The Analysis of Network Centric Maritime Interdiction Operations (MIO) Using Queueing Theory

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Canada

Overview

- TTCP Action Group 1
- NCMW Analysis
- Maritime Interdiction Operations
- Queueing Theory
- Results
- Conclusions

The Technical Cooperation Program

- is an international organization that collaborates in defence scientific and technical information exchange; program harmonization and alignment; and shared research activities for the five nations.
- Australia, Canada, New Zealand, United Kingdom and United States

MARITIME SYSTEMS GROUP
AG-1 – NetCentric Warfare Study

- MAR Group is responsible for collaborative research and development of Maritime and Undersea Warfare technology
- Action Group 1
  - Three year mandate to explore and quantify the effects of Netcentric Warfare on Maritime Coalition operations.
  - Chair: Ray Christian, NUWC
  - Two sub-groups
    - Broad issues and longer-term NCMW effects
    - Short-term/tactical effects

RATIONALE FOR TWO COMPONENT STUDIES

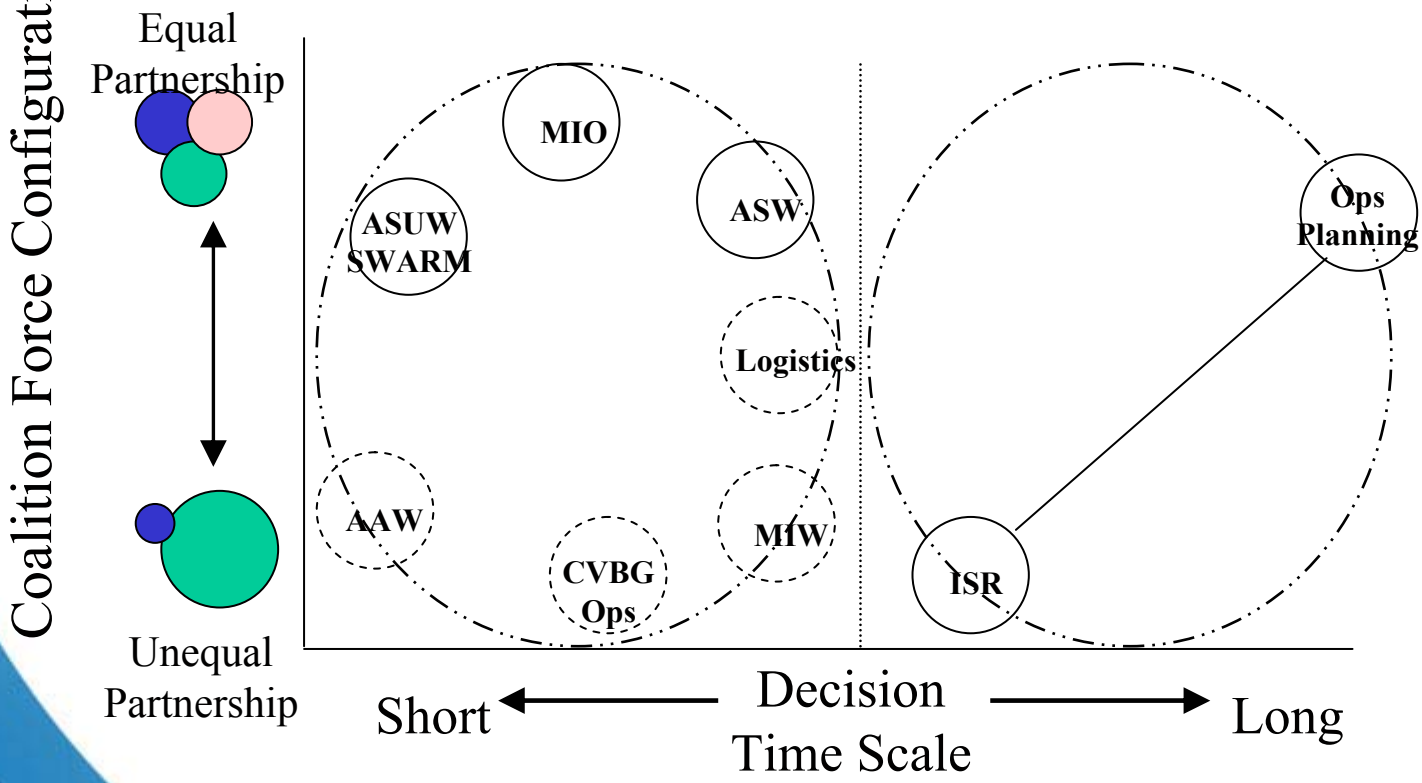
(Scales of Coalition Interoperability)

Study B (Tactical Level)

- TACSIT-based tasks
  - Relevant
  - Littoral
- Sense-Decide-Respond
- Connectivity dependence
- Tactical MOEs/MOPs

Study A (Broad Issues)

- First Principles:
  - NCW
  - Net-enabled Distributed Maritime Systems
- Quantitative analysis of alternative networking options in:
  - ISR
  - Operational Planning



Definition of NCMW

- Network Enabled

Network enabled forces are those that have a networked information system infrastructure that is being used to augment current capabilities.

Infrastructure

- NetCentric

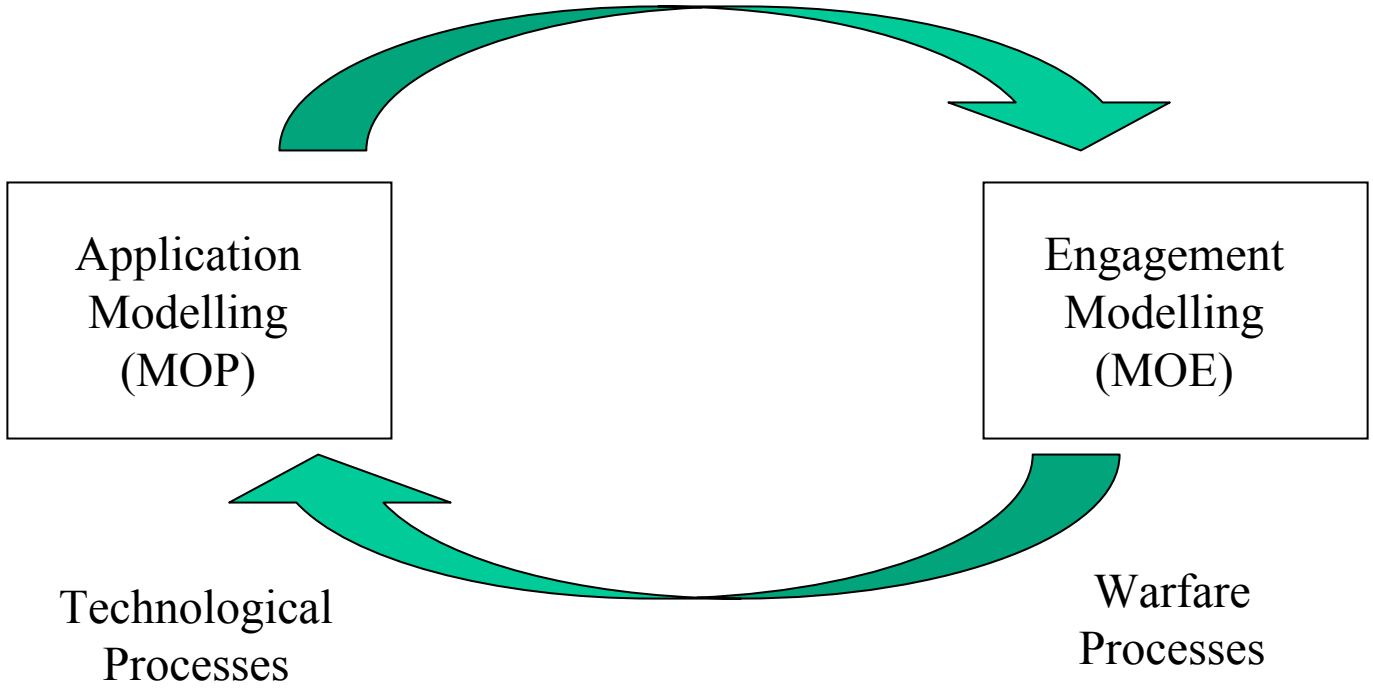
Network-centric warfare is the conduct of military operations using networked information systems to generate a flexible and agile military force that acts under a common commander's intent, independent of the geographic or organisational disposition of the individual elements, and in which the focus of the warfighter is broadened away from individual, unit or platform concerns to give primacy to the mission and responsibilities of the team, task group or coalition.

Human Usage

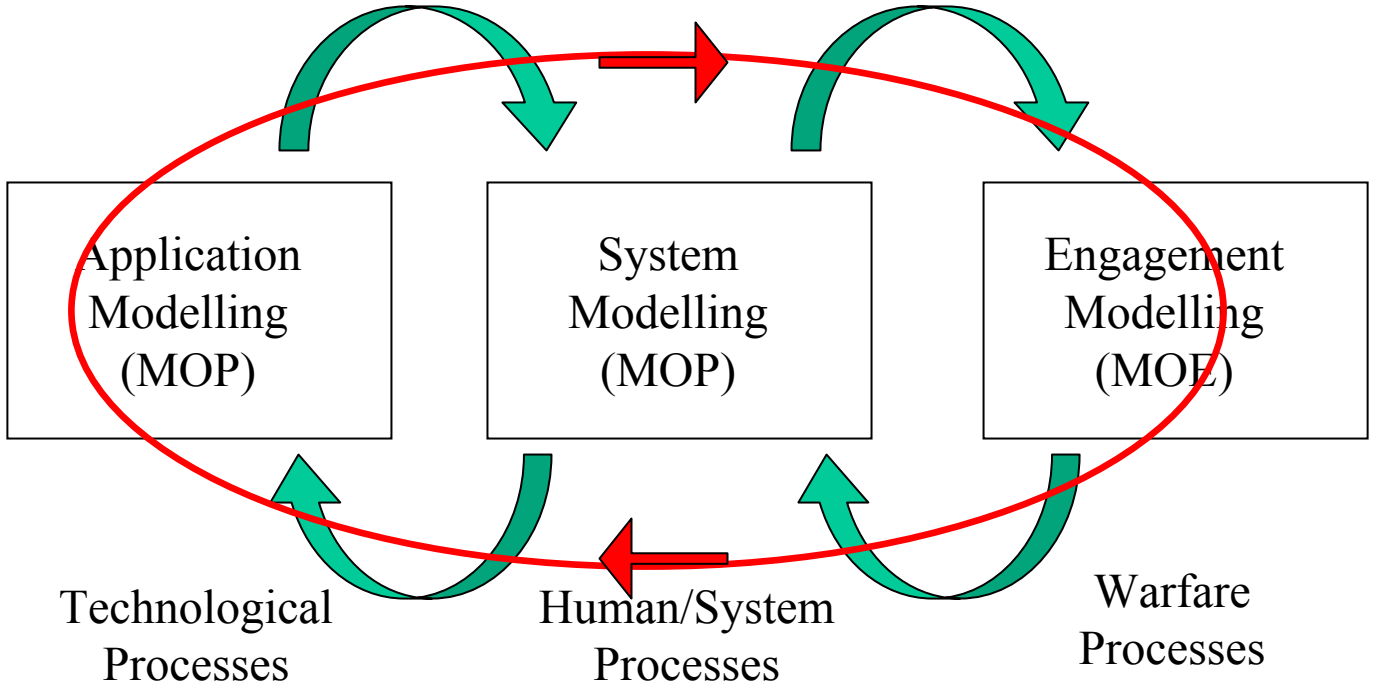
Enabling Technology

- Technical Interoperability
- Secure, wide bandwidth network communications
- IP addressable sensors
- Collaborative Planning tools
- WWW – Spiders / search engines
- Agent based programming
- Digital Imagery
- Multi-level secure operating systems
- Secure encryption

Evaluation of NCMW Military Effectiveness



Evaluation of NCMW Military Effectiveness



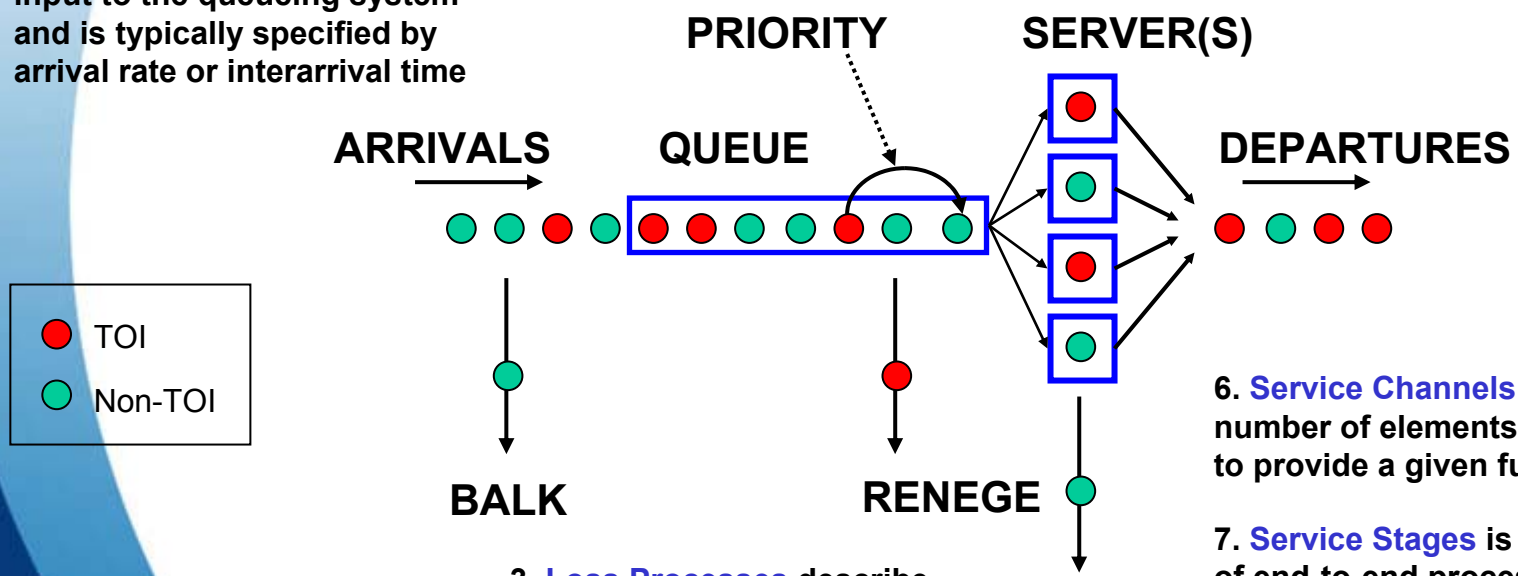
Description of a Queueing System

4. **Queue Discipline** describes how a customer is selected for service once in queue (FIFO, priorities, etc.)

5. **System Capacity** is the maximum size of a queue; finite or infinite

2. **Service Pattern** is described by service rate or service time

1. **Arrival Pattern** describes the input to the queueing system and is typically specified by arrival rate or interarrival time



6. **Service Channels** are the number of elements available to provide a given function

7. **Service Stages** is the set of end-to-end processes for completion of service

3. **Loss Processes** describe how customers can be lost (balking and reneging)

KEY QUEUEING METRICS:
- Probability of a customer acquiring service
- Waiting time in queue until service begins
- Loss rate due to either balking or reneging

R&I

Queueing Theory interrelates key system characteristics and can be used to identify where investment should be made to improve performance and effectiveness

Linking NCMW Technology to QT Paramters

NCMW Products

- ISR push
- Improved (sub)Surface picture (clss/ID), continuous tracking
- Net-enabled comms
- Shared DB (access and dataminig)
  - Sync. platform experience
- ReachForward
  - Offboard Presence in area of hailed vessel
- Reachback
  - Common language for hailing (reachback)
  - Intelligence cells on Carrier
- Just in Time/sync Logistics

Pot'l Mil Effects

- Decreased numbers to intercept
- Decreased time to intercept
- Decreased numbers of night (high risk) boardings
- Decreased Decision Time
- Decreased Query Time
- Decreased Frustration
- Decreased Boarding/secure time
- Decrease Search time
- Increased intercepter availability

QT Inputs

- Arrival rate
- Mean Escape Time
- Mean Engagement Time
- # Servers
- Queue Discipline
- Server Type
- Queue Length (Process capacity)

MAR AG-1 Workshop: Auckland NZ, November 2002

- Can Queueing Theory give insight into either stage of analyzing Maritime Interdiction Operations (MIO)?
- Hypothesis:
  - *In coalition force MIO operations, network-enabled collaborative planning/re-planning increases the probability of intercepting a contraband vessel.*
- Collaborative Planning/Re-planning
  - Networked planning distributed across the force giving all coalition members access to the planning process.

Maritime Interception Operations (MIO)

"MIO is the act of denying merchant vessels access to specific ports for import or export of goods to or from a specific nation or nations. MIO exercises our right [based on the authority of the UN or other sanctioning body] to perform the following:

1. Send armed boarding parties to visit merchant ships bound to, through, or out of a defined area
2. Examine each ship's papers and cargo
3. Search for evidence of contraband
4. Divert vessels failing to comply with the guidelines set forth by the sanctioning body
5. Seize vessels and their cargo which refuse to divert."

"The use of force is closely controlled during MIO… [and] is a measure of last resort…"

Source: NWP 3-07.11, Maritime Interception Operations

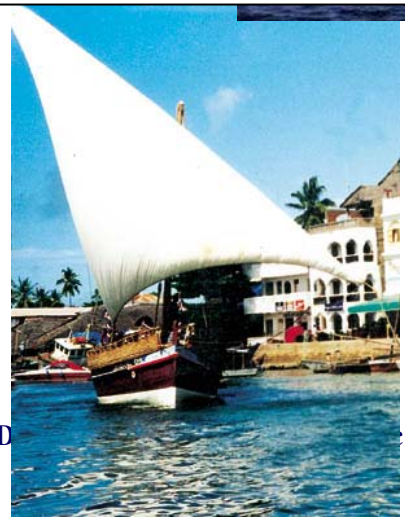
Types of Interception Operations

		Search Time	
		Short	Long
Number of Targets	Few	Illegal Immigrants	IRAQ MIO (cargo ships)
	Many	IRAQ MIO (dhow)	LIO Counter-Drug

Shipping in the Persian Gulf

There are relatively few tankers compared to thousands of dhows and other small boats – thus a queueing problem can arise for MIO forces with the transition to smuggling oil with small vessels

Note the proximity of allied warships to the targets



Go-Fast Interdiction


MAERSK

MIO Engagement Time Line

PLAN MIO AND POSITION ASSETS

T0

SURVEILLANCE AND DETECTION – SEARCH FOR CONTACTS OF INTEREST (T01)

T1

CLOSE THE MV (T12)

T2

QUERY THE MV (T23)

T3

DISPOSE OF THE MV (T34)

- CLEAR AND RELEASE
- APPROACH
- STOP
- BOARD
- TAKEDOWN
- SEARCH
- DIVERT

T4

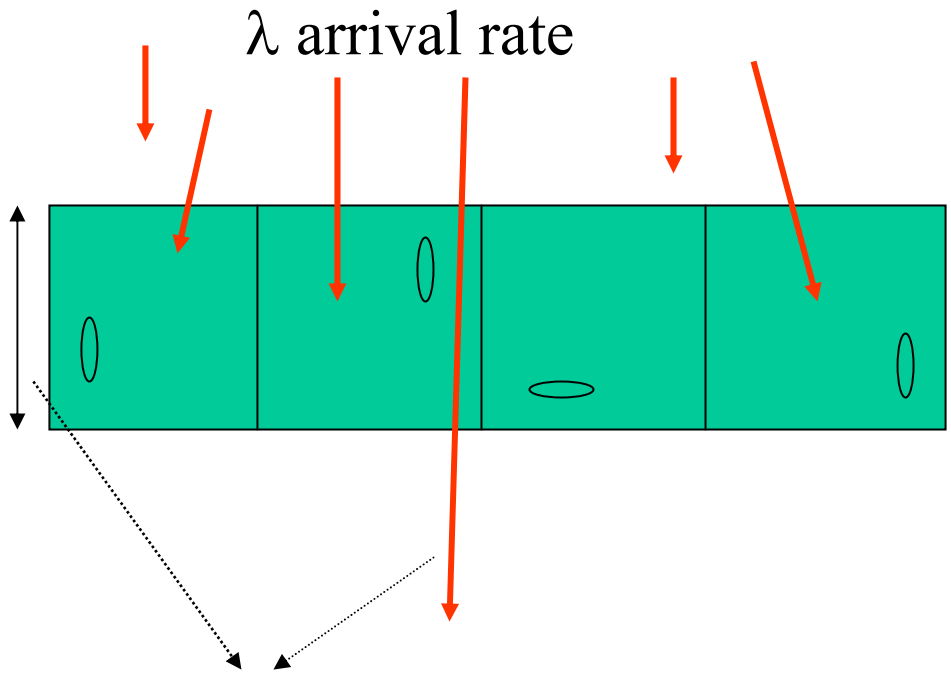
REPOSITION AND RESUME SEARCH FOR CONTACTS (T45)

T5

RETIRE

Mean Service Rate = 1/(Service Time)

"Basic MIO Scenario"



N_s MIO Boxes

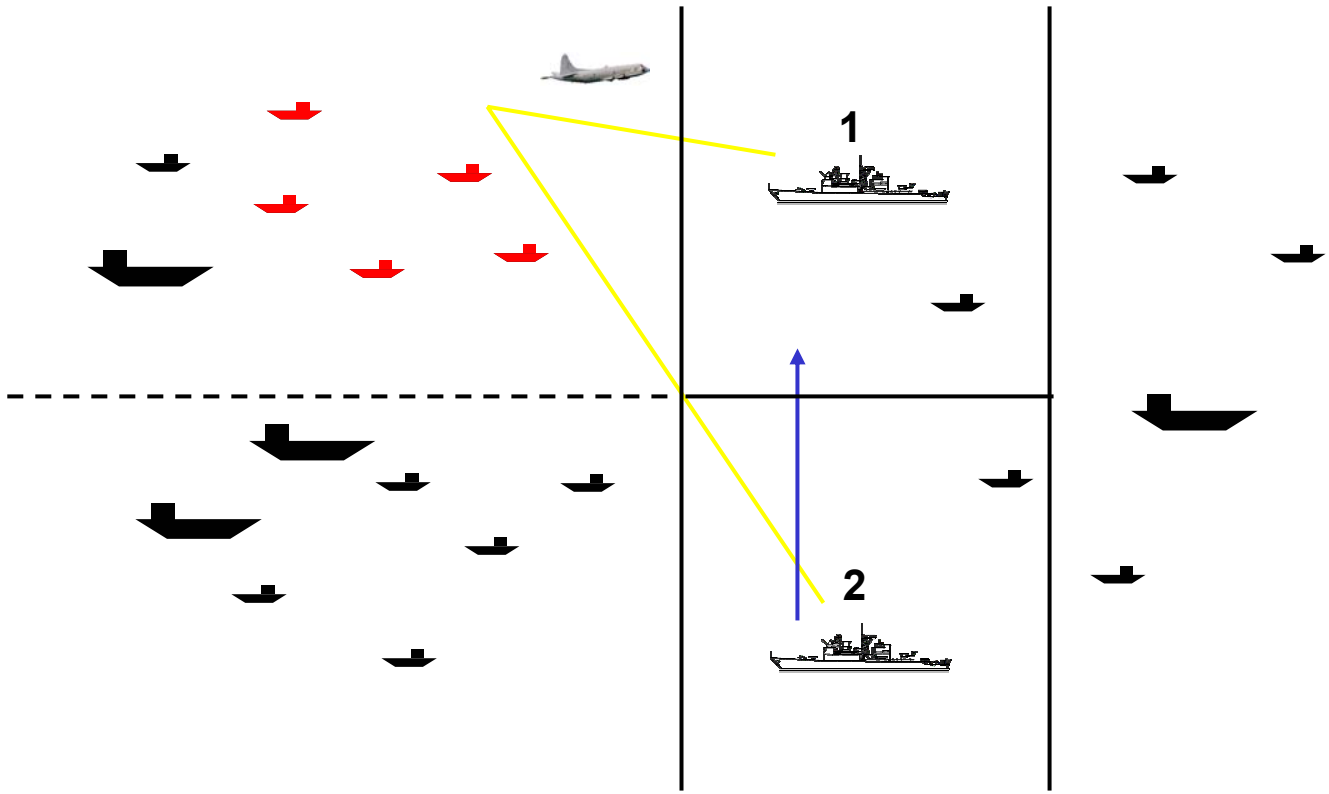
Mean Escape Time
(depth/speed) $1/\alpha$

Mean Engagement Time
$1/\mu = E[\Sigma$ MIO phase times$]$

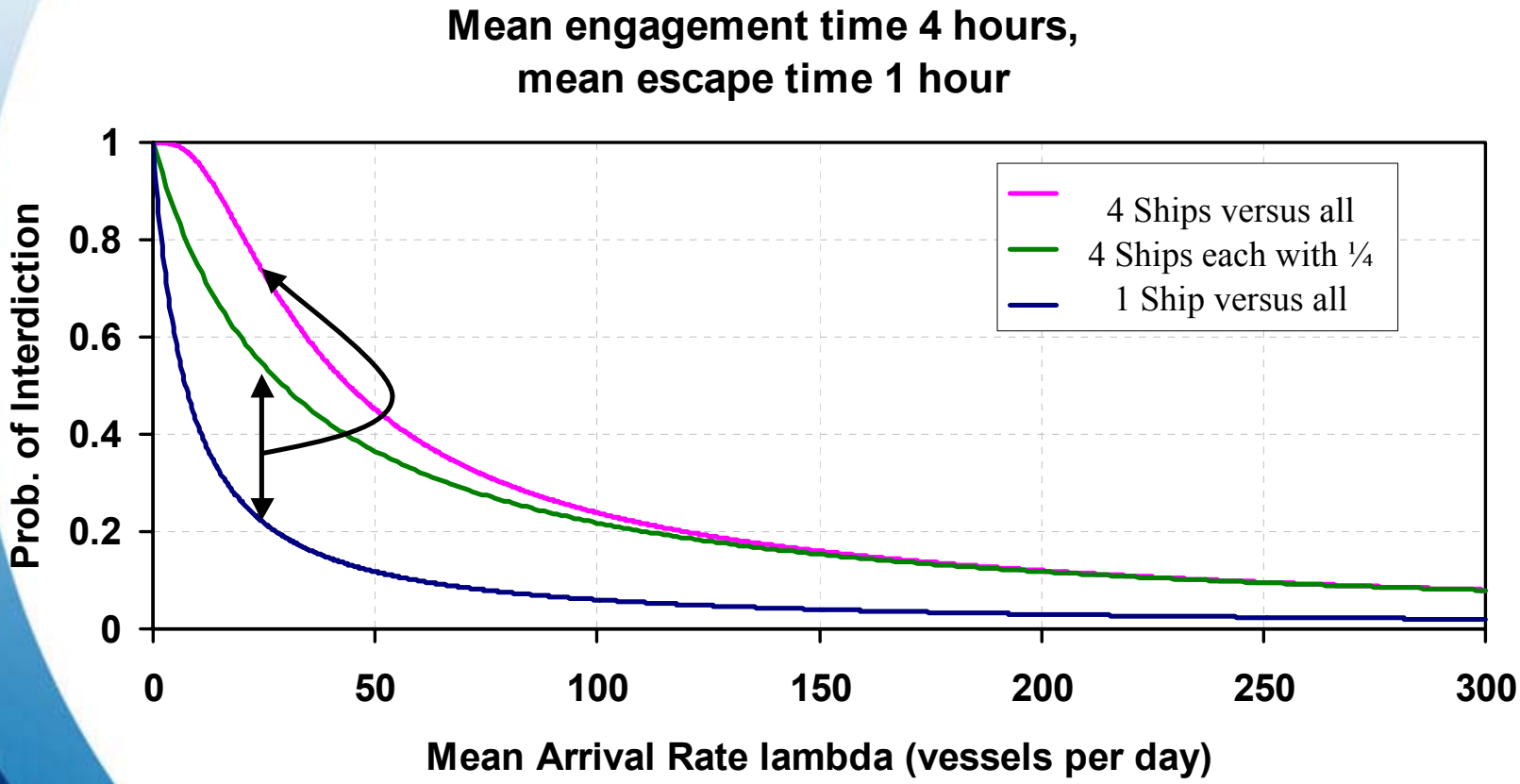
Collaborative Re-Planning

- Look at two scenarios
  - Basic Barrier/Blockade
  - Barrier/Blockade with Holding Pen
- Red Force tactic is to swarm the blockade in order to obtain a breakout of some members.
- Blue force must handle this surge of targets.

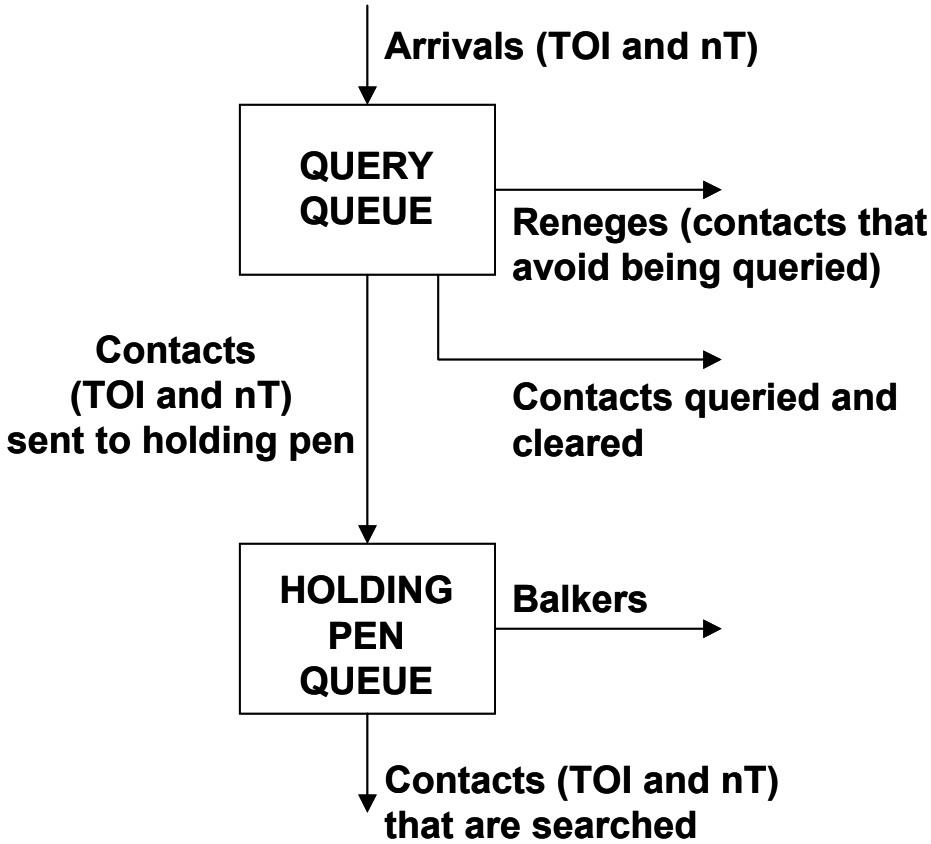
Adaptive Redeployment to Counter Blockade Breakout



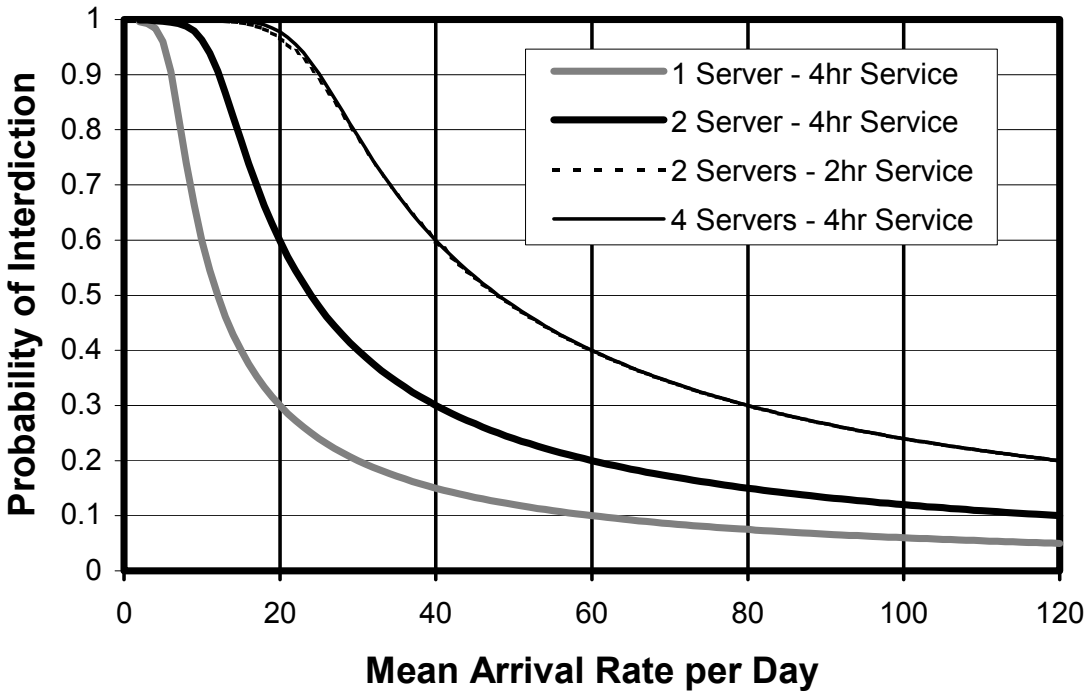
Blockade Breakout – Re-planning



Examination of Holding Pens in MIO



Holding Pens



1. Total Service rate (service rate times # servers) < arrival rate
2. Periodically clear out the pen

1. Resource balance between barrier and holding pen
2. Backlog reduction

Conclusions

- Queueing Theory provides a good model for linking MOP to MOE for steady state demand (or avoidance) of service operations.
- First Backward step – Netcentric applications that enable collaborative planning and re-planning, and timely access to information may improve MIO operations
- Definitive studies require well developed concepts and applications in order to identify “revolutionary” effects.
- Good quality data on current practice is required.
- Transition state analysis needed to examine dynamic events.