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Ph.D. DISSERTATION DEFENSE

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Title:	Using Search Optimization Techniques in Modular System Upgrades: Parametric Analysis and Case Studies
Chairperson:	Dr. Mo Mansouri, School of Systems and Enterprises, Stevens Institute of Technology
Committee Members:	Dr. Yan Chen, School of Business, Stevens Institute of Technology Dr. John P. Gianvittorio, Hardware Engineering Center, Raytheon Technologies Dr. Onur Asan, School of Systems and Enterprises, Stevens Institute of Technology Dr. Alparslan Emrah Bayrak, School of Systems and Enterprises, Stevens Institute of Technology

ABSTRACT

Systems Engineers are often tasked with the decision to when to upgrade a system. It is a difficult decision that involves many factors such as the technology involved, market niche, competitors and their motives, upgrade costs, and return-on-investment (ROI). To simplify this complex multi-dimensional problem, a modular system is assumed such that parts are perfectly independent of one another and there is no change propagation.

Search optimization techniques were used to explore which new innovation or technology to implement in a modular system upgrade amid many options. Within the context of modular systems, a model is proposed that will examine how to choose new technologies or innovations so that system upgrades are optimized. The model incorporates the expectation of future technologies or innovations, and the time-dependence value of module performance characteristics. A critical module performance characteristic m_c is explored and calculated, and this will be the reference parameter the Systems Engineer will use when deciding to upgrade a modular system.

Hence, a formulation is derived where a critical module performance characteristic m_c is used as a benchmark to determine if a system upgrade should be pursued. By calculating m_c, a systematic framework was developed on how modular upgrades should be done by using optimization techniques, and so insights were obtained on how to do modular upgrades better. In particular, an extensive parametric analysis revealed the conditions when the Systems Engineer should be

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hesitant to upgrade: 1) Higher expectations of module performance mean higher thresholds for upgrading, and an aversion to upgrade, 2) More uncertainty about future module performance upgrades demand hesitancy to upgrade the modular system, 3) As the current default performance holds its value well in the future, the performance standards for upgrade should be more stringent, 4) Having better performance as a default makes upgrading less appealing.

To exemplify the practical use of the search optimization method within a Systems Engineering context, a Monte Carlo case study was performed where different upgrade strategies were compared. It was seen that using search optimization techniques can improve profit as much as 44% when compared to a "never upgrade" strategy. In addition, the evolution of the iPhone was analyzed, and it was calculated that using search optimization could have earned Apple an additional $1.9B, or 0.28% increase, in its iPhone business.

Finally, a comparison of the search optimization technique with the real options methodology was performed. Both are strategic decision-making tools at the disposal of the Systems Engineer, but there are significant differences between them.