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NAVAL POSTGRADUATE SCHOOL

Monterey, California

RESULTS OF PLAYING AN EVASION GAME

by

Alan R. Washburn

January 1978

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NAVAL POSTGRADUATE SCHOOL
Monterey, California

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A Searcher whose speed is v_S attempts to come within distance R of an Evader whose speed is v_E, knowing that the Evader must stay within a square of side L. This game has been played repeatedly at the Naval Postgraduate School under each of the following three assumptions: Game 1) The Evader is given no information about the position of the Pursuer. Game 2) The Evader knows at all times the bearing to the Pursuer. Game 3) The Evader knows at all times the range and bearing to the Pursuer. For $L/v_p = 15.42$ seconds,

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20. Continued.

v_E/v_P = .2, and R/L = .0286, the mean times to detection were 265, 367, and 407 seconds in the three cases. It is concluded that bearing alone is almost as good as range and bearing for purposes of evasion.

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SUMMARY

A Searcher whose speed is v_S attempts to come within distance R of an Evader whose speed is v_E, knowing that the Evader must stay within a square of side L. This game has been played repeatedly at the Naval Postgraduate School under each of the following three assumptions:

Game 1) The Evader is given no information about the position of the Pursuer.

Game 2) The Evader knows at all times the bearing to the Pursuer.

Game 3) The Evader knows at all times the range and bearing to the Pursuer.

For $L/v_P = 15.42$ seconds, $v_E/v_P = .2$, and $R/L = .0286$, the mean times to detection were 265, 367, and 407 seconds in the three cases. It is concluded that bearing alone is almost as good as range and bearing for purposes of evasion.

INTRODUCTION

Modern ASW often involves a search for a target that is not ignorant of the position of the searcher. Assuming that both Searcher and Evader must follow continuous tracks, there is currently no theory capable of computing or even usefully approximating the mean time to detection in such circumstances. In order to gain some understanding of the sensitivity of this time to precisely what information the Evader has about the searcher, the experiment described in the Summary has been carried out using officer students as players.

Experimental Setup

Each player saw the playing area as a square on his own cathode ray tube, within which he could control his own position up to his maximum speed using a two degree of freedom joystick. The Pursuer's position was represented as a dot surrounded by a circle of radius R, the capture distance. In Game 1, the Evader saw only a dot representing his own position. In Game 2, he also saw a strobe pointing toward the pursuer that emanated from the dot. In Game 3, the Pursuer's position, together with the surrounding capture circle, was shown instead of the strobe. In all cases, the game continued until either the Evader was included within the capture circle, or until the Evader touched the boundary, whichever came first. In 245 trials, there were three boundary terminations. There were also some instances of termination due to such things as machine failure or having to go to class; in which case the truncated time was added to the time for the next play, counting the sum of the two times as one trial.

In all experiments the positions of Pursuer and Evader were initially chosen at random within the square.

Subjects

The subjects were officer students enrolled in courses taught by the author. Each subject played Pursuer and Evader several times. Although an attempt was made to discover which subjects were the better players, and although there was definite evidence of learning, the data will be treated as coming from a single population in this report.

Quantitative Results

The experimental cumulative distributions of the times in the three experiments are shown in Figures 1-3, in each case together with an exponential curve having the same mean. The hypothesis of exponential times is not rejected at the .5 level in any of the experiments by a Kolmogorov-Smirnov test, and the exponential curve provides a strikingly good visual fit in Figures 2 and 3. The fact that the three experiments involve different numbers of trials is because one class of students played Game 2, whereas another class played Game 1 or 3 at the preference of the players. Game 3 was usually chosen because Game 1 is rather boring.

Available Theory

When the Evader's position is randomly chosen but stationary, the theory of random search [1] predicts that the time to capture will be exponential with mean $.5(L/v_P)/(R/L) = 270$ seconds. A correction is available for "dynamic enhancement" in the event the Evader moves about randomly. The correction has the effect of decreasing the average time to capture; the effect would be small when $v_E/v_P = .2$. The theory predicts the results of the first experiment quite accurately, but fails in the experiments where the Evader maneuvers intelligently.

Observations on Play

For a stationary Evader, the Searcher should perform an exhaustive search of some sort (a raster-scan or "ladder" search, for example), and the time to capture should be uniform over the interval [0, 270 sec] with a mean of 135 seconds. Most Searchers in fact attempted to search exhaustively in Experiment 1, but the resulting search times are certainly not uniform over the specified interval. There are four reasons for this, listed in order of what the author feels to be increasing importance:

1) The Searcher was not initially placed in a corner, thus requiring him to spend a few seconds to get to the closest one.
2) The persistence of the scope face was only a few seconds, so that it was difficult for the Searcher to place segment $n+1$ right next to segment n.

3) The theory does not allow for the double coverage that is unavoidable in actually carrying out an exhaustive search.

4) The Evader was not quite stationary. His speed, while small and randomly directed, was sufficient to turn what was planned to be an exhaustive search into what turned out to be a random search.

In Games 2 and 3, Searchers who tried to search exhaustively quickly figured out that the repetitive nature of the resulting motion made it easy for the Evader to avoid indefinitely. The word got around (no attempt was made to preserve trial independence by forbidding communication), and soon all Searchers were employing "unpredictable" tactics. There seemed to be two different philosophies about how to do this:

1) Employ broad, twisting sweeps of about the same radius of curvature as the largest circle that would fit in the screen, with occasional visits to the four corners. The idea was that sooner or later the Evader would guess the direction of the curvature wrong and get caught.

2) Select a small region within which the Evader could be trapped, conditional on his being there in the first place. After searching the small region, select another one, and continue until finally the correct region is selected.

There were likewise two tactics for the Evader that were commonly used:

1) Attempt to get behind the Searcher on the grounds that he probably would not return to where he has just been.

2) Within the constraints of the region, try to get away from the Searcher as fast as possible.

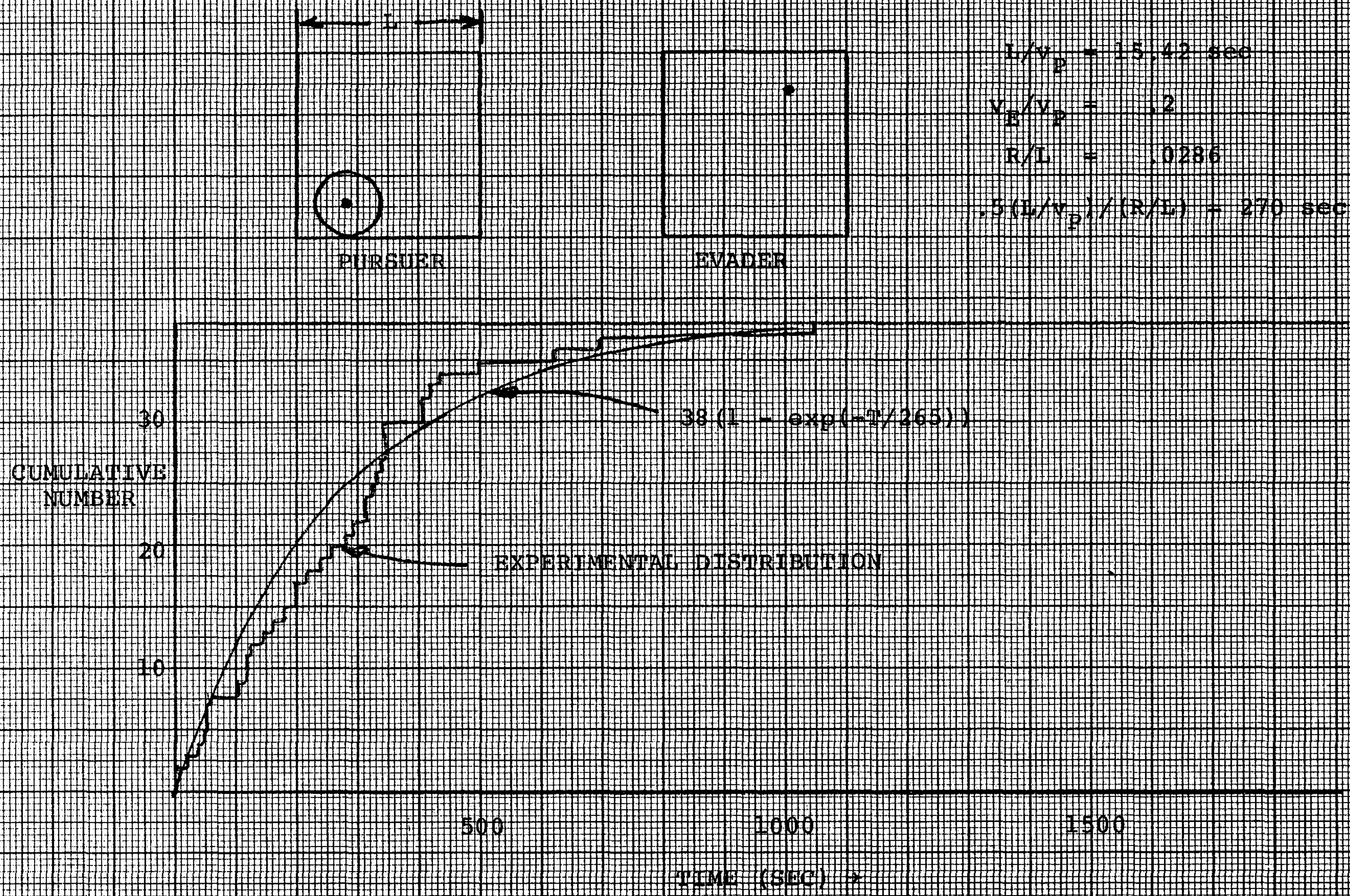
It is interesting that a mixture of the Evader's 1) and 2) has the potential for being optimal in the sense of game theory; in order to counter 1), the Searcher must employ reversals or frequent tight turns that reduce his speed of advance, thus making him vulnerable to 2).

There were no significant differences in strategy evident between Games 2 and 3. The difference in mean time to capture is attributed to those occasional incidents in Game 2 when the Evader would mistakenly interpret a slowly changing bearing to mean that the Searcher was far away. Usually, however, the Evader was able to do his "passive ranging" well enough to move in the correct direction.

REFERENCE

[1] Koopman, B.O., "The Theory of Search, Pt.I. Kinematic Bases," Operations Research 4, 324-346 (1956).

FIGURE 1: NO EVADER INFORMATION



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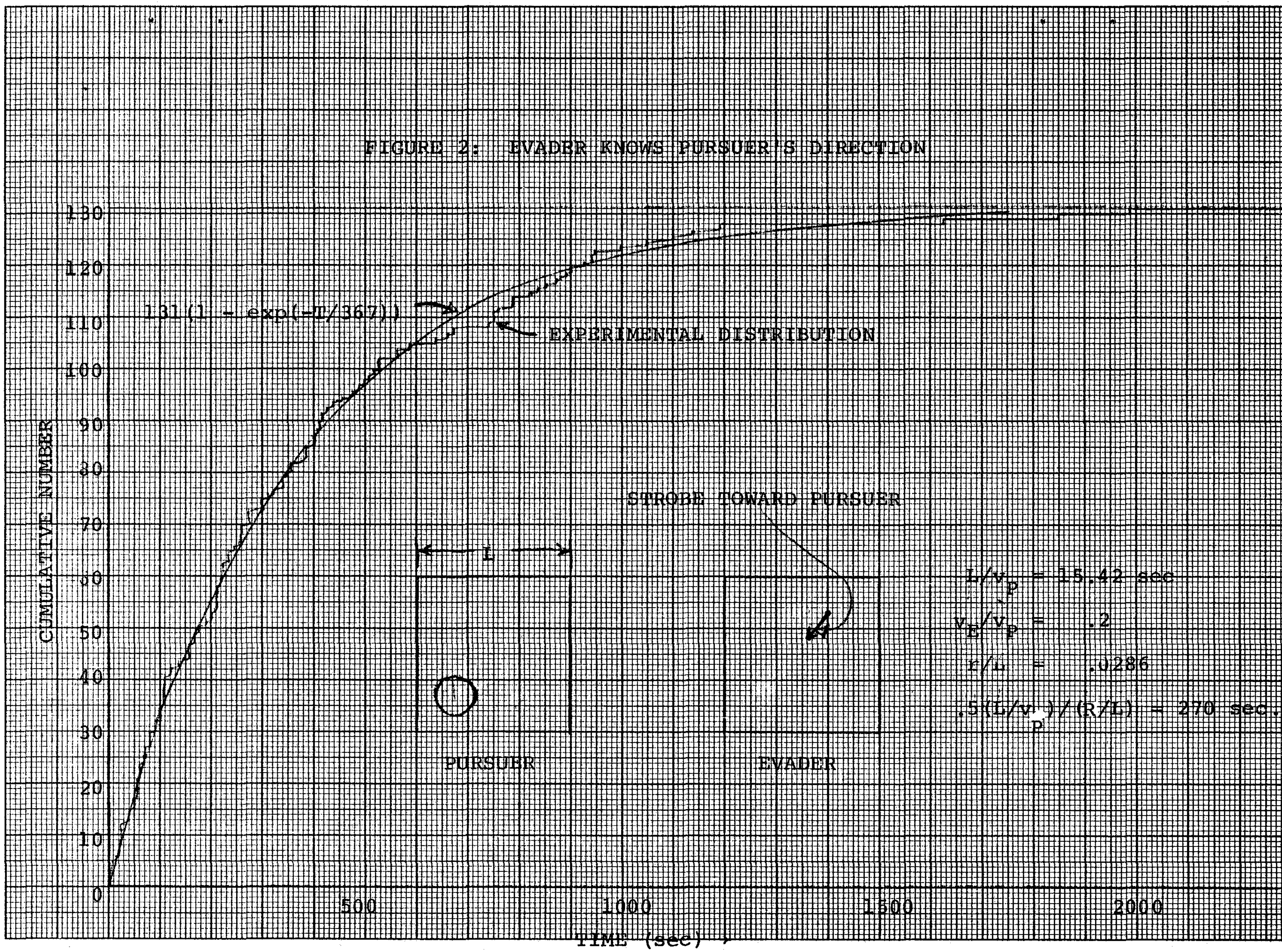

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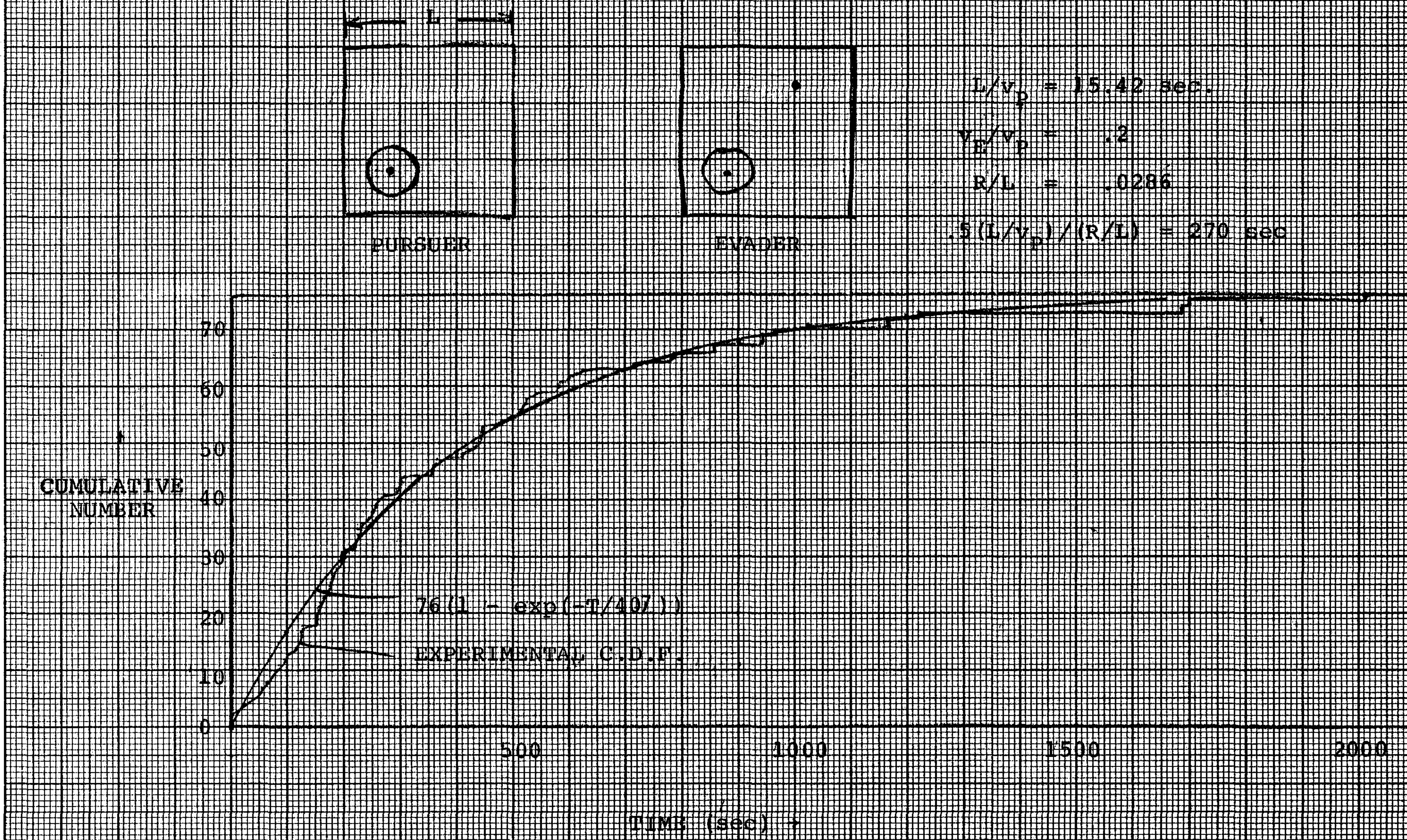
FIGURE 3: EVADER KNOWS PURSUER's POSITION



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