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An Analytical Model That Provides Insights into Various C2 Issues

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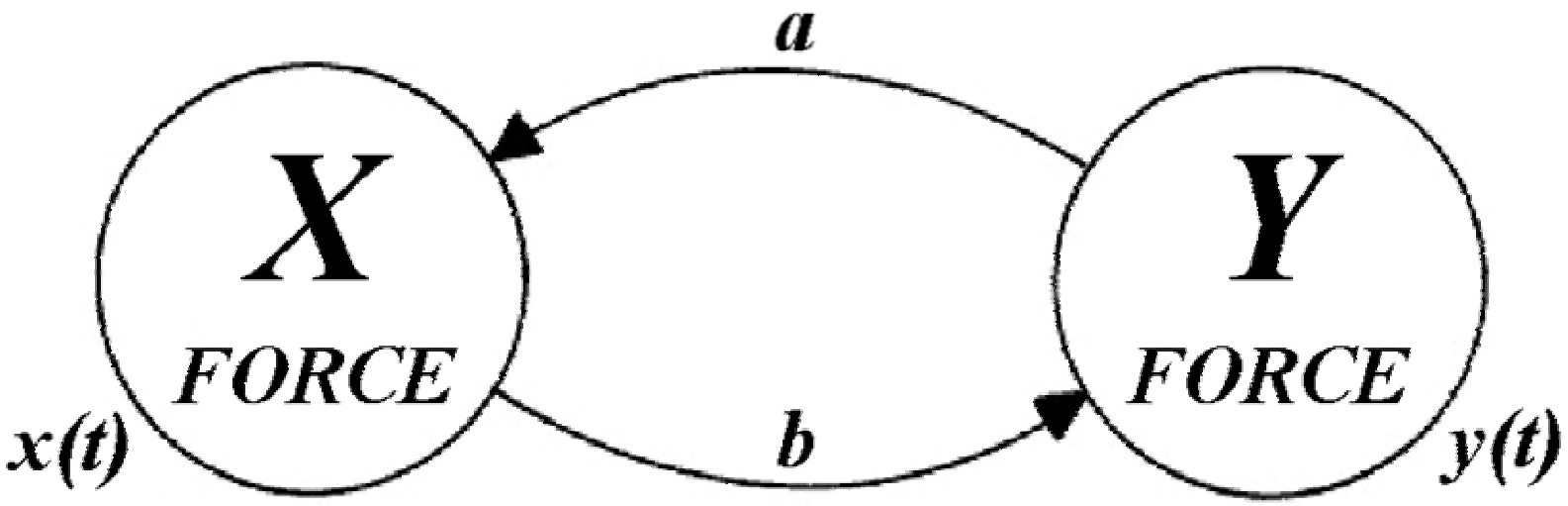
Overview

- *Model of Parallel Acquisition of Targets*
  - *Kill Rate Consequences*
    - ✓ *Taylor's New General Methodology for Lanchester Attrition-Rate Coefficients*
    - ✓ *Analytical Expression for Kill Rate*
      - *Higher Kill Rate Than for Serial Acquisition*
- *Insights into Network-Centric Warfare*

Effects of Parallel Acquisition

- ***More Efficient Target Acquisition***
- ***Force Multiplier***
  - ***Inflict More Casualties on Enemy***
  - ***Sustain Fewer Casualties***
- ***Example***
  - ***X Force Can Effect Change from Serial to Parallel Acquisition of Targets***

Basic Lanchester-Type Paradigm



$$\frac{dx}{dt} = -a\,y \qquad \text{with } x(0) = x_0$$

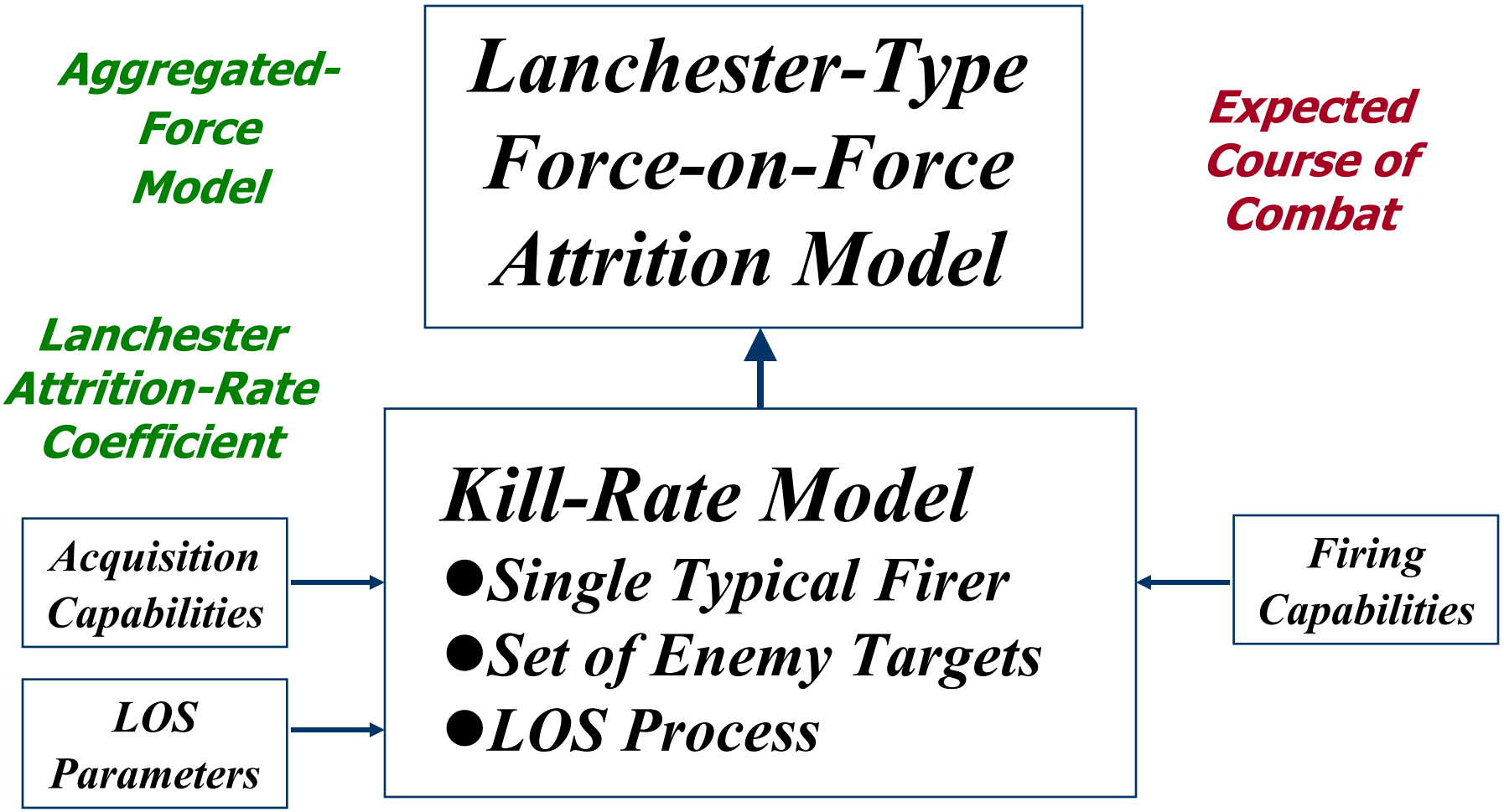
$$\frac{dy}{dt} = -b\,x \qquad \text{with } y(0) = y_0$$

Simplified Representation

Lanchester Attrition-Rate Coefficients

- ***a* and *b* are Called *Lanchester Attrition-Rate Coefficients***
- ***a* = *Rate at Which an Individual Y Firer Kills X Targets (Single-Weapon-System-Type Kill Rate); Kill Rate of Single Typical Firer***

Conceptual Combat Model



Kill-Rate Model

- ***Considers Single Typical Firer against Passive Target***
  - ***No Consideration of Duel***
- ***Does Not Consider Effect on Target by Any Other Firer***
  - ***Can Develop Correction Factor to Account for Such Effects***

New General Methodology
for Lanchester Attrition-Rate Coefficients

- ***Recently Developed by Taylor***
- ***Greatly Expands Modeling Capabilities***
  - ***Great Detail in Target-Engagement Cycle***
    - ✓ ***Special Treatment of First Round(s)***
    - ✓ ***Actual Distributions for Event (e.g. Interfiring) Times***
  - ***Battle Damage Assessment***
  - ***Command & Control at Platform Level***
  - ***Insights into Network-Centric Warfare***

Conditions Considered

- ***Heterogeneous-Target Environment***
- ***Stochastic Line of Sight (LOS)***
- ***Target-Acquisition Times Independent (But Otherwise Arbitrary)***
- ***Interfiring Times Independent (But Otherwise Arbitrary)***

New Methodology

- **Kill Rate Computed as Ratio of**
  - **Expected Number of Kills in Target-Engagement Cycle to**
  - **Expected Duration of Target-Engagement Cycle**

$$a_{ij} = \frac{\bar{n}^{cycle}_{k_{X_i Y_j}}}{\bar{t}_{cycle_{Y_j}}}$$

Can Now Model

- *In Tank Warfare*
  - *First Round Chambered*
  - *Tank Commander Acquires Targets While Gunner Engages*
  - *Automatic Loader (in Russian Tanks)*
- *Information Aspects*
  - *Battle Damage Assessment*
    - ✓ *Time to Assess*
  - *False Targets*

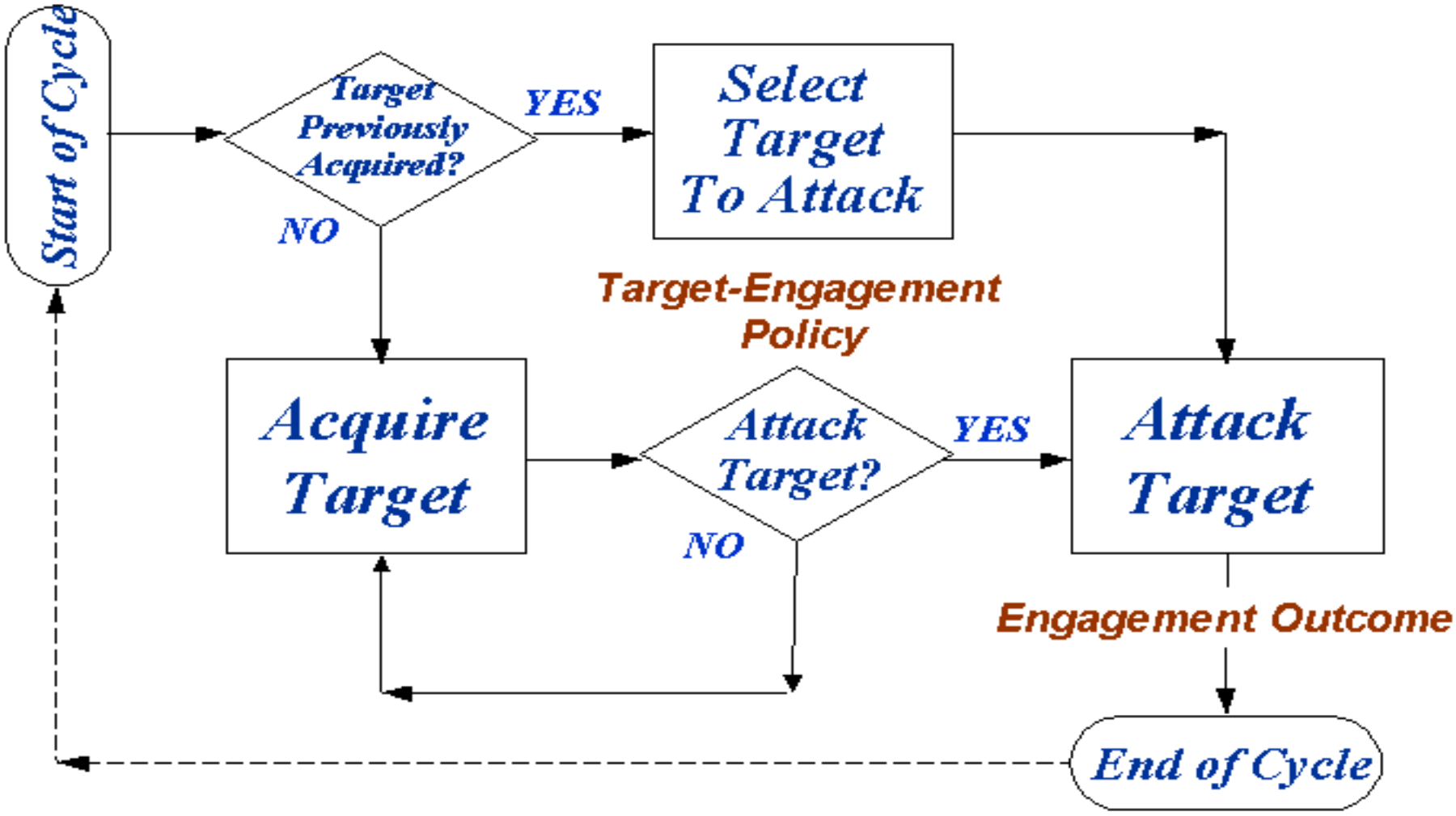
Conditions in Specific Cases

- ***Heterogeneous-Target Environment***
- ***Stochastic Line of Sight (LOS)***
- ***Target-Acquisition Times Exponential (and Independent)***
- ***Interfiring Times Exponential (and Independent)***
  - ***Can Be Extended to Log Normal/Erlang Times***

Key Question

- ***Can New Targets Be Acquired While an Acquired Target Is Being Engaged?***
- ***Simplest Model Considers Two Cases***
  - ***No New Target Can Be Acquired***
    - ✓***Serial Acquisition***
  - ***New Target Can Be Acquired (At Same Rate)***
    - ✓***Parallel Acquisition***

Target-Engagement Cycle
(Parallel Acquisition of Targets)

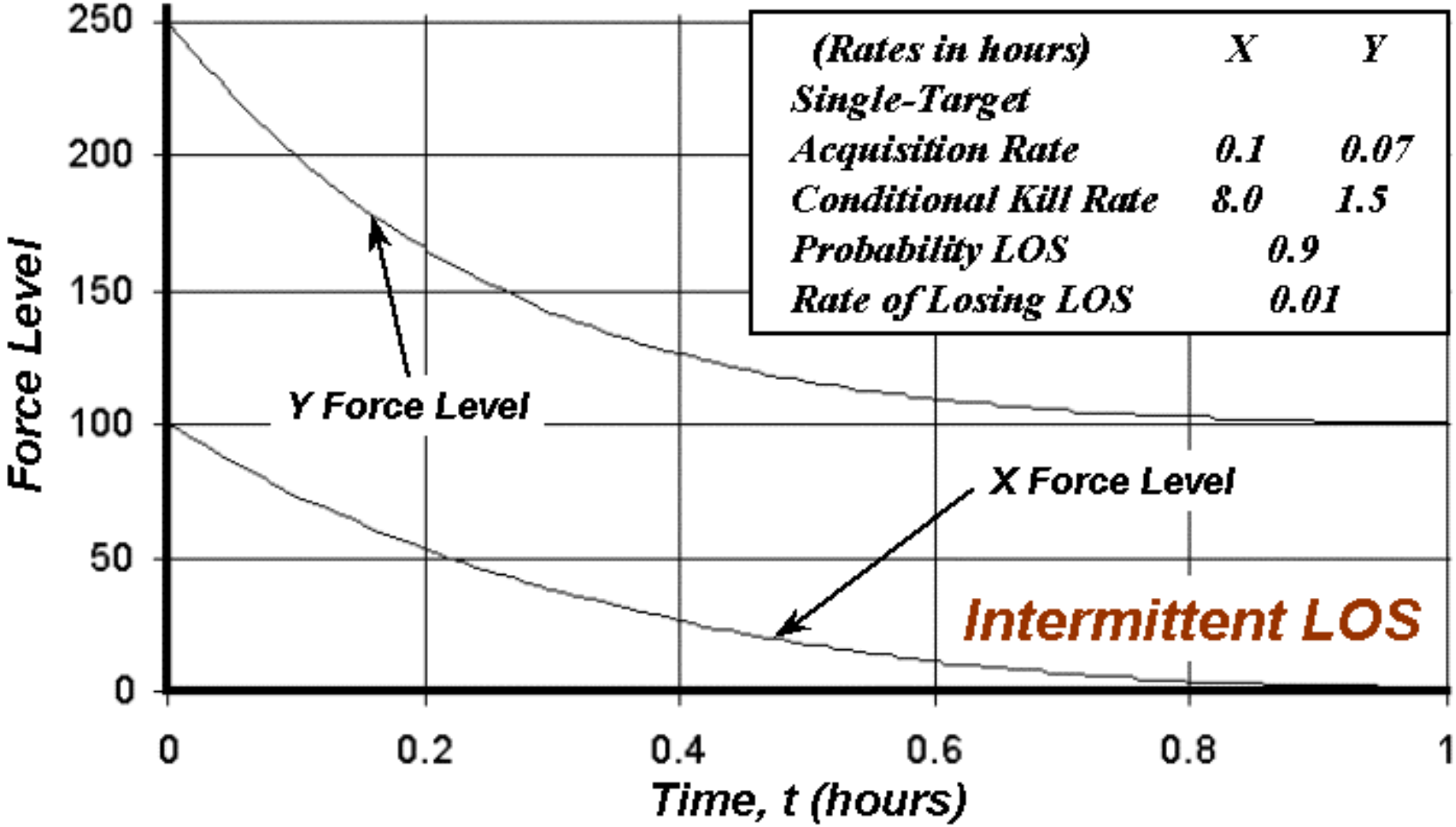


Some Computations

- *Y Always Uses Serial Acquisition*
- *X Can Change from Serial Acquisition of Enemy Targets to Parallel Acquisition*
  - ☞ *Computations Done for These Two Cases*
    - ✓ *Serial Acquisition by X*
    - ✓ *Parallel Acquisition by X*

Both Sides Serial

(Force-Level Decays)



Combat Model

(Only X Force Uses Parallel Acquisition)

$$\frac{dx}{dt} = -\frac{P_{K(LOS)_{XY}}\, y}{\frac{1}{P_{LOS}\,\lambda_{XY}\,x} + \frac{1}{\theta + \mu}}$$

Intermittent LOS

$$\frac{dy}{dt} = -\frac{P_{K(LOS)_{YX}}\, x}{\frac{1 - B(t)}{P_{LOS}\,\lambda_{YX}\,y} + \frac{1}{\theta + \mu}}$$

Target Availability

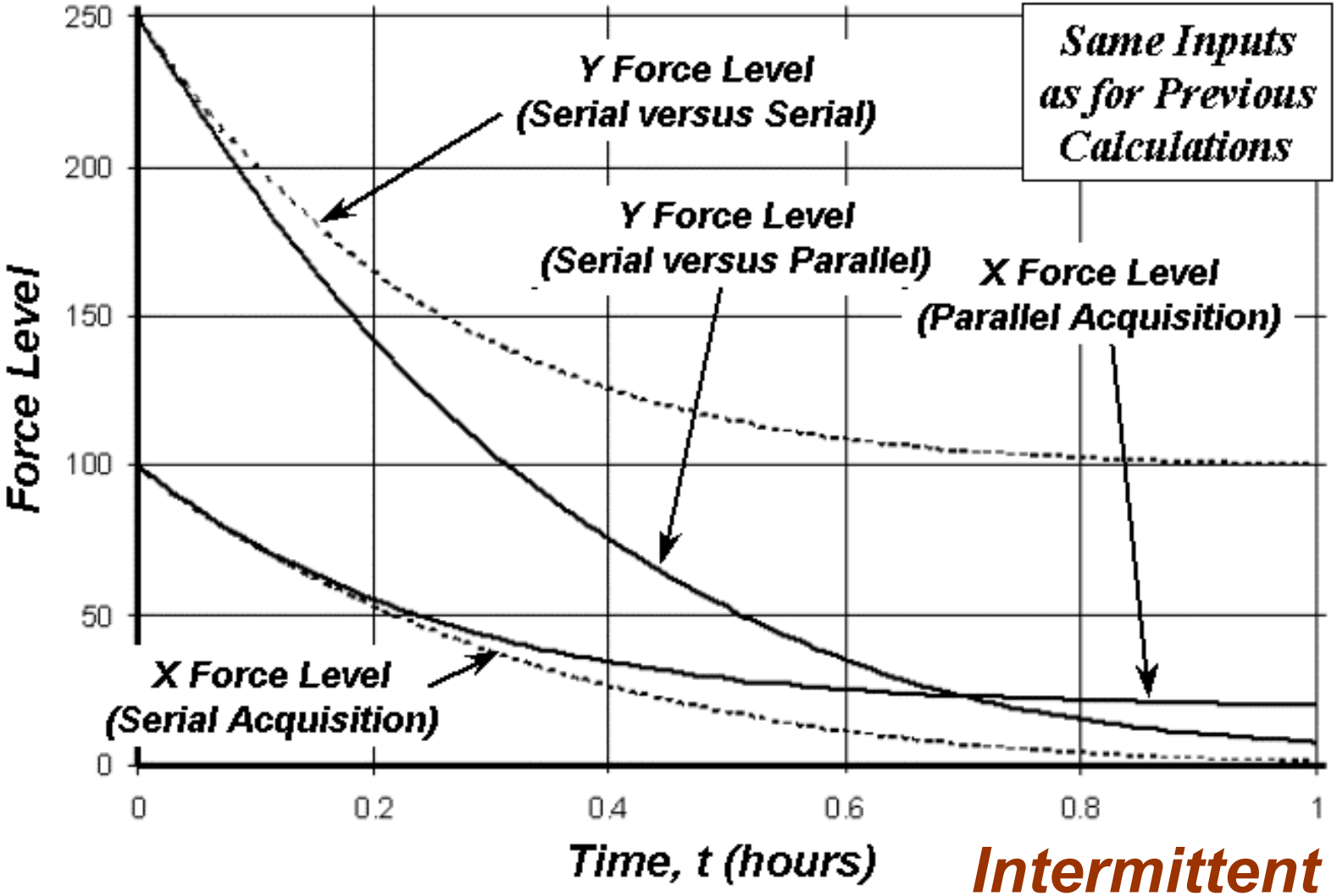
- *Typical X Firer Keeps on Continuously Acquiring Targets from Beginning of Battle*

  Intermittent LOS

- *Target Availability Given by (Assuming Steady State for LOS Process and No Targets Initially Acquired)*

$$B(t) = P_{LOS}\left\{\frac{\lambda_{YX}}{\lambda_{YX}+\mu}\left[1 - e^{-(\lambda_{YX}+\mu)t}\right]\right\}$$

Effects of Changing from Serial to Parallel Acquisition



Intermittent LOS

Benefits to X

- ***Inflicts 62% More Attrition***
- ***Suffers 19% Less Attrition***
- ***Turns Defeat into Victory***

Final Comments

- ***Significant Benefits from Parallel Acquisition Demonstrated for Combat at Platform Level***
- ***Ideas Can Be Adapted to Modeling Network-Centric Warfare***
- ***Such Analytical Models Very Convenient for Showing Benefits from Network-Centric Warfare***