Self-Organized Air Tasking: Examining a Non-Hierarchical Approach for Joint Air Operations (114)

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Agenda

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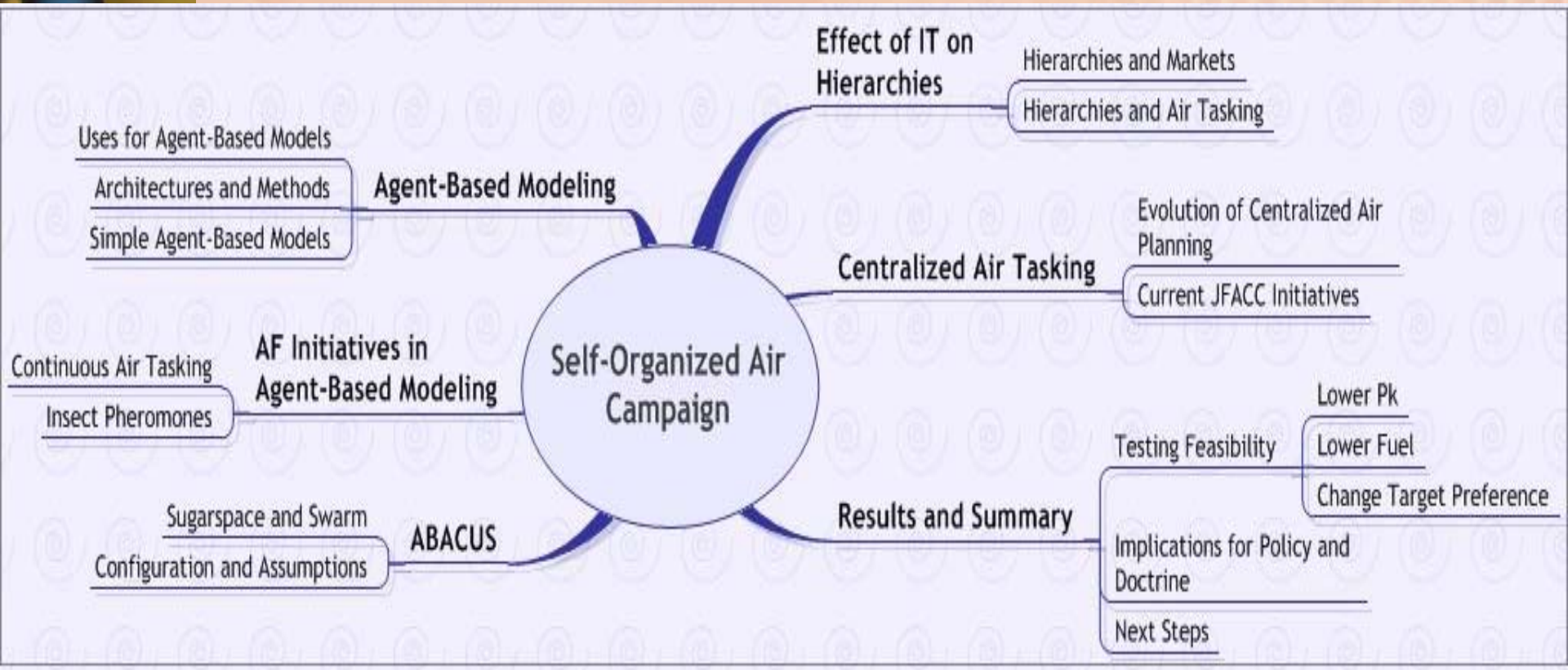
  - Problem statement
  - Hypothesis
- Promise of a non-hierarchical air campaign
  - Air Force operations – Centralization of control
  - Hierarchies, markets, and air tasking
- Motivation and Research Method: Agent-based modeling
- Application of agent-based simulation to air operations: ABACUS model
  - Findings
  - Issues and caveat
  - Operationalizing the model
- Next Steps

Structure of Paper

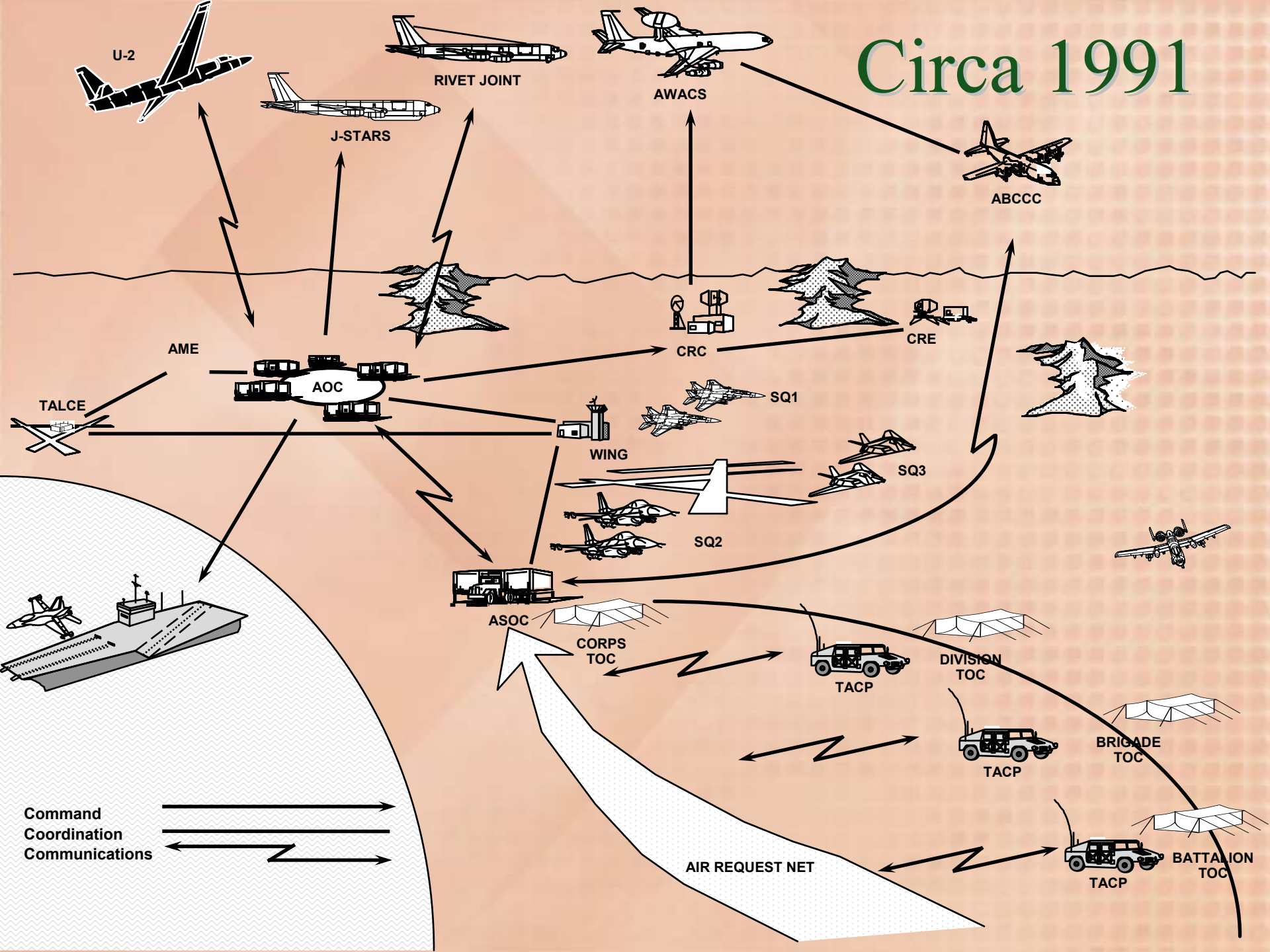


Problem Statement

- Air Force operations may be inefficient, due to their scripted nature.
- A decentralized execution – where attacking aircraft select targets dynamically – may lead to a more efficient use of scarce resources in an air war.
- The first step: Is such a decentralized execution feasible?

Hypothesis

It is possible to structure a non-hierarchical approach to air tasking in the conduct of Joint air operations


Circa 1991
U-2
RIVET JOINT
AWACS
J-STARS
ABCCC
AME
AOC
CRC
CRE
TALCE
SQ1
WING
SQ3
SQ2
ASOC
CORPS TOC
TACP
DIVISION TOC
BRIGADE TOC
TACP
TACP
BATTALION TOC
AIR REQUEST NET
Command
Coordination
Communications

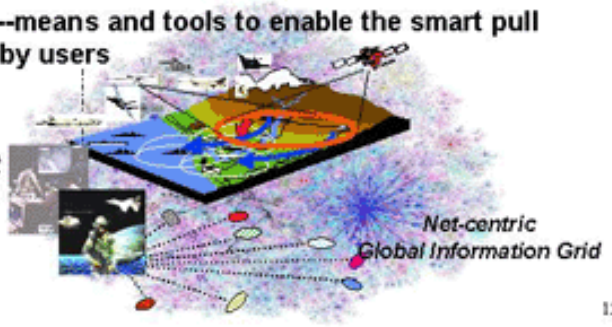
Digitization of the Battlefield

Horizontal Fusion - Power To The Edge

Part of an integrated network transformation effort:

- *GIG Bandwidth Expansion--Provides ubiquitous, secure, robust foundation fiber optic network*
- *Advanced WB SATCOM--incorporates mobile/tactical users and global intelligence services via optical cross links and EHF up/downlinks*
- **Horizontal Fusion--means and tools to enable the smart pull and fusion of data by users**

Fused Information Available on the Net Customized for Use



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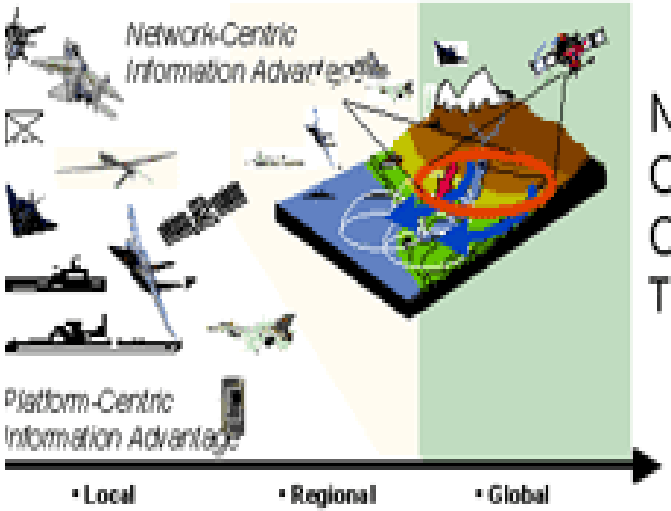
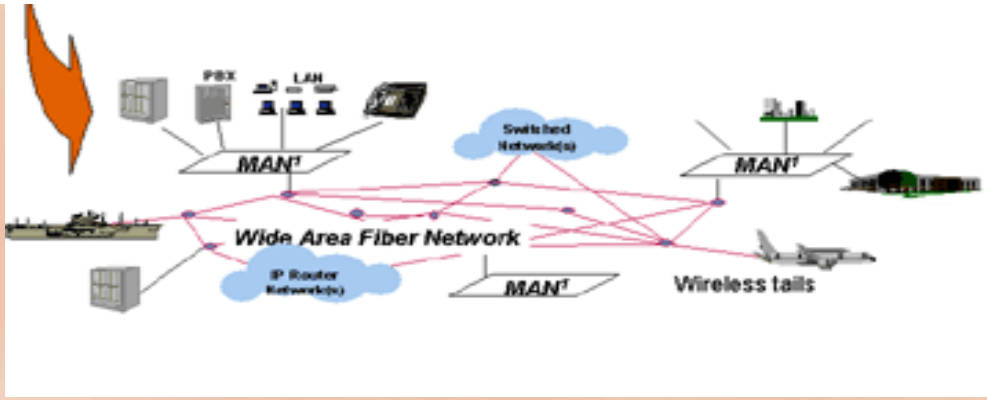


Network Centric Operations The Way Ahead



Initiatives to Provide the Common Picture

- Global Information Grid (GIG)
  - "globally interconnected, end-to-end set of information capabilities, associated processes and personnel for collecting, processing, storing, disseminating, and managing **information on demand to warfighters**, policy makers, and support personnel"
- DoD C4ISR Architecture Framework
  - Common data abstraction (integrated design environments) allow for the sharing of information throughout the planning and execution phases.
  - Defines standards and protocols for data transport
- Defense Information Infrastructure Common Operating Environment (DII COE)
  - "Multi-faceted approach for enhancing software and data reuse and interoperability"

GIG Systems Reference Model

Air Force Operations

- Strategic vs. tactical
  - Support to ground troops
    or
    Douhet/Warden school of strategic warfare
- Move to centralize after Vietnam experience
  - Inefficient resource allocation
- Navy use of airpower still somewhat decentralized, semi-autonomous platforms
- Tension remains regarding centralized control
  - As decentralized execution is an "Air Force tenet," this research may be viewed by some as advocating autonomous operations

Hierarchies and Markets

- Advances in information and communication technologies have led to innovations in private sector organizational structures, due to decentralized decision making
  - Represents a change from time when CEO/Ruler had enough knowledge to make decisions for his enterprise
  - Reduced layers of approval.
  - Larger span of control for senior management enabled through decision support technologies
- Flattened (but not dissolved) hierarchies evolve into market-based organizational structures
  - The hierarchy is challenged at each function and level to prove its contribution to the firm's competitive edge.
  - 'New' organizational structure is driven by customer relationships and the firm's core competencies in serving a dynamic marketplace.

Hierachy – authority is used to effect resource allocation

Markets – price system signals resources allocations needs and opportunities

Hierarchies and Air Tasking

- Reducing information asymmetries can lead to decentralized decision-making (as more nodes have “full” knowledge of environment)

- In an intelligence-rich environment; it may be costlier – with regards to time – to require platforms to get approval for resource reallocation
  - If the transaction cost for markets involves finding out the prices, the GIG may provide all the information necessary for decentralized asset reallocation

Motivation

- During campaign, inside the planning cycle
  - Air attack assets will become unexpectedly available
  - Targets will emerge
- A completely scripted air campaign, as effective as it is, by definition does not address these contingencies
- RMA was made up of several elements, the increase of which should exert pressures on existing doctrine:
  - speed, agility, lethality, and **information**

Construct a non-hierarchical model for the tasking of air assets in order to test a value network (agent-based) approach to the servicing of targets in an air campaign

JFACC & Phasing

- The source of Grand Strategy for U.S. air operations is the Joint Force Air Component Commander (JFACC)
- JFACC, reflecting Joint Force Commander's intent, establishes goals for each phase of the campaign.
- Air Apportionment: Scheduling of resources and target classes for priority attack
- Air Allocation: Scheduling of individual platforms against individual targets

Commander's Intent: Gain and Maintain Air Superiority

- Destroy/disrupt enemy aircraft and cruise missiles in flight
- Suppress enemy surface-based air defenses
  - Destroy/disrupt fixed SAM launchers
  - Destroy/disrupt mobile SAM launchers and AAA guns
  - Destroy/disrupt tracking and guidance radars
- Suppress generation of enemy air sorties via attacks on airfields
- Degrade enemy command and control of air forces and integrated air defenses
  - Destroy command bunkers and other critical nodes
  - Destroy/disrupt communications
  - Destroy EW/GCI radars
  - Destroy mobile command posts
  - Destroy airborne command/control and surveillance platforms

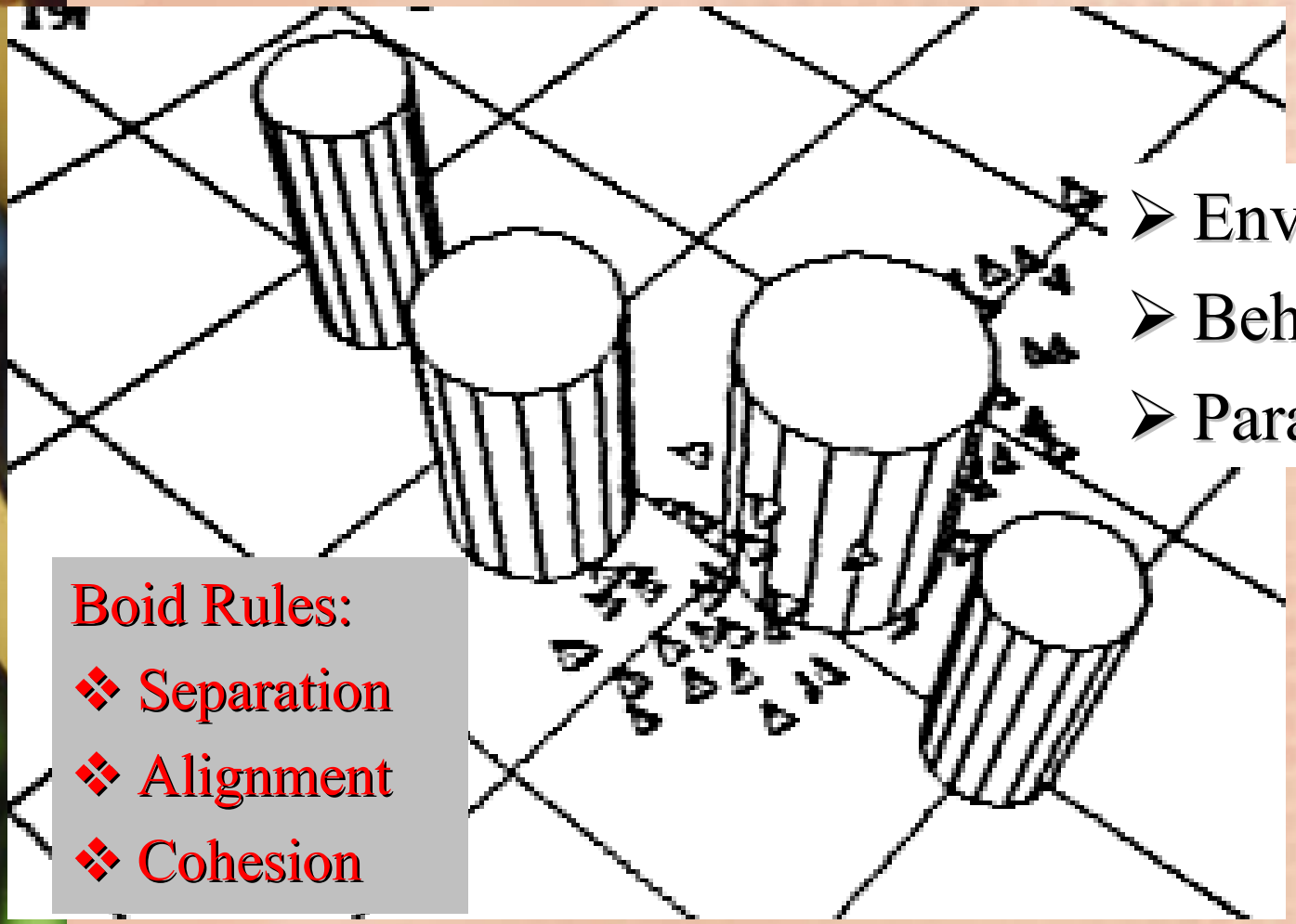
Model Challenge: Test the Decentralized Execution of a Grand Strategy

"The big issue in decentralization is the emergence of coordinated behavior in the absence of a coordinator" - Scott E. Page

Method: Agent-Based Modeling

- Used primarily for three purposes
  - Social Systems – Anthropomorphic applications for social insight
    - "Bottom-up social science" [Epstein and Axtell, *Growing Artificial Societies*]
  - Computational Economics
  - Artificial Life – Decentralization of grand strategy
    - ***Focus for this work: use agent-based simulation to test the feasibility of decentralizing the execution of a grand strategy for air operations***

Agent-Based Models



- Environment
- Behaviors
- Parameters

Boid Rules:

- Separation
- Alignment
- Cohesion

Boids with Obstacle Avoidance – Craig Reynolds (1986)

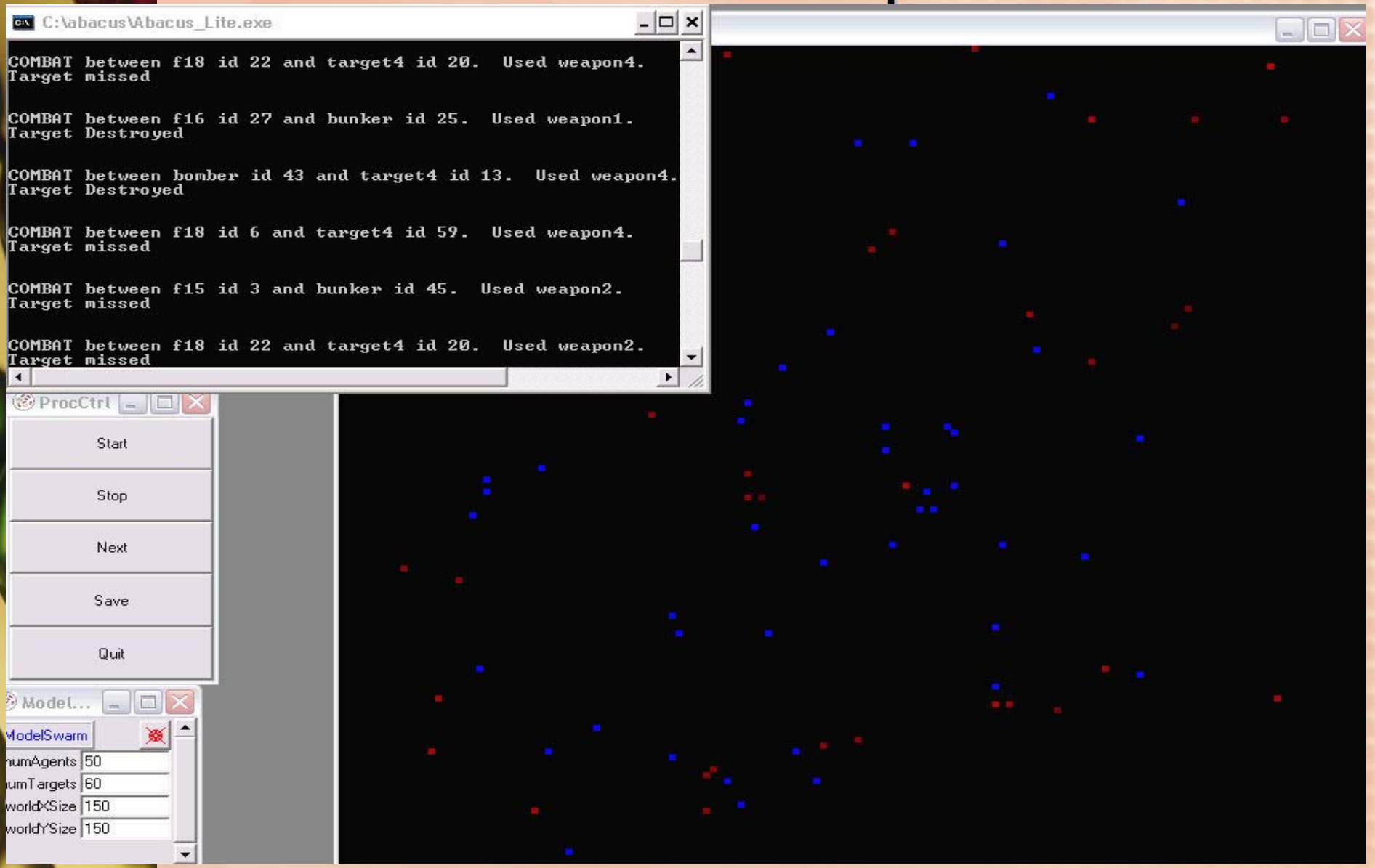
http://www.red3d.com/cwr/boids/

Building ABACUS

- Swarm modeling environment
  - Objective C
  - Allowed for construct of rule-based agents and environments; and parameterization
- Sugarscape application – build within Swarm
  - Used because it combined autonomous, mobile agents with cellular automata
    - Originally, targets were to be represented by static cells
- ABACUS uses two types of agents: Aircraft and targets (mobile and fixed)

Agent-Based Air Campaign Using Swarm

Applying Agent-Based Simulation to Air Operations



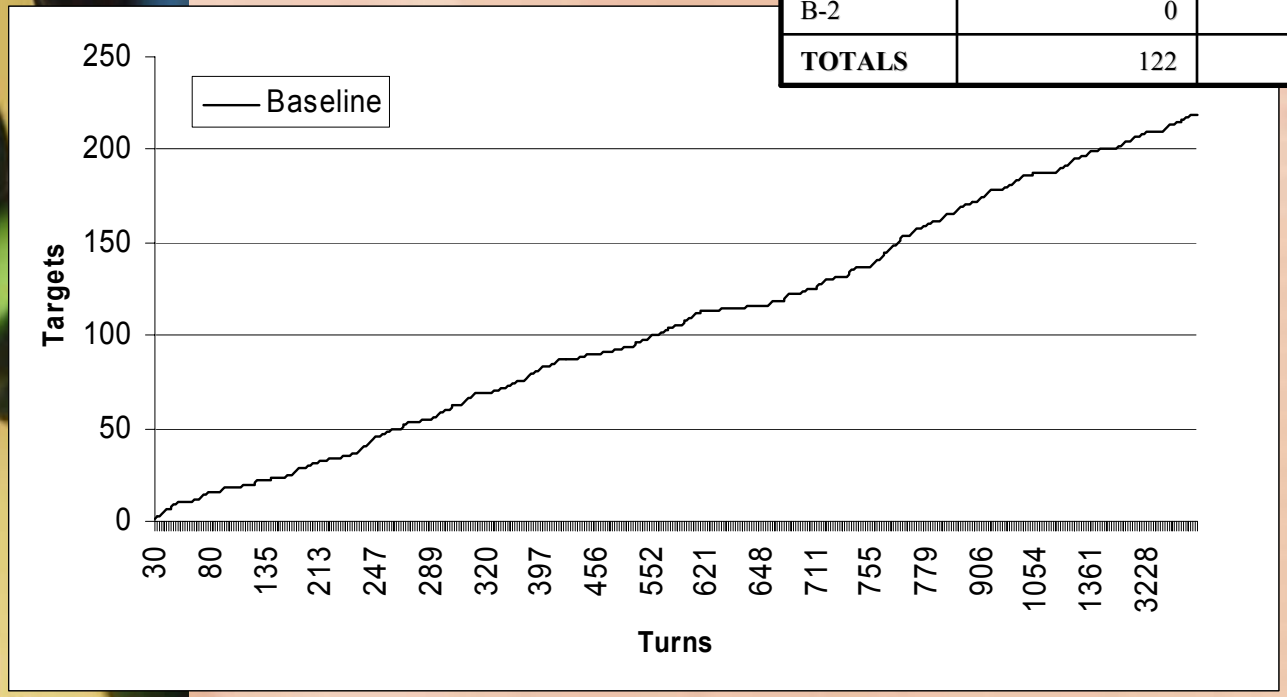
Findings

- Two tests for feasibility
  - Are targets killed in a **reasonable** amount of time?
  - Does the resulting campaign appear to be a **reasonable** approximation of air combat?
- Test three scenarios for ‘reasonableness’
  - Cut PK
  - Cut Fuel
  - Prefer SAMS over Command and Control (C2) nodes
    - Default is to prefer C2 nodes

Baseline Results

- ✓ Targets are killed over time

Baseline	609 total weapons				
	AGM-65	TMD-WC-SFW	JDAM	Mk-82	**TOTALS**
F15E	93	0	0	169	262
F16	29	0	0	82	111
F18EF	0	0	56	62	118
B-2	0	118	0	0	118
TOTALS	122	118	56	313	609

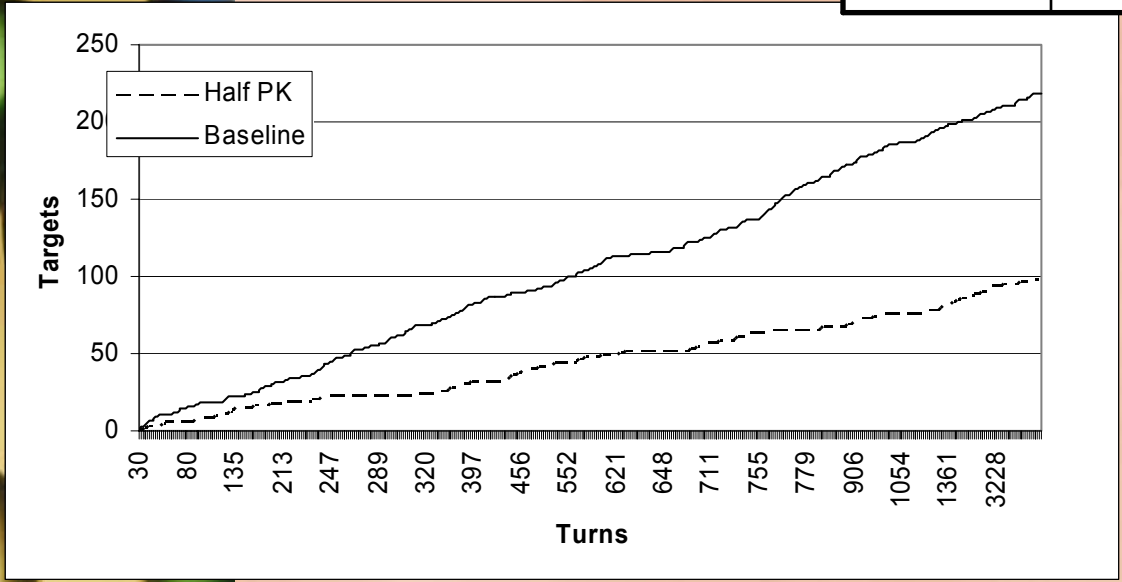


Reasonable behavior?

Cut the Pks by Half

- ✓ Fewer targets are killed over time
- ✓ More weapons expended over time

Half Pk	1088 total weapons				
	AGM-65	TMD-WC-SFW	JDAM	Mk-82	**TOTAL**
F15E	137	0	0	260	397
F16	38	0	0	129	167
F18EF	0	0	129	212	341
B-2	0	183	0	0	183
TOTAL	175	183	129	601	1088

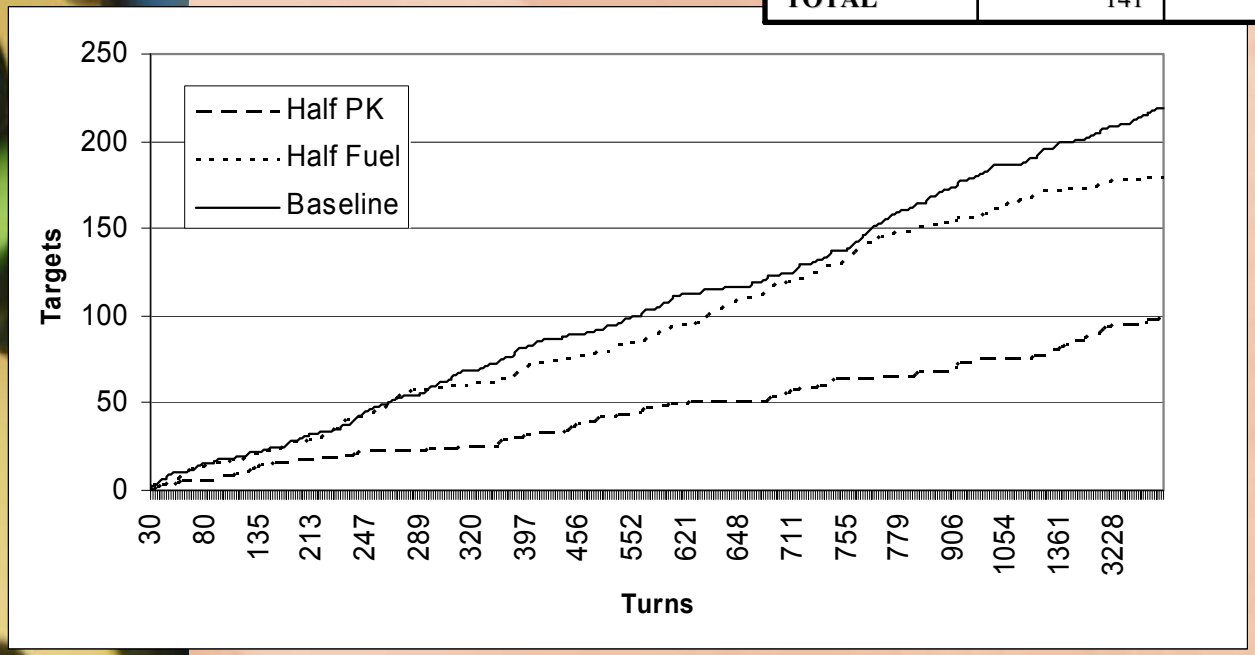


Reasonable behavior? With less effective weapons, we should find more futility (more weapons, fewer results)

Cut Fuel by Half

- ✓ Fewer targets are killed over time
- ✓ More weapons expended

Half Fuel	694 total weapons				
	AGM-65	TMD-WC-SFW	JDAM	Mk-82	**TOTAL**
F15E	86	0	0	165	251
F16	55	0	0	121	176
F18EF	0	0	84	119	203
B-2	0	64	0	0	64
TOTAL	141	64	84	405	694

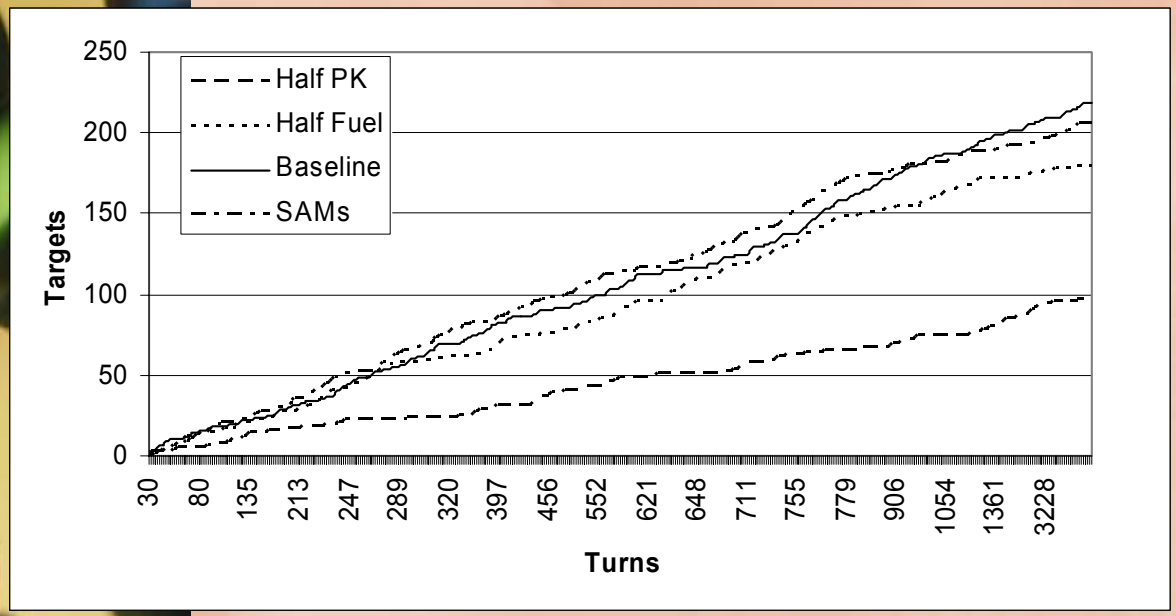


Reasonable behavior? Mission times are shorter, less time-on-station; also run takes longer (more targets generated because of longer run time)

Change Preference from C2 to SAMs

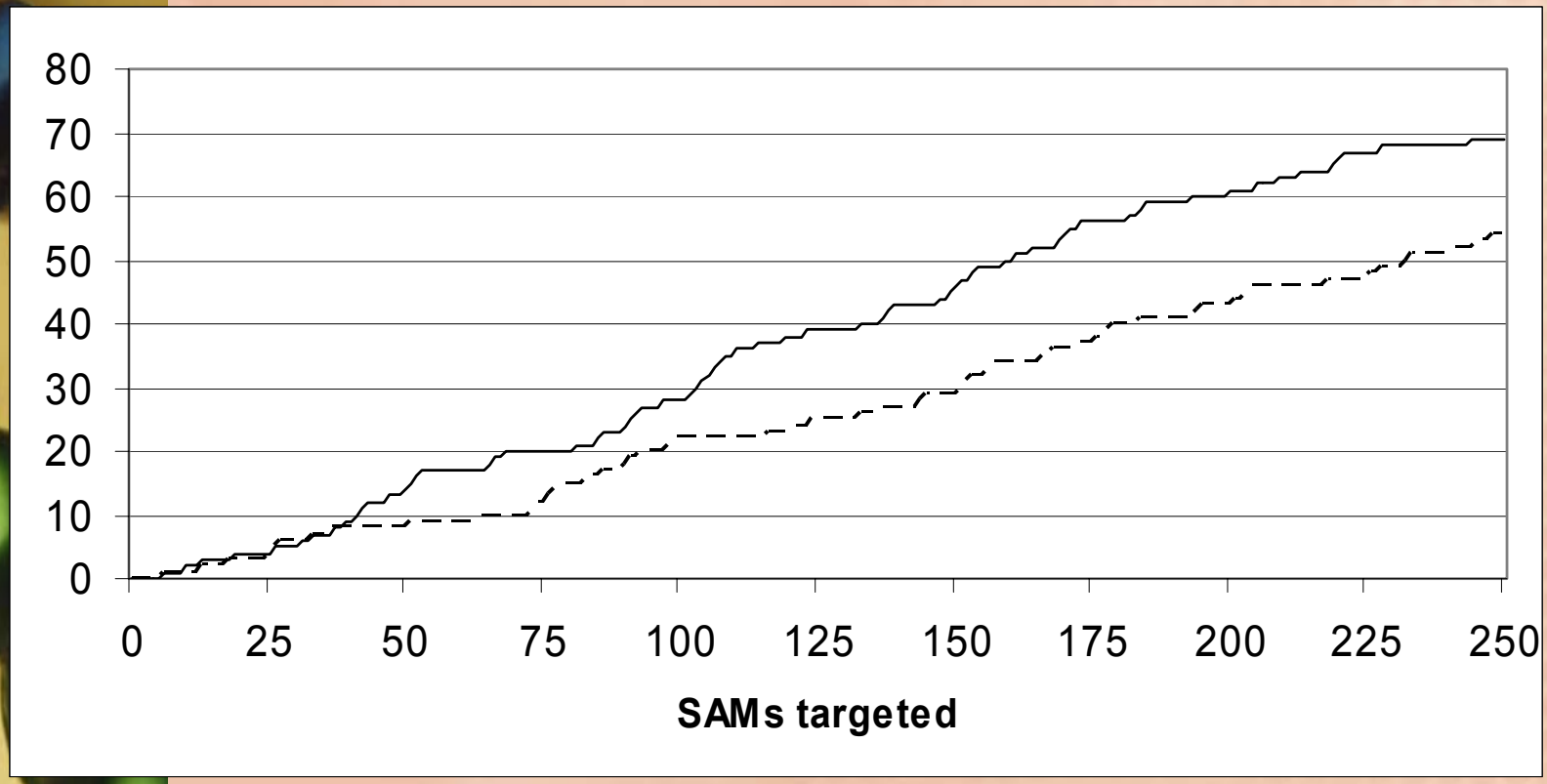
- ✓ Slightly more targets are killed
- ✓ More weapons used

Prefer SAMs	664 total weapons				
	AGM-65	TMD-WC-SFW	JDAM	Mk-82	**TOTAL**
F15E	67	0	0	139	206
F16	46	0	0	104	150
F18EF	0	0	95	116	211
B-2	0	97	0	0	97
TOTAL	113	97	95	359	664



Reasonable behavior? There are more SAMs than C2 Nodes

SAMs are Preferred



SAMs Preferred

Baseline

Issues

- Why would a non-hierarchical campaign not be **THE** answer?
  - Strategic effects (Warden) are best achieved through degradation of key targets in a timely sequence, to encourage the collapse of interlocked systems
- Why would the Air Force resist?
  - History is not kind to decentralized air tasking
- Where might it work,?
  - In a target-rich, resource-constrained environment with extremely good target intelligence available to all platforms
- Where might it not work?
  - Anywhere else

Caveat

"I don't think we've automated a man's capability to read the situation and say, 'Well it's a very fine target, but it's only the lead element, so let's go here and further develop the situation.'"

- LGEN John M. Riggs, USA

Operationalizing the Model

- Agent communication in model is through landscape
  - In practice, they would communicate across the "digitized battlefield."
- Inform emerging doctrine regarding
  - JFACC communication links
  - (intelligent) RPVs

Next Steps

- Needs IV&V
- Assign awareness to red agent behavior
  - Provide for active defenses.
- Introduce uncertainty, perhaps provide for partial coverage area for (assumed) sensors.
- Compare agent-based approach to centrally-planned against efficiency metrics; adherence to commander's intent
  - Which is a more efficient use of resources?
  - If perfect information is assumed for both approaches, why would self-organizing be preferable?

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