



Institute for Defense Analyses
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Potential Applicability of Ops Analysis Techniques

Presentation to MORS workshop on Analysis of Non-
Traditional Security Challenges: Methods and Tools
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The Original Motivation for this Brief

- Develop the ability to evaluate engagement, security cooperation, military assistance to civil authorities, interagency coordination, deterrence, public information, stability & humanitarian ops, civil affairs, and PSYOPS in some **quantitative** manner, *relating effort input to measurable results output*, defining measures of required capability/capacity, and all the other things that we more or less know how to do for military combat operations but that have not been widely applied to these "**soft**" **dimensions of military power**

Sounds like simulation: "driving a model of a system with suitable inputs and observing the corresponding outputs"

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Questions Related to OR and Non-Traditional Security Challenges

- What did OR do before we had a tradition?
- What is OR as a discipline?
- What kind of quantification does “soft” military power admit?
 - What disciplines are involved?
 - What is the state of their ability to quantify effort input to measurable results output?
- Are we ready for simulation?
- What is the way ahead?

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Eras of Operations Research

- Before OR
 - War gaming at War Colleges – some mathematical analysis (Lanchester/Chase equations)
- World War II
- Operations Research as a discipline
- Complexity sciences?

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- *Operations research is a **scientific method** of providing executive departments with a **quantitative** basis for decisions regarding the operations under their control.*
 - Many other aspects can enter: politics, morale, tradition, items often important but impossible to express in numbers. **It is the prerogative and responsibility of the executive officer to add these factors** to the quantitative basis provided by the operations research group, to reach final decision.

Morse & Kimball, *Methods of Operations Research*, 1950



- Multidisciplinary research teams
 - Physics, Math, Biology, Chemistry, Economics
- Methods:
 - Operational Statistics
 - Operational Experiments
 - Analytical Methods
- “hemibel thinking”
 - Factor of 3 improvements

“The object here is to assist in finding means of improving the efficiency of operations in progress or planned in the future. To do this, past **operations are studied to determine the facts, theories are elaborated to explain the facts, and finally the facts and theories are used to make predictions** about future operations.”

“Operations research is fruitful *only* when it studies *actual operations*.”



Applying OR to “Soft” Military Power

“A well schooled man is one who searches for that degree of precision in each kind of study which the nature of the subject at hand admits” Aristotle

Are we asking of operations research something that it is ill-suited to do?

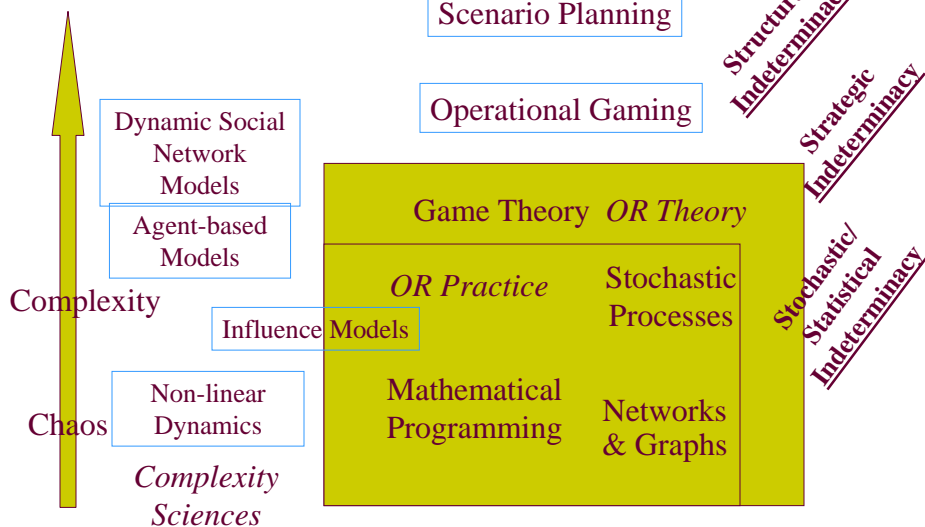
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Analytic Methods and Indeterminacy

Unpredictability



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Structural Indeterminacy

- Structure
 - Boundary of system
 - Elements
 - Relevant relations between elements
- Feature
 - Significant indeterminacy in structure
- Techniques
 - Operational (War) Gaming
 - Scenario Planning
 - Social Sciences (non-kinetic, soft power)

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Features of Problem that Should Inform the OR Approach

	Deterministic	Statistical Indeterminacy	Stochastic Indeterminacy	Strategic Indeterminacy
Features	1. State space clearly defined 2. Persistent data 3. Units of measure understood 4. Relationships determined 5. Initial state known	1. State space clearly defined 2. Persistent data 3. Units of measure understood 4. Probability distributions known or ability to run enough trials	1. State space clearly defined 2. Persistent data 3. Units of measure understood 4. Relationships determined 5. Transition probabilities known	1. Conflicting interests 2. Players specified 3. Information conditions well specified 4. Probability distributions for "moves of nature" specified 5. Player tastes and beliefs known 6. Players consistent and logical (rational)
Techniques	Mathematic Analysis and Programming	Regression, Analysis of Variance	Stochastic Processes	Game Theory
Solution Characteristics	Unique solution	Unique distribution	Unique distribution	Nash Bargaining solution (2 players) Sets of solutions (>2)

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OR techniques presume structure and have difficulty accounting for history



Complexity Science Approaches

- Non-Linear Dynamics
 - Deterministic
 - Chaos: strong sensitivity to initial conditions
- Agent-based modeling
- Dynamic Social Network Modeling
 - Agents on networks
- Statistical Mechanics/Thermodynamics, Statistical Fields, Information & Computation Theory, Fractals/Scaling/Renormalization, ...

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Agent-based models

Features

1. Local interactions give rise to global behaviors
 2. Specified relations
 3. Can be admit emergent behavior
 - history matters
 4. Difficult to validate rules
- Analysis poses real challenges:
 - History as:
 - News (chronological)
 - Perspective of single actor
 - Global perspective
 - Large patterns
 - Distinguishing typical from idiosyncratic results
 - Sensitivity analysis
 - Sharing results difficult
 - Limits of reports
 - Useful for training & experimental learning

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Value of Good Gaming

- Multiple actors affect outcome
 - Humans simulating humans
- Actors have bounded rationality, adapt in non-optimal ways
 - History matters
- Information conditions (who knows what and acts when) are path dependent
 - Command and Control matters
- Decision makers participate in the analysis
 - Synthetic experience
 - Participation in the analysis

**Gaming was the method of choice before
Ops Research or computer simulation**

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Representative Disciplines Involved in “Soft” Power

- Anthropology
 - Economics
 - Government
 - History
 - International Relations
 - Political Science
 - Psychology
 - Regional and Functional area studies
 - Sociology
- Characterized by high degree of structural and strategic indeterminacy
 - Rely principally upon statistical analysis
 - Challenge of reduction
 - Limited ability to quantify effort input to measurable results output
 - Even in economics with readily quantifiable data

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Criteria for investing in simulations of “soft” military power

- Internal Validity
 - Error free programming
- Usability
 - Ability of the researchers, and customers, to understand how the model works
- Extendibility
 - Ability of future users to adapt the program to new uses
 - Reusability: ability to access and use components of the model
- Replication of results
 - Reproducible from someone starting from a description of the simulation
 - Criteria
 - Numerical identity, distributional equivalence, relational equivalence (similar functional form)

Robert Axelrod, *Advancing the Art of Simulation in the Social Sciences*, 1997

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U-boats as IEDs: Selected Examples of WW II OR applicable to the Long War

- Use of MOEs
 - Sweep rates
- Equipment Evaluation
 - AA guns for merchant vessels
 - Relevant MOE
 - Aircraft anti-sub depth bombs
 - Enemy counter measures
 - Acoustical torpedoes
 - Radars
 - Alternative tactics
- Strategical Kinematics
 - Force requirements
 - Requirements for air escort
 - Allocation of effort against U-boats deployed, repair bases, factories
- Tactical Analyses
 - Damage due to suicide planes
- Search Theory
 - Independent patrol
 - Group operations
 - Disposition of air cover
 - Torpedo evasion

We are now back into operations!

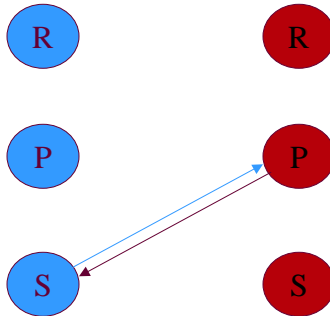
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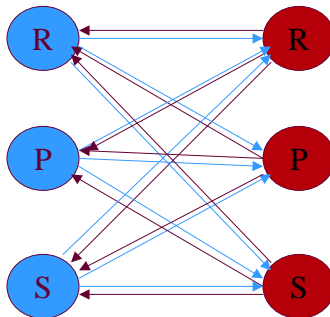
- **Traditional Operations Research**
 - Get the facts!
 - Operational statistics, operational experiments
 - Use multi-disciplinary teams
 - Apply hemibel thinking
- **Exploit data extraction, mining, and display technologies**
 - Google, WALMART, DARPA TIA products
- **Impose strict criteria for simulations**

“in most cases where operations research studies [in WWII] produced striking effects the analysis was cogent but not complicated” Kimball and Morse 1950

Rock-Paper-Scissors



Combined Arms Rock-Paper-Scissors



How many outcomes (states) are possible?

$$2^{2mn} = 2^{18}$$

Dominant Strategy is clear, but difficult to execute

Outcome depends on information and timing

Human decisions and METT-TC considerations severely limit ability to predict outcomes