

PROBABILISTIC MODELS FOR OPERATOR DECISION-MAKING IN  
INTELLIGENCE, SURVEILLANCE, AND RECONNAISSANCE TYPE  
SCENARIOS

A Thesis

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by

Jesse Peter Veverka

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## ABSTRACT

This thesis contains three published papers related to modeling a Human in the Loop (HITL) operator interacting with a system of autonomous vehicles in Intelligence, Reconnaissance and Surveillance (ISR) type Scenarios. The thesis begins with an empirical study of one such actual system, moves to a narrow-scope detailed experimental software simulation introducing probabilistic models and culminates in experimental investigation using a time dependent information tracking function with a set of analytically tractable probabilistic models.

This first paper, entitled, “Experimental Study of Information Load on Operators of Semi-Autonomous Systems” presents a set of experimental results studying the relationship between Human in the Loop performance and user workload in the RoboFlag test-bed. Operators played a series of games to evaluate performance as a function of information load (speed and number of vehicles). Results showed a positive relationship between game speed and total score. In addition operators reported using more automation as number of robots increased but trusting automation less as game speed increased.

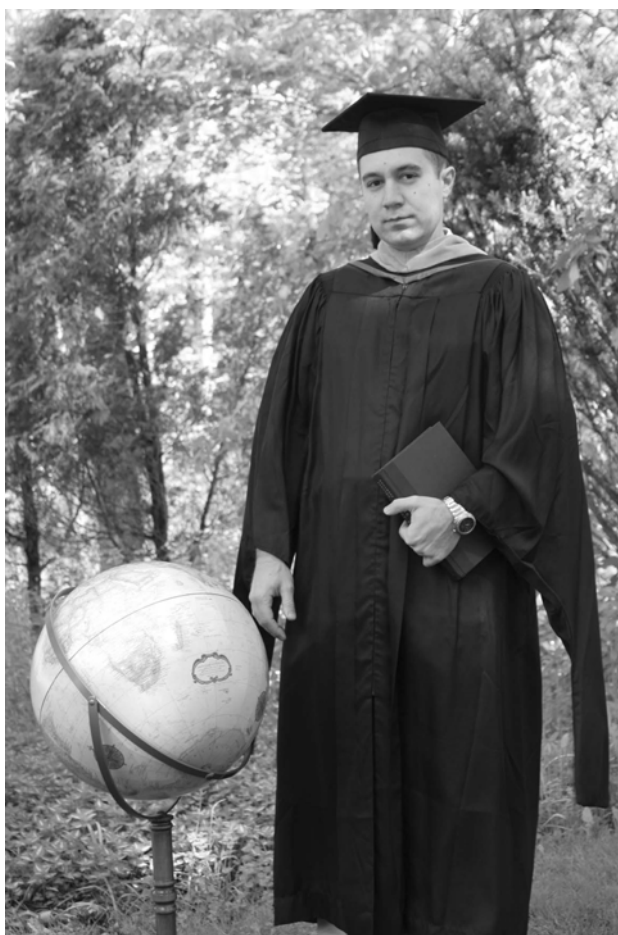
The second paper, entitled “Modeling Tradeoffs in Decisions by Operators Controlling Autonomous Vehicles” presents the results of two decision-making experiments and two operator decision models for an Intelligence, Surveillance and Reconnaissance (ISR) type mission. The first experiment used 25 possible scenarios, each of which included enough trials to allow a formal statistical model to be derived. The distribution of operator decision data was modeled with a binomial distribution as a function of environmental variables. An optimal decision-making policy was also prescribed for all scenarios. Results show good agreement between operator data and the optimal decision-making policy in most scenarios, except when the relative utility

between the choices was similar. Lower order probabilistic models using conditional probabilities and Gaussian random variables are also derived; results show a strong ability to use lower order models for operator decisions. The second experiment presented operators with the same binary decision, but from a more general choice of 90 possible scenarios. This allows the evaluation of the probabilistic model as data becomes sparse. Operator data from the second experiment was successfully binned and compared to the results of first experiment, demonstrating consistent operator decision-making between experiments.

The final paper, entitled “Operator Decision Modeling for Intelligence, Surveillance and Reconnaissance Type Scenarios with a Time Dependent Information Function” presents a model of operator + vehicle interaction for a simplified Intelligence, Surveillance and Reconnaissance type mission utilizing a time dependent information function for target identification. The model is developed and evaluated using operator decision-making experiments where an operator controls a friendly uninhabited aerial vehicle (UAV) tasked with identifying enemy targets within a two-dimensional map. Operators must make two decisions: 1) which target to choose first, and 2) if and when to task the UAV to the second target to start data collection. Two sets of experimental data were collected. In all experimental scenarios, target choice and time on target were recorded. The data was analyzed in order to develop an analytically tractable model of operator choice. An optimal decision-making policy was also prescribed for all scenarios and compared to the operator data. Finally a both tabular and lower order probabilistic model developed to model decision making in this experiment.

## BIOGRAPHICAL SKETCH

Jesse Veverka received a B.A. in economics from Cornell University in 2000. He worked as an investment-banking Analyst at Bear, Stearns & Co. Inc., NY, NY from 2000-2002. In 2003 he entered Cornell's Master of Engineering program in aerospace space engineering. He spent the 2003-2004 academic year at the Korean Advanced Institute of Science and Technology (KAIST) in Daejeon, South Korea as a Fulbright Scholarship Grantee. His academic interests are in cognitive science, economics, linguistics and East and South East Asian languages. He has studied Japanese, Korean, Mandarin Chinese, Indonesian, Thai and Spanish and is a native speaker of English. He is an avid world traveler.



百世修来同船渡，千载修得共枕眠

To my family, friends and those dear to me.

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I would like to thank all those who have given me advice, support, friendship or inspiration (in some cases unbeknownst to them): my brother Jeremy, my father Joseph, my mother Joy, Atif Chaudhry, Jacob Dreizin, Mr. Jack Fabulous<sup>1</sup>, Bobby Fischer, Christina “Baby” Han, Professor Yoshihiko Ichikawa, Najung Kim, Wenchia Koo, Dan Maas, Paul Otañez, Dr. Rohan Munisinghe, Hiromi Nishigaki, Richard Sleboda, His Majesty King Bhumibol Adulyadej of Thailand, and Allan C. Weisbecker<sup>2</sup>. Finally I would like to thank Mr. B. Chew, unquestionably the most vocal and outspoken of any of my colleagues or associates.

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<sup>1</sup> Sole surviving alter ego of our former band *3Jane*.

<sup>2</sup> Author of *Cosmic Banditos*, *In Search of Captain Zero* and his soon to be released smash-hit personal epic *Can't You Get Along With Anyone? A Writer's Memoir*. Allan, this footnote is for you.

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## PREFACE

Any great expenditure of effort for which an individual is accorded respect affords that individual, at least temporarily, an audience; a chance to express one's opinion and to have others listen. Therefore, this is my opportunity to express my opinion and to have you, the reader, give it pause for thought.

We stand at the crossroad of a new century and a historical turning point the likes of which have been previously unknown to the West: the rise and eventual dominance of the East in economic, cultural, social, political *and military* power. As economists are fond to point out, the best military defense is a strong economy. A strong economy trumps everything - a large standing army, a militaristic culture, or even an extremely advanced arms industry - everything, because only a strong economy provides the lifeblood that makes military dominance possible to maintain in the long run<sup>3</sup>. Unfortunately, the West, and the United States in particular, have lost their economic vitality. At Purchasing Power Parity China has already achieved 70% of the GDP of the United States and yet China continues growing at three to four times the rate. It is not a question of if China and the *Asian Bloc* will come to dominate the world power structure, but rather how the United States will react.

Although I would like to offer the hope for a positive outcome, the political events of this new century in combination with the vast influence of the deeply entrenched Military-Industrial Complex (made famous in President Eisenhower's farewell address<sup>4</sup>) give me grave cause for concern as to the direction the United

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<sup>3</sup> One may look at the historical example of North Korea and South Korea as empirical evidence of this point. At the end of the Korean War in 1953, North Korea enjoyed economic and military dominance over South Korea. Just slightly more than 50 years later, South Korea's economy has outstripped North Korea's some 25 fold and despite the North's larger troop count and absolute commitment to militarization, its ability to mount a meaningful invasion of South Korea has now been relegated to history.

<sup>4</sup> January 16<sup>th</sup>, 1971

States is choosing to take<sup>5</sup>. Nonetheless, I take this opportunity to implore the reader to consider carefully how actions and complacency on all our parts may be contributing to this chain of events. We as engineers must make it a priority to ensure that the knowledge we create is used towards good ends. No amount of clever engineering will ever make up for the value of life lost through unnecessary war making.

Ithaca, New York

July 2006

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<sup>5</sup> The reader is encouraged to read *Blow Back* and *The Sorrows of Empire* by Chalmers Johnson for a very detailed, scholarly and objective examination of the events leading up to current conditions.