoothbore
- Columns of fire
- High rate of fire



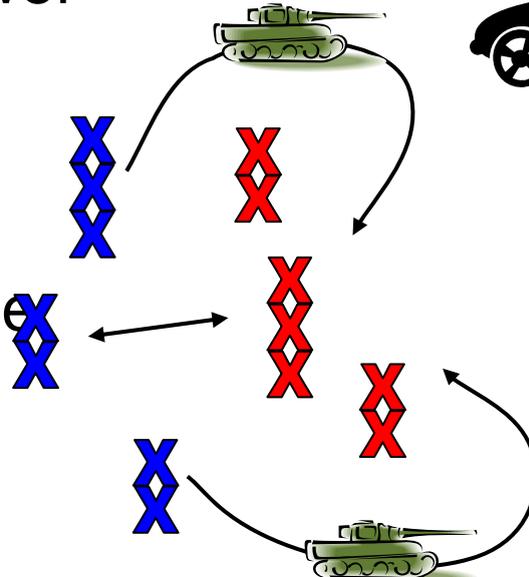
## 2<sup>nd</sup> Gen Warfare

- Rifle, machine gun, artillery
- Massed firepower defeated massed manpower



## 3<sup>rd</sup> Gen Warfare

- Maneuver
- Tactics overcome technology



1: Lind *et al.*: "The Changing Face of War: Into the Fourth Generation"



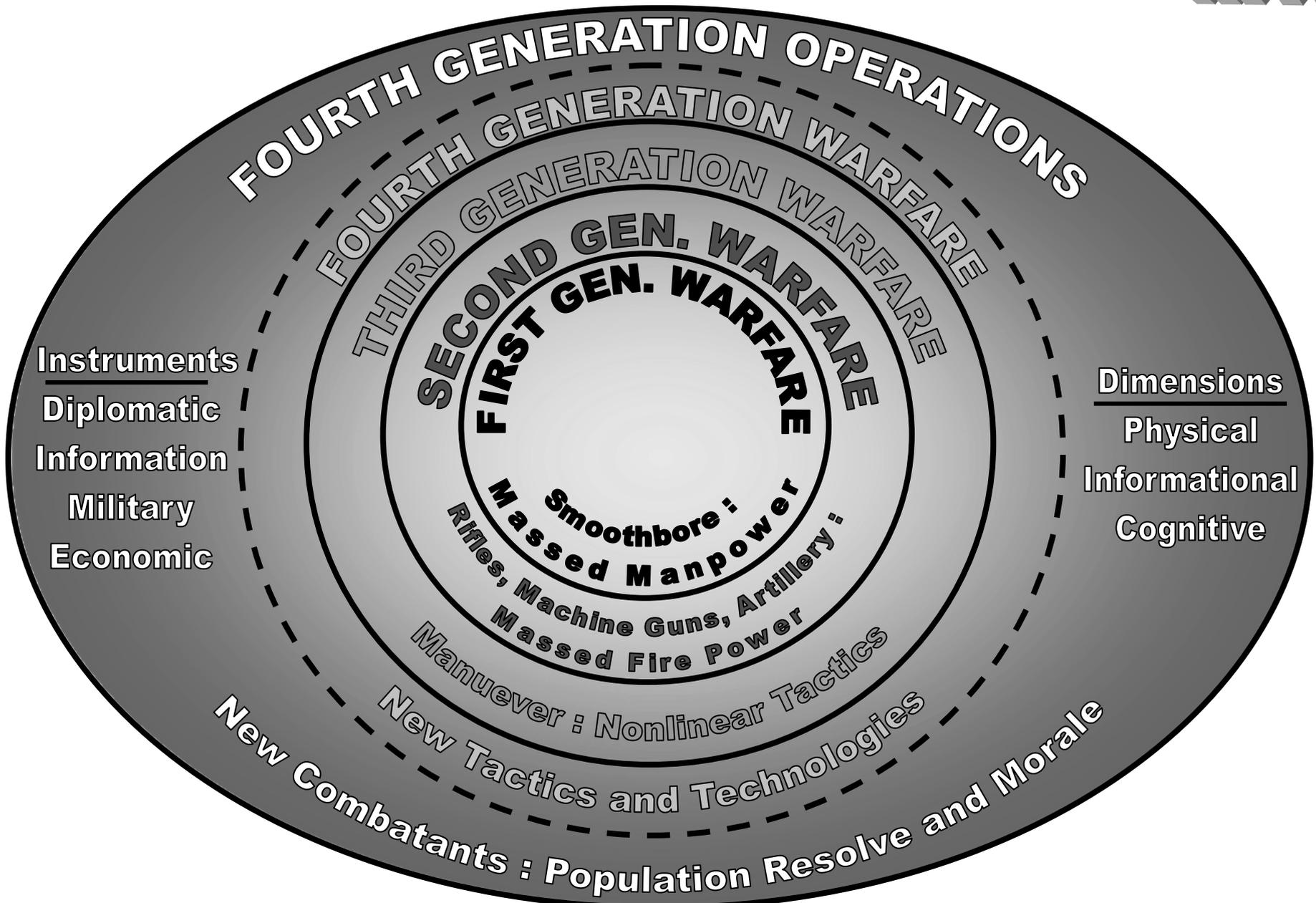
# 4<sup>th</sup> Generation Warfare (Continued)



- Change of ideas or technology
- Common traits
  - Increased individual independence
  - Decrease logistics train
  - Increased maneuver
- Terrorism, insurgency, guerrilla warfare, irregular warfare, or asymmetric warfare ?

1: Lind *et al*: "The Changing Face of War: Into the Fourth Generation"

*Targets will include such things as the population's support for the war –  
William Lind*





# Terms & Definitions



**Traditional (Regular) Warfare** – *A confrontation between nation-states or coalitions/alliances of nation-states.* This confrontation typically involves *force-on-force* military operations in which adversaries employ a variety of *conventional military capabilities* against each other in the air, land, maritime, space, and cyberspace domains. The objective may be to convince or coerce key military or political decision makers, defeat an adversary's armed forces, destroy an adversary's war-making capacity, or seize or retain territory in order to force a change in an adversary's government or policies.

IAW AFDD 2-3 Irregular Warfare, pg 2



# Terms & Definitions



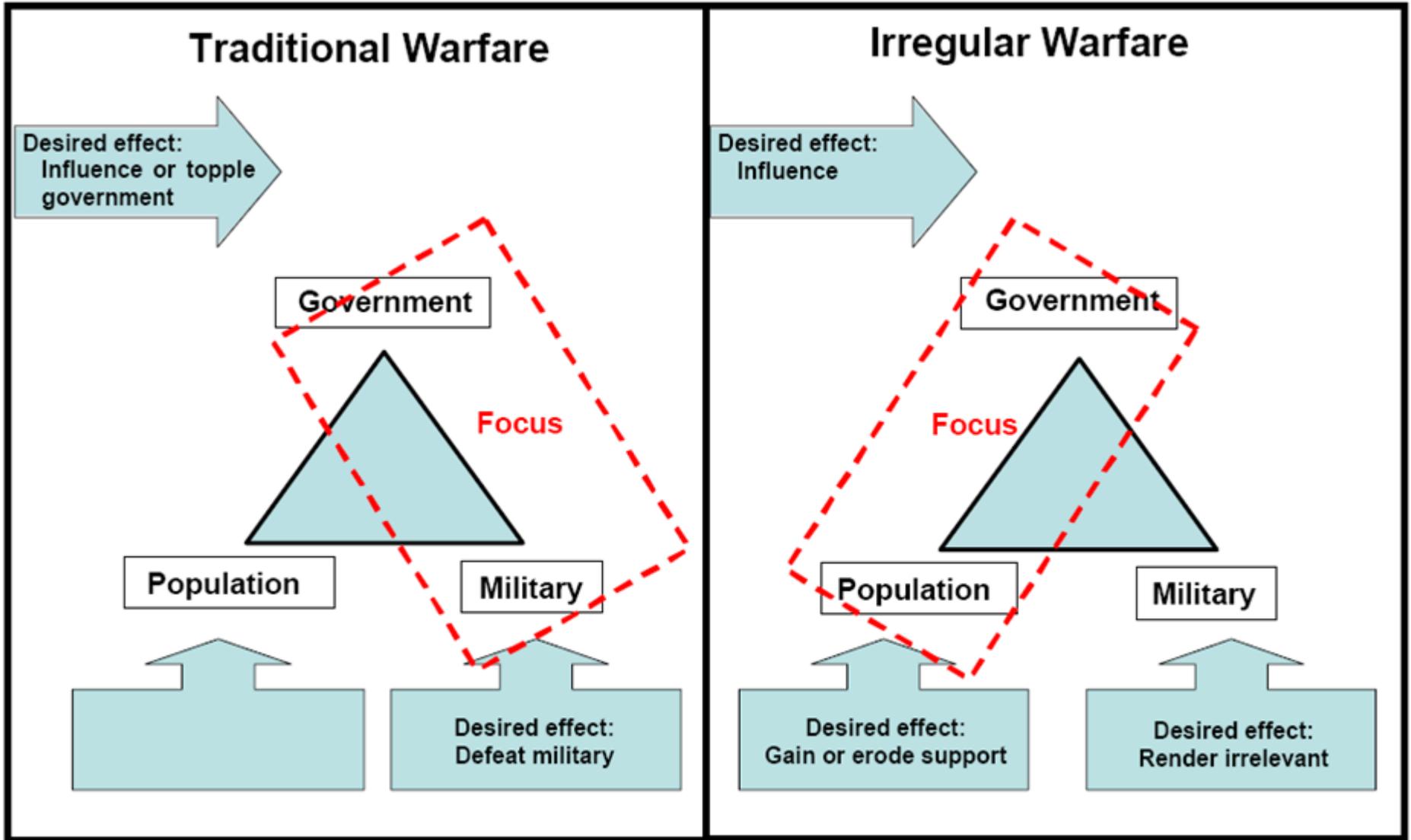
**Irregular Warfare (IW)** – A violent struggle among *state and non-state actors* for *legitimacy and influence* over the relevant populations.



IAW AFDD 2-3 Irregular Warfare, pg 2



# Clausewitzian Trinity



**Figure 1.1. Contrasting Traditional and Irregular Warfare**



# Terms & Definitions



**Conventional Warfare** – A broad spectrum military operations conducted *against an adversary by traditional military or other government security forces* that do not include chemical, biological, radiological, or nuclear (CBRN) weapons.

**Unconventional Warfare** – A broad spectrum of *military and paramilitary operations*, normally of long duration, predominantly conducted *through, with, or by indigenous or surrogate forces* who are organized, trained, equipped, supported, and directed in varying degrees by *an external source*. It includes, but is not limited to, guerrilla warfare, subversion, sabotage, intelligence activities, and unconventional assisted recovery.

IAW AFDD 2-3 Irregular Warfare, pg 2



# Key Points of Clarification



- Conventional & Unconventional terms refer to the weapons or forces conducting the operations
- IW:
  - May be conducted by conventional, unconventional, or both depending on the circumstances
  - Not a lesser-included form of regular warfare; encompasses a spectrum significantly different from regular warfare
  - Includes both insurgency and counterinsurgency
- Regular Warfare & IW are not mutually exclusive; both forms may be present in a given conflict.



# IW “Truths” for Airmen



- USAF must be prepared to *simultaneously conduct irregular and traditional* warfare operations.
- IW is a *different form of warfare* and not a lesser form of conflict within traditional warfare. The struggle *for legitimacy and influence over a relevant population is the primacy* focus of operations, *not the coercion of key political leaders or defeat of their military capability*.
- IW is *intelligence-intensive*.
- *Unity of effort across all instruments of power* is essential to overall success.
- *Integrated C2 structures* enable flexibility at all levels and are vital to successful COIN operations.
- Operational effectiveness can be very difficult to measure; thus feedback through a *strong operations assessment and lessons learned process is essential to strategic success*.
- The *adversary may be highly complex and adaptive*.

IAW AFDD 2-3 Irregular Warfare, pgs 8-10



# What is an Insurgency?



JP 1-02 defines an insurgency *as an organized movement aimed at the overthrow of a constituted government or occupying power through the use of subversion and armed conflict.*

Army/USMC FM 3-24 further defines insurgency as an organized, *protracted politico-military struggle* designed to *weaken the control and legitimacy* of an established government, occupying power, or other political authority while increasing insurgent control.

Insurgency is always a form of *internal war*; the one possible exception to this rule involves what can be termed a *“liberation insurgency,”* where indigenous elements seek to expel or overthrow what they perceive to be a foreign or occupation government.

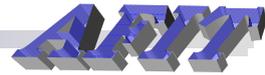
*Political power* is the central issue in an insurgency and both the insurgent and counterinsurgent has this as its aim. The insurgent attempts to overthrow or subvert an established government or authority; the counterinsurgent uses all of the instruments of national power to support the government in restoring and enforcing the rule of law.

Each insurgency has its own *unique characteristics* based on its strategic objectives, its operational environment, available resources, operational method, and tactics.

Insurgencies normally seek to either *overthrow the existing social order and reallocate power within the country, or to break away from state control and form an autonomous area.*



# Elements of National Power



- JP 1-0 (2007):
  - Diplomatic
  - Informational
  - Military
  - Economic



- National Strategy for Combating Terrorism (2006) *in National Security Strategy (2002 & 2006)*:
  - Diplomatic
  - Informational
  - Military
  - Economic
  - Financial
  - Intelligence
  - Law Enforcement

*{less clearly*



# Background



- Commanders have always been interested in the probable actions of their foes...and allies
- Cultural anthropologists, sociologists, and psychologists have studied clans, tribes, groups and individuals since the inception of these fields of study.
- Nations and alliances through the ages have drawn on the skills of learned advisors to aid the conduct of conflict by judging a foe, whether they were princes, paupers, traveler, academics, oracles, wizards, traitors, scouts, or the press.



# Background



- Considering a foe's behavior, intents, and likely tendencies is not new
  - “And when people are entering upon a war they do things the wrong way around. Action comes first, and only when they have already suffered that they begin to think” - *Thucydides*
  - “If you know the enemy and know yourself, you need not fear the results of a hundred battles” – *Sun Tzu*
  - “Geography, tribal structure, religion, social customs, language, appetites, standards were at my finger-ends. The enemy I knew almost like my own side.” – *T.E. Lawrence*
- More recently, we have continued such efforts
  - In 1943, Walter C. Langer and others authored *A Psychological Analysis of Adolph Hitler His Life and Legend* for the Office of Strategic Services
  - During the Cold War (and still today) *Kremlinology* has been practiced to understand the inner workings of the extremely opaque central government of the USSR (and Russia).



# So What Has Changed?



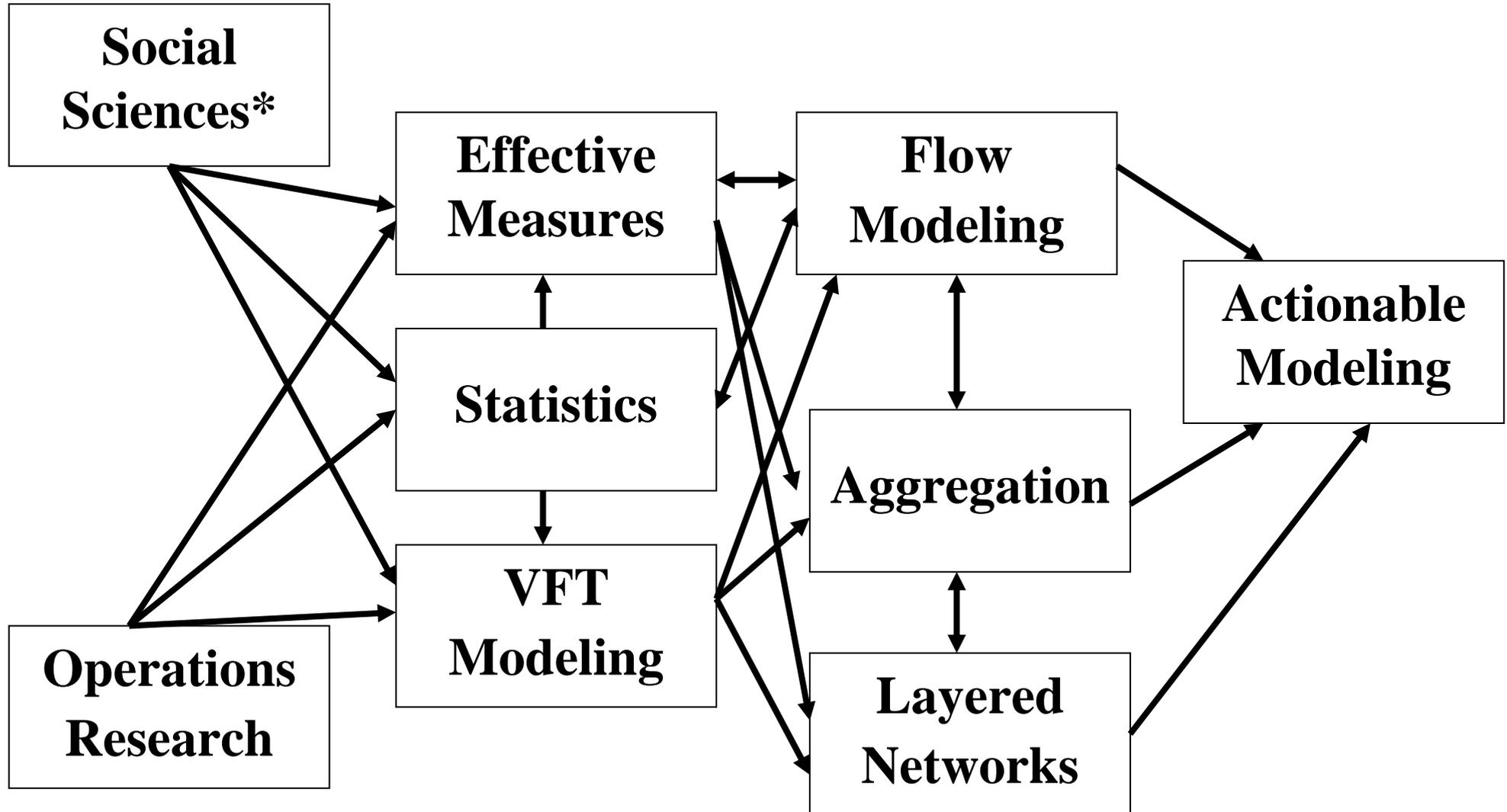
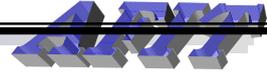
- In the past, commanders have studied their foes; information was gathered on enemy commanders and leaders. Campaigns were studied, tendencies, weakness and areas where a susceptibility might be exploited were noted.
  - National leaders studied other national leaders
  - Force commanders studied opposition force commanders
  - Local commanders studied the forces arrayed against them
- Today, technology now gives us the means to collect, analyze, organize, and model immense amounts of data in a systematic way and make that data available to the appropriate level of command from the JCS to a strategic corporal on a road block.
- The challenge is to assure the right data, analysis, and answers, in an actionable form, gets to the right people in a timely fashion.



# Background



- A Human Network is a formal or informal social structure made of nodes (individuals or organizations) that are linked by one or more specific types of relationships, such as values, ideology, financial exchange, kinship, common enemies, conflicts, or trade.
- A Human Network System considers the *human network*, the *function* of the system, and the *resources* (personnel, training, machinery, material, doctrine) needed to allow the **system** to accomplish its function



\*Social Sciences = Social, behavioral, cognitive, and decision sciences data/methods/tools



# Social Science Influence



## Social Sciences

- **Social Sciences**

- Social Scientists seek to understand both formal and informal social interactions
- Information on social patterns and influence in a social setting, enables analysts to investigate the formation of attitudes and opinions with respect to decisions of interest
- Fields of interest include Psychology, Behavioral Science, Sociology, Anthropology, Organizational Behavior and Organizational Theory, Semiotics, and Reflexive Control

- **SNA assumes**

- Actors and their actions are viewed as interdependent rather than independent, autonomous units
- Relational ties between actors are channels for transfer or “flow” of resources (either material or nonmaterial).
- Network models focusing on individuals view the network structural environment as providing opportunities for, or constraints on, individual actions
- Network models conceptualize structure (social, economic, political, and so forth) as lasting patterns of relations among actors



# Operations Research Influence



## Operations Research

- **Operations Research (O.R.)**
  - Operations Research is the discipline of applying advanced analytical methods to help make better decisions.
  - Using techniques such as mathematical modeling to analyze complex situations, operations research gives decision makers the power to make more effective decisions and build more productive systems based on:
    - More complete data
    - Consideration of all available options
    - Careful predictions of outcomes and estimates of risk
    - The latest decision tools and techniques
- **O.R. draws upon analytical technologies, including:**
  - Simulation –To try out approaches and test ideas
  - Optimization- Narrowing choices to the very best when there are virtually innumerable options and comparing them is difficult
  - Probability and Statistics - Helping measure risk, mine data to find valuable connections and insights, test conclusions, and make reliable forecasts
  - Decision Analysis –The use of logical methods for the improvement of decision making.
  - Network modeling – function, structure and data



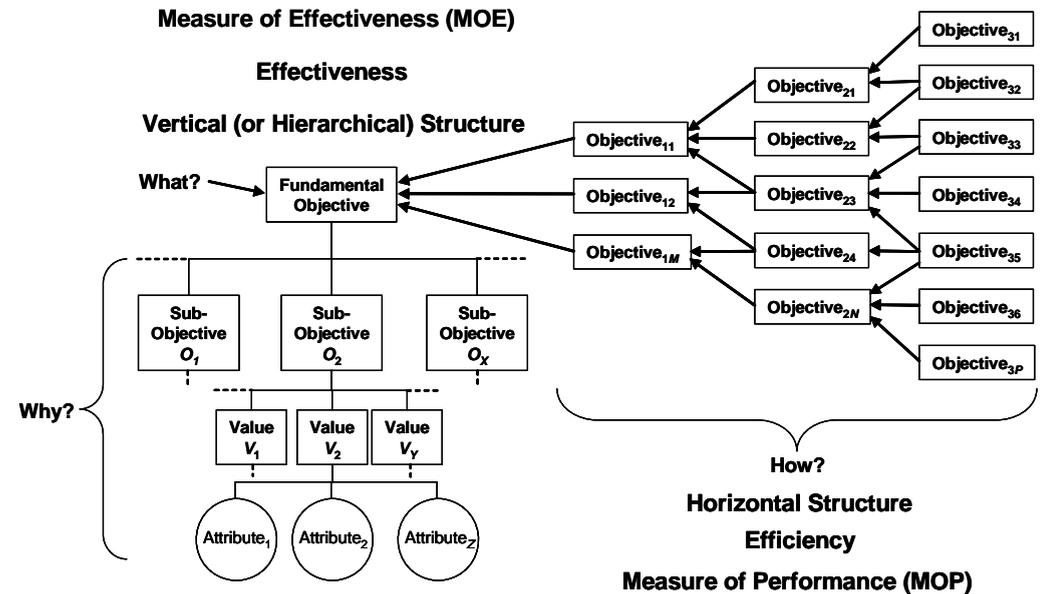
# Effectiveness Measures



- Measurement turns real-world system behavior into a set of 'vital signs' for the purpose of monitoring the system
- Measurement is carried out within a specific context

- **Effectiveness vs. Efficiency**

- **Measure of Effectiveness (MOE)**
  - External measure
  - Invariant to means of achievement
  - Are we doing the right things?
- **Measure of Performance (MOP)**
  - Internal measure
  - Coupled to means of achievement
  - Are we doing things right?



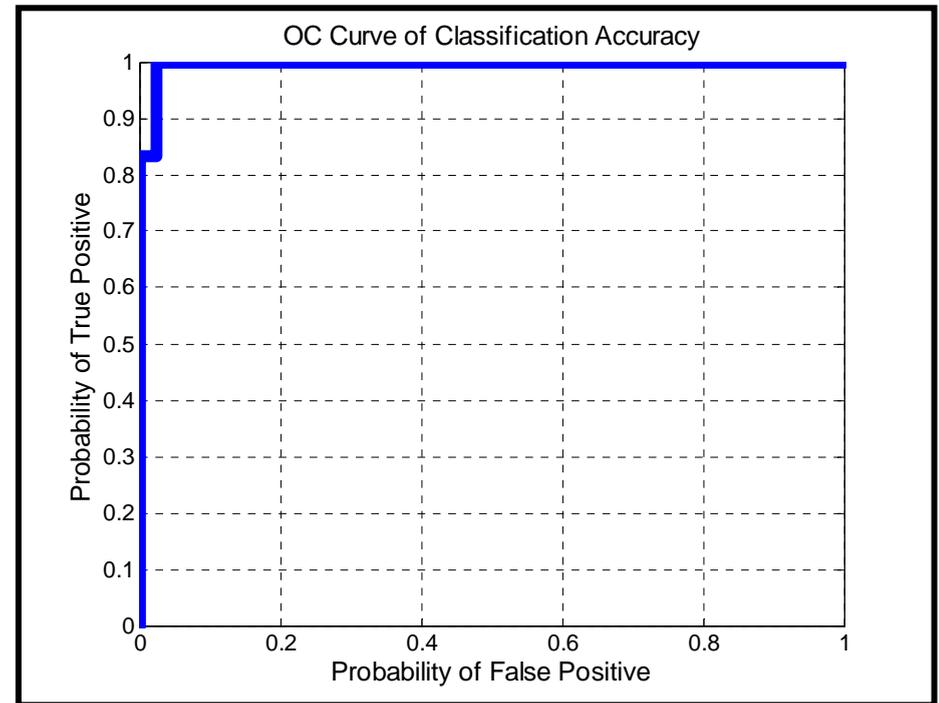
- We wish to create effective measures of relations
- Common aggregation techniques can result in reduced numerical meaning
- An effect is a system state change
  - Effectiveness gauges the relative magnitude of the change



# Statistics



- **Statistics** - a branch of applied mathematics concerned with the collection and interpretation of quantitative data and the use of probability theory to estimate population parameters
  - Bayesian Belief Network
  - Multivariate Statistical Analysis
  - Discriminant Analysis
  - Statistical Process Control
  - Design of Experiment
  - Hypothesis Testing
  - Other statistical and probabilistic approaches
- **Facilitates**
  - Interpretation
  - Categorization
  - Risk Assessment
  - Profiling
  - Focusing Effort

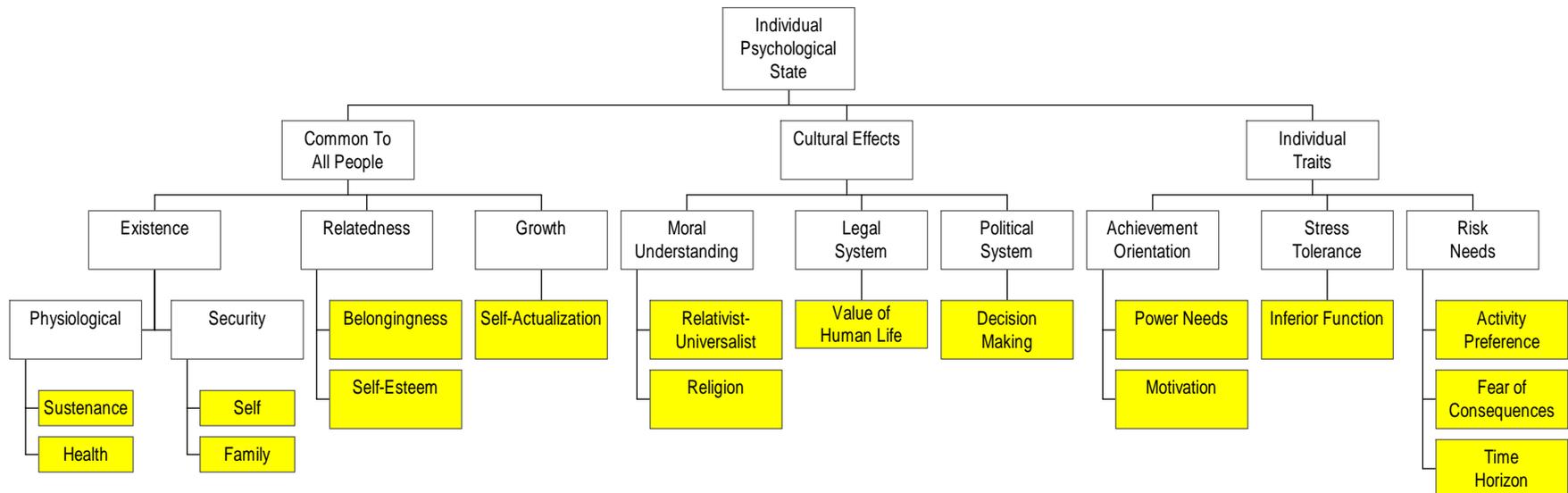




# Value Focused Thinking



- **Decision Analysis (DA)** is a set of quantifying methods for analyzing decisions
- **Value-Focused Thinking (VFT)** is a decision making process based on the values of the decision maker rather than the available alternatives
  - Value models provide decision-makers with an objective, defensible, and repeatable structure
  - VFT provides a method to develop effective weights and measures for social networks and other behavioral analysis models

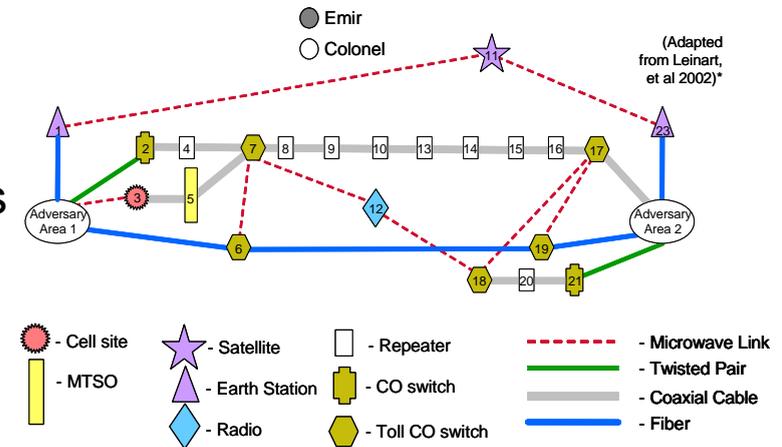
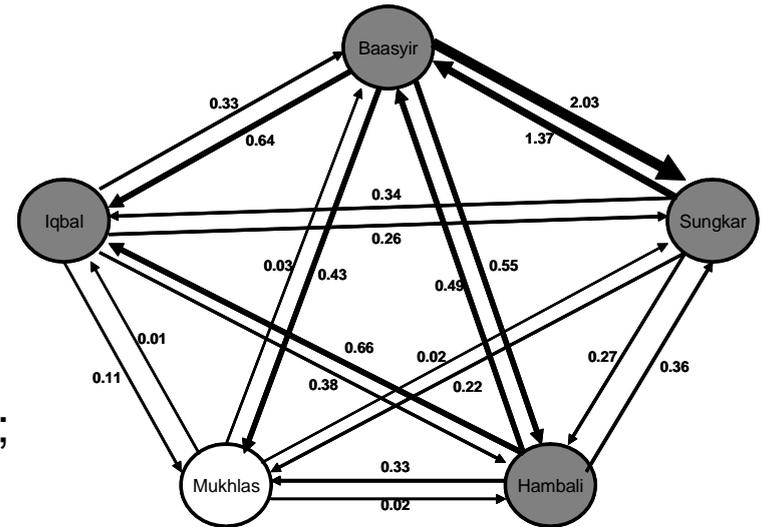




# Flow Modeling



- **Network Flow Models** have been widely used to solve complex problems
- Three properties are responsible for the widespread use of network flow models:
  - **Visual Content** - These models allow for a problem to be depicted by means of diagrams; and the pictorial appeal of these network diagrams makes the problem more easily understood by many users.
  - **Model Flexibility** - Network models having similar structures can be used in a wide array of application areas. The DoD has wide experience in using network models both for its own operations and for targeting.
  - **Solvability** - There exist computationally very efficient algorithms, step-by-step solution procedures, for most network flow problems. These special purpose algorithms achieve these extraordinary efficiencies by exploiting the special structure inherent in the network flow problems.

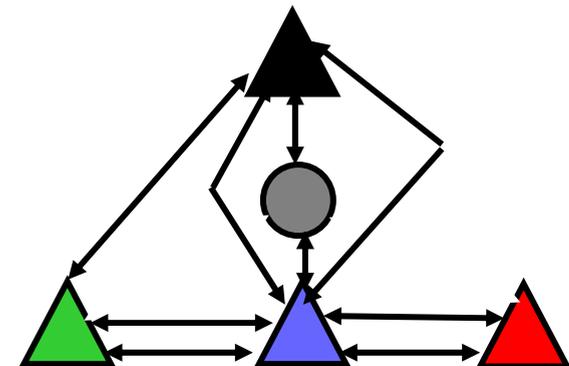
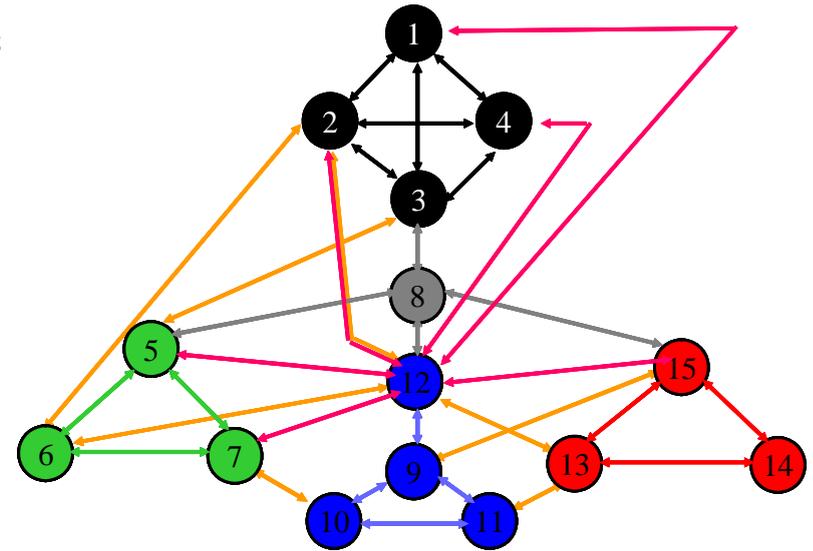




# Aggregation



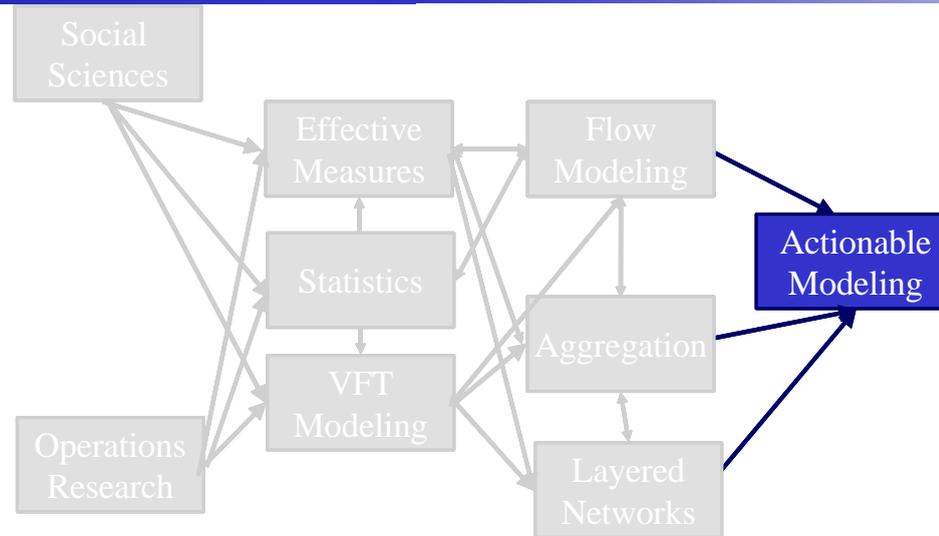
- Purpose of aggregation
  - Reduce computational time for analysis of large networks
  - Gain insight to network activity
- Identify appropriate subgroups
  - Natural close knit groups
  - Interest in their interactions
- Aggregate into subgroups and apply node measure
  - Node measures transform relational arc data into information about a node
  - Weighted arcs offers greater information about relationships



- Aggregate as needed
- Smaller network to analyze



# Actionable Modeling



- The ultimate goal is to provide actionable modeling to the **operators** and the **analysts**
- Models must be dynamic, adaptable, and evolve
- Descriptive, Prescriptive and Predictive models are required
- A suite of modeling tools is required to meet the needs of specific operators and analysts:
  - Models don't perform analysis they do computations and visualization
  - Analysts do analysis, aided by models where appropriate
- Context, function, and purpose matter!



# Perspectives



- **SNA Models tend to be Descriptive Models**

- A model that attempts to describe the actual relationships and behavior of a system
- The “what is” question
- For a decision problem, such a model seeks to describe how individuals make decisions

- Provides insight
- Perhaps create requirements

- **Network/OR Models are Predictive, Proscriptive and Descriptive Models**

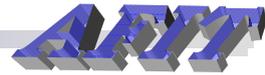
- A model that attempts to describe the best or optimal solution of a system
- The “what’s best” & “what if” questions
- For a decision problem, such a model is used as an aid in selecting the best alternative solution

- Provides insight
- Perhaps create requirements
- Actionable Options Evaluations

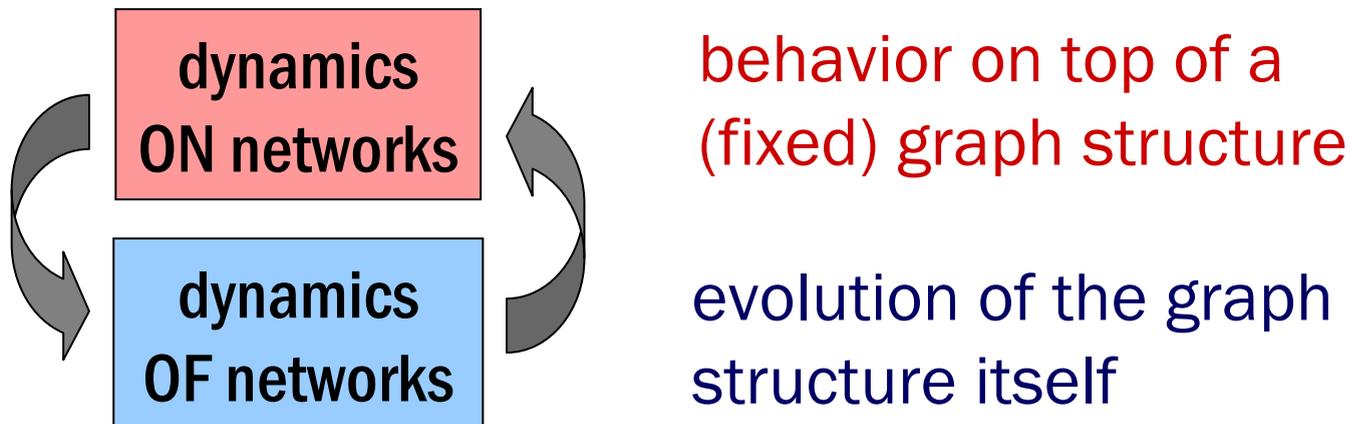
*Models never perform analysis.  
Analysts do analysis, aided by models where appropriate.*



# Challenges in Studying Networks



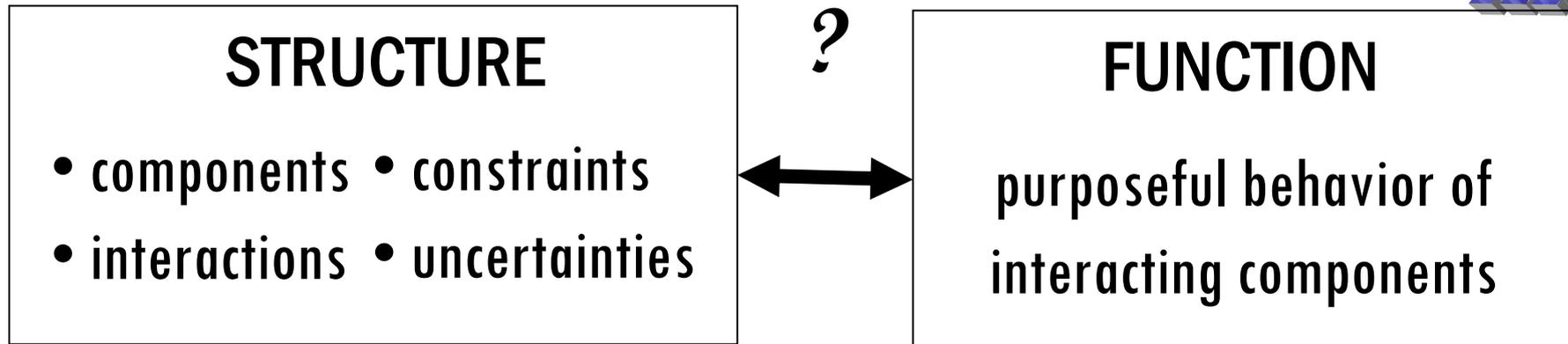
- The term “network” is ambiguous
  - a Rorschach test
  - a discrete approximation to any continuous relationship
- “graph”  $\Leftrightarrow$  mathematical definition e.g.,  $G = (N, A)$
- “network” = graph + data (annotation)
- network dynamics are fundamental to many systems:



Many systems of interest involve the interaction of the two



# Structure vs. Function



- One approach: study the system of interest as ***an artifact***
  - ***Assume no prior knowledge about system***
  - Q1: *What is the system structure?*
  - Q2: *What is the system function?*
  - Q3: *How does structure support function?*
- Hard to know what “matters” from outside looking in
  - modeling choices: affect the outcome
  - different assumptions lead to different (opposite!) results
- A view incompatible with traditional engineering design
  - design of components/interactions to ensure system function
  - assumes knowledge of relationship: structure and function



# Graph Theory as a Basis



- A graph  $\mathbf{G} = (\mathbf{V}, \mathbf{E})$  is a collection of *vertices*  $\mathbf{V}$  (also: *nodes*) and *edges*  $\mathbf{E}$  (also: *arcs*, *links*)
- Focus: features of **graph connectivity**
  - **Node degree** (i.e., number of connections)
  - **Distance** (i.e., number of edges between two nodes)
  - Path length, “degrees of separation”, graph diameter
  - Connectivity patterns: clustering, assortativity
  - Centrality (betweenness)
  - Efficiency (ability to propagate information)
- Vast amounts of data: **ensemble-based view**
  - largest values, smallest values (in expectation)
- Averages, distributions, correlations - structure



# Current SNA Measures



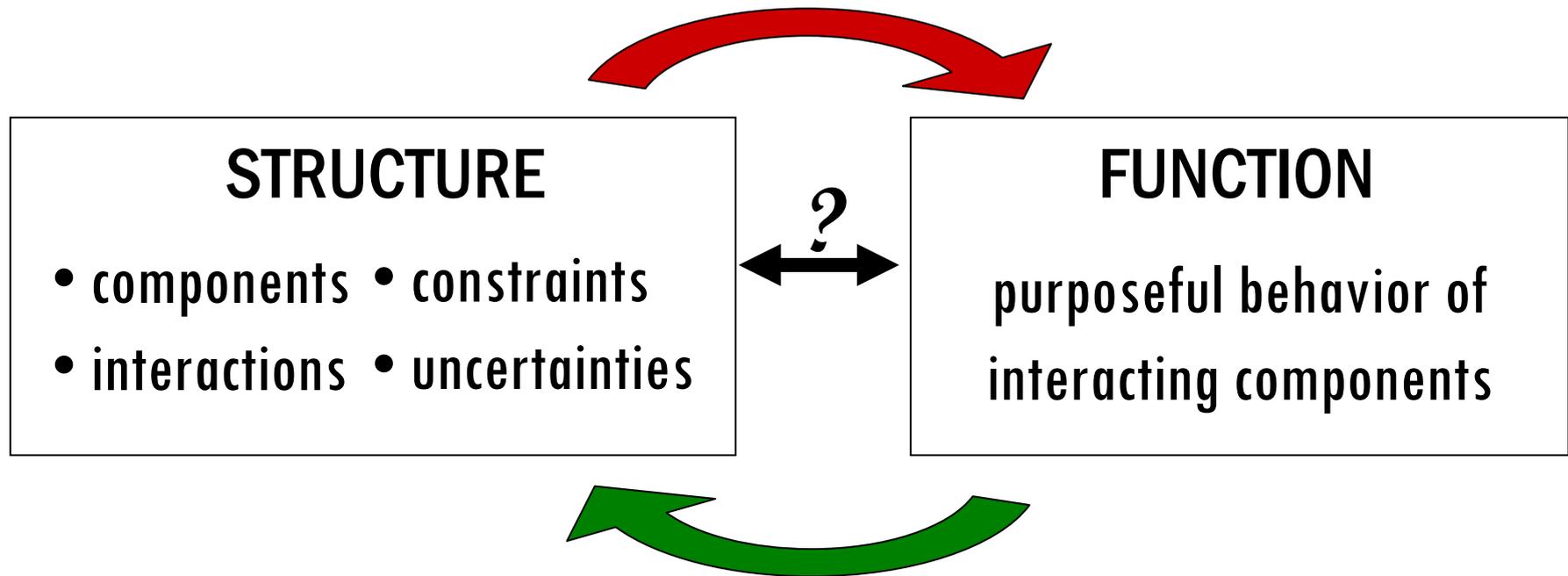
<b>SNA Measures of Individual Importance</b>			
	<b>Calculates</b>	<b>Measures</b>	<b>References</b>
<b>Degree Centrality</b>	Number of direct connections to other nodes	Connection to others; network activity; power	Freeman, 1979; Wasserman and Faust; 1994 Hanneman, 2001
<b>Closeness Centrality</b>	Inverse of the sum of the shortest paths to all other nodes in the network	Members "key" to network communication; reach; reachability	Freeman, 1979; Wasserman and Faust; 1994 Hanneman, 2001
<b>Betweenness Centrality</b>	Proportion of times a node is on the shortest path between other pairs of nodes	Information control; role as an intermediary; brokers; "gatekeepers"	Freeman, 1980; Wasserman and Faust; 1994 Hanneman, 2001
<b>Information Centrality</b>	Proportion of times a node is on any path between other pairs of nodes	Information control; role as an intermediary; brokers	Sthepenson and Zelen, 1989; Wasserman and Faust; 1994 Hanneman, 2001
<b>Eigenvector Centrality</b>	Nodes assigned loading on first principal component, calculations identical to Principal Components Analysis	Overall importance to the network; how close am I to actors who are close to others	Bonacich, 1972; Bonacich, 2001



# System View



Design of components/interactions to insure system function



Model the structure to explain observed function

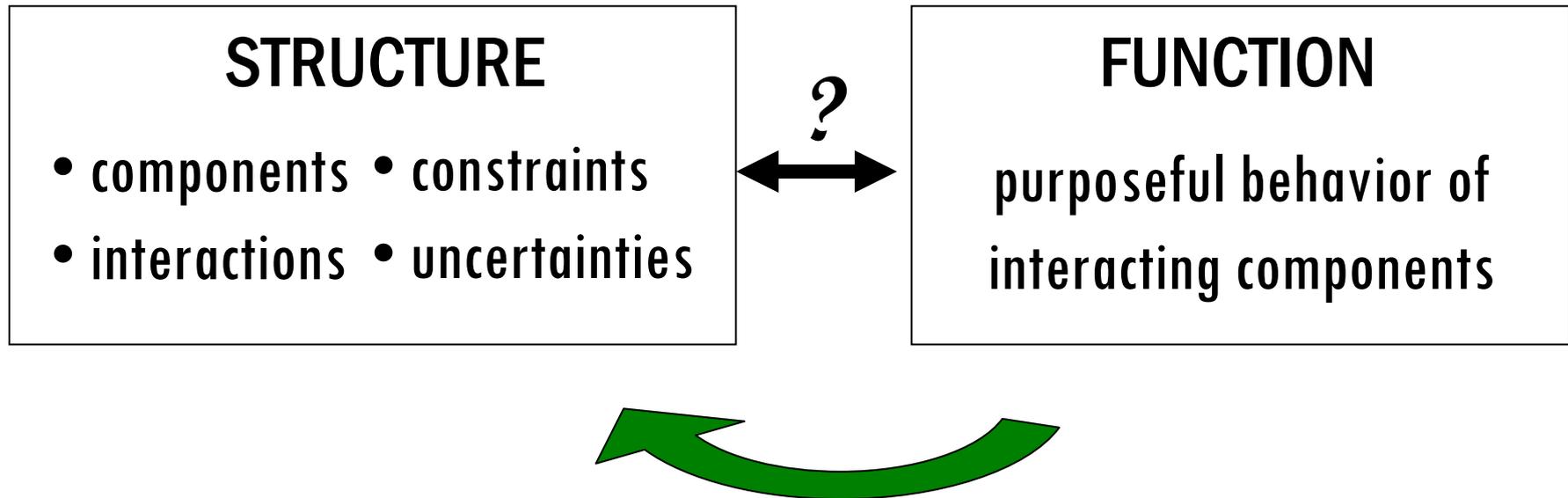
**What “matters” for the given system under study?**



# Human Network Research



The structure of the network has been “designed” to achieve an existing function



What was this human network designed to do?  
How does it's function relate to its structure and vice versa?  
What resources (human, physical and political are needed?  
Structural measures are not enough  
– context and function matter!



# Clandestine Networks



- When a group chooses “secrecy as part of its existence”, it has then determined the nature of relationships that must exist between persons who possess the secret (Simmel, 1906: 470)
- “Risk enforces recruitment along lines of trust,” which forces clandestine networks to use ***pre-existing networks*** of relationships (Erickson, 1981: 188)
- The use of pre-existing social network layers ***sets limits on the social structure*** of the clandestine network (Erickson, 1981: 188).

The risk premium paid by clandestine networks is their reliance on pre-existing network layers



# Clandestine Networks



- Consider how some data is collected – we find a good source and build up from it ; the snowball effect
  - If the data has been collected based on the first person observed in a clandestine network how will that effect the centrality measures?
  - Is the most central person truly the leader or are they simply the idiot practicing poor OPSEC that we built the network around?
  - How many messages did you get this week directly from the commanding general vs. from a friend? Although the traffic from the general may be less frequent (an apparent pendant node), it may be considerably more important.
- Content, context and function matter as well as structure

**The risk premium paid by clandestine networks is their reliance on pre-existing network layers**



# Human Network Analysis

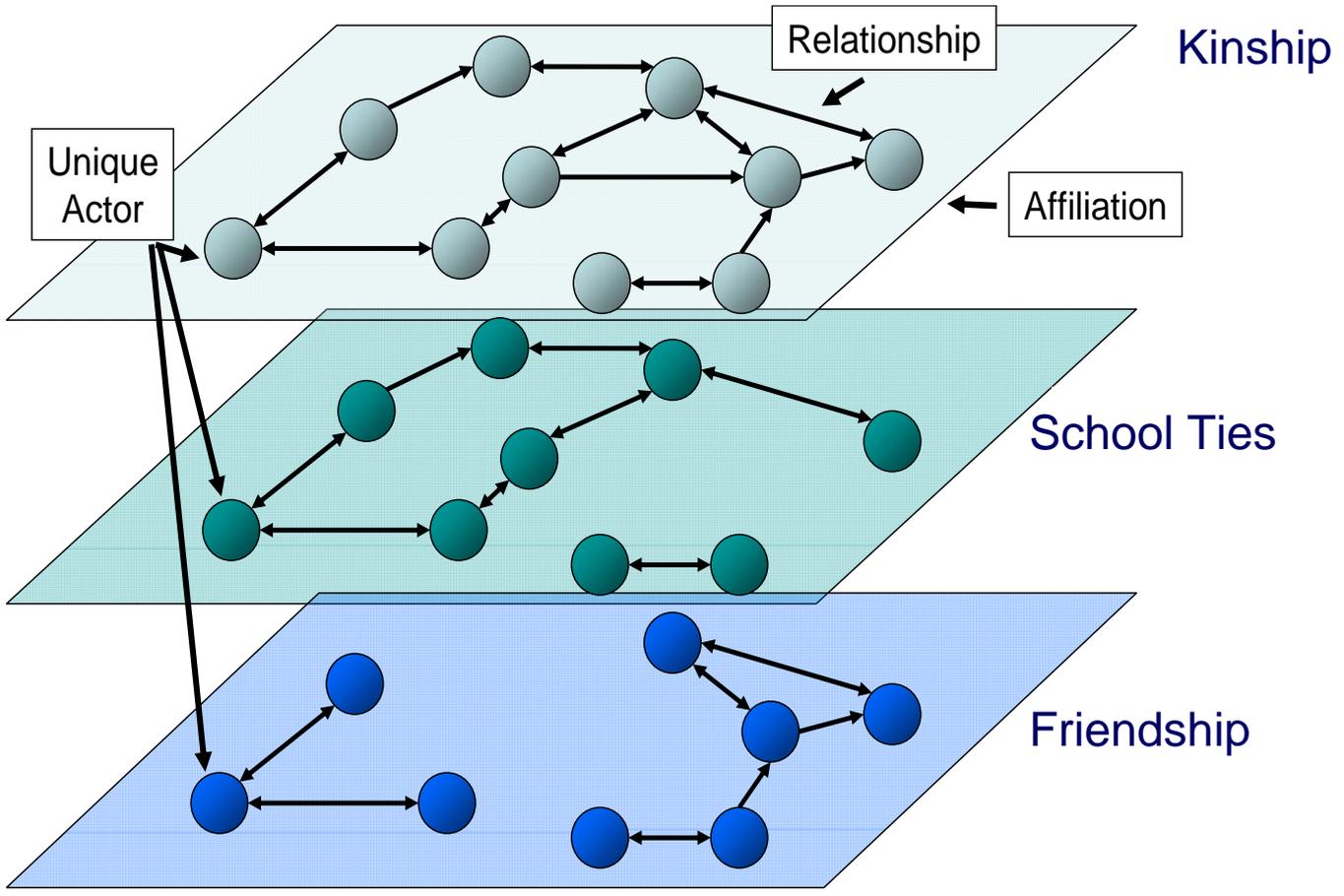
## Staffing Needs – Just My Opinion



- HNA needs to be a “team sport”, but the team must contain people with backgrounds in social sciences, operational modeling, AND military and intel *operations!*
  - The social scientists are needed to assure that the theories are properly applied
  - The operational modelers are need to assure the translation of the theories and functions into actionable models that meet the needs of the folks in the field
  - The operators need to be able to specify requirements (know what to ask for) and understand the uses and limitation of the tools they are being given
- The ideal people will have background in all these areas, but at a minimum, the team members needs to have rudimentary understanding of each area and strength in at least one
- We also need to find the right folks for the tasking as individuals in each of these specialties tend themselves to come from different “tribes” and “cultures” – It is important for them to be effective that they have mutual respect for each others abilities

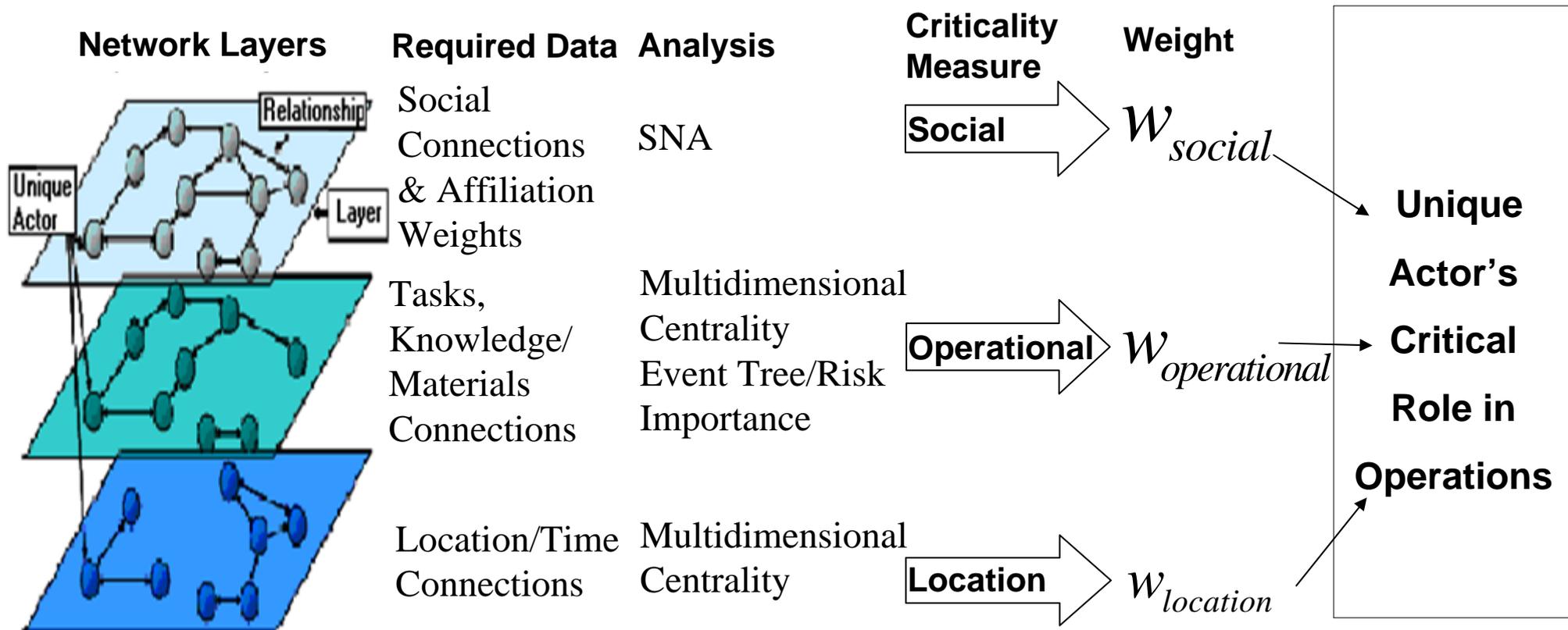


# Multiple Social Network Layers





# Research Approach for Operational Scenario





# Doctoral Research at AFIT in HNA



## **Completed**

- *Modeling and Analysis of Resolve and Spirit for the “Long War”, Maj Michael J Artelli, DSS -07D*
- *Analysis of Layered Social Networks, Maj J. Todd Hamill, DSS-06S*
- *Modeling and Analysis of Social Networks, Capt Robert S. Renfro II, DSS-01S*

## **In progress**

- *Characterizing and Detecting Unrevealed Elements of System Networks, Lt Col James A. Leinart, DSS -08J*
- *An Analysis of Layered Social and Infrastructure Networks, Capt Kevin T. Kennedy, DSS – 09S.*
- *Identifying Communities in Networks (working title), Capt Kevin Calhoun, USAF, expected graduation date Sept 2009*
- Doctoral students in class work or taking their exams who anticipate HNA dissertations: Mr. James Morris, Mr. Jacob Loeffelholz, and Mr. Keith Anthony



# Unrestricted Masters Research at AFIT in HNA



## Completed

- *A Layered Social and Operational Network Analysis*, Capt Jennifer L. Geffre, GOR-07M, (Military Operations Research Thesis Award)
- *Isolating Key Players in Clandestine Networks*, Capt Travis J. Herbranson, GOR-07M
- *Examining Clandestine Social Networks for the Presence of Non-Random Structure*, Capt Joshua S. Seder, GOR-07M
- *Gauging the Commitment of Clandestine Group Members*, 2Lt Doneda D. Downs, GOR-06M.
- *Modeling and Analysis of Clandestine Networks*, Capt Clinton Clark, GOR - 05M
- *Modeling Transnational Terrorists' Center of Gravity: An Elements of Influence Approach*, Capt Cheryl Hetherington, GOR – 05M
- *Aggregation Techniques to Characterize Social Networks*, Capt Sara E. Sterling, GOR - 04M
- *Malicious Hackers: A Framework for Analysis and Case Study*, Capt Laura J. Kleen, GOR - 01M
- *A Value Driven Approach for Evaluating PSYOP*, 1Lt Phillip M. Kerchner, GOR-99M

## In Progress

- *Street Gangs: A Modeling Approach to Evaluating "At Risk" Youth*, Bernard Jacob Loeffelholz, GOR - 08M



# FOIL

## Future Operations Investigation Laboratory

Director: Dr. Richard F. Deckro



- **FOIL** - a light flexible weapon
- **FOIL** - to prevent from accomplishing a purpose; to cut the ground from under
- **FOIL** - a character whose qualities or actions serve to emphasize those of the protagonist or of some other character by providing a contrast with them

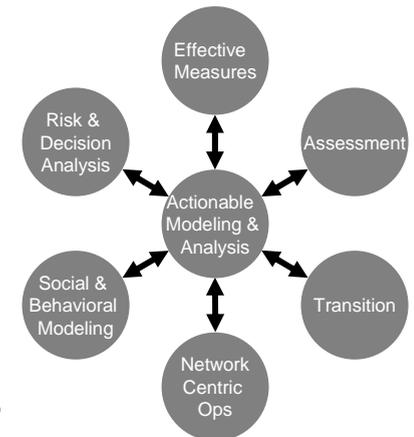
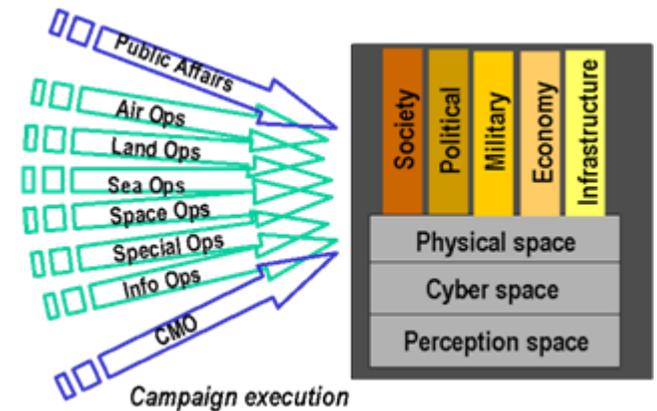
Lab provides operational analysis and research into asymmetric, counter insurgency conflict and its consequences in the 22nd century

Future combat operations are unlike past conventional wars

- Transnational
- Network Centric
- Influence and perception driven
- Communications differences
- Counter insurgency against nontraditional irregular forces
- Transition through the phases of conflict
- A War of Will – “Do or do not... **there is no try**”

Key to success will be

Measures, Models and Analysis to support such efforts, Develops and Incorporates the concepts and practices of DIME and PMSEII into modeling transition across *all* the phases of war and peace.





# Questions?



Bloody Knife, Custer's scout, on Yellowstone Expedition.  
Photographed by William R. Pywell, 1873.