Business Case Analysis of Medium Altitude Global ISR Communications (MAGIC) UAV System

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BUSINESS CASE ANALYSIS OF MEDIUM ALTITUDE GLOBAL ISR COMMUNICATIONS (MAGIC) UAV SYSTEM

by

Ramesh Kolar

June 2012

Thesis Advisor: Daniel Nussbaum
Thesis Co-Advisor: Raymond Franck

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Results are presented for 500, 1000, 2000, and 3000 nm ranges. MAGIC outperforms Reaper and Global Hawk, while Predator outperforms MAGIC at the 500 nm. MAGIC outperforms all others in the 1000, 2000 and 3000 nm range. The analysis is extended to cover other payloads for the same ranges. The results show that MAGIC is favored over Reaper for 1000 nm and 2000 nm range, and the return ratio is marginal for 500 nm. MAGIC is favored in all ranges when compared with Global Hawk.
BUSINESS CASE ANALYSIS OF MEDIUM ALTITUDE GLOBAL ISR COMMUNICATIONS (MAGIC) UAV SYSTEM

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Civilian, Department of the Navy
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Submitted in partial fulfillment of the requirements for the degree of

MASTERS OF BUSINESS ADMINISTRATION

from the

NAVAL POSTGRADUATE SCHOOL
June 2012

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<table>
<thead>
<tr>
<th>Acronym</th>
<th>Abbreviation</th>
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<tbody>
<tr>
<td>APB</td>
<td>Acquisition Program Baseline</td>
</tr>
<tr>
<td>APUC</td>
<td>Average Production Unit Cost</td>
</tr>
<tr>
<td>BCA</td>
<td>Business Case Analysis</td>
</tr>
<tr>
<td>CER</td>
<td>Cost Estimation Relationship</td>
</tr>
<tr>
<td>COCOM</td>
<td>Combatant Commander</td>
</tr>
<tr>
<td>CONOPS</td>
<td>Concept of Operations</td>
</tr>
<tr>
<td>DoD</td>
<td>Department of Defense</td>
</tr>
<tr>
<td>FY</td>
<td>Fiscal Year</td>
</tr>
<tr>
<td>HALE</td>
<td>High Altitude Long Endurance</td>
</tr>
<tr>
<td>ISR</td>
<td>Intelligence, Surveillance, and Reconnaissance</td>
</tr>
<tr>
<td>JCTD</td>
<td>Joint Capabilities Technology Demonstrator</td>
</tr>
<tr>
<td>LCC</td>
<td>Life Cycle Cost</td>
</tr>
<tr>
<td>NCCA</td>
<td>Naval Center for Cost Analysis</td>
</tr>
<tr>
<td>nm</td>
<td>Nautical Miles</td>
</tr>
<tr>
<td>NMS</td>
<td>National Military Strategy</td>
</tr>
<tr>
<td>NSS</td>
<td>National Security Strategy</td>
</tr>
<tr>
<td>NPV</td>
<td>Net Present Value</td>
</tr>
<tr>
<td>NPVLCC</td>
<td>Net Present Value of Life Cycle Cost</td>
</tr>
<tr>
<td>O&amp;S</td>
<td>Operations &amp; Support</td>
</tr>
<tr>
<td>OMB</td>
<td>Office of Management and Budget</td>
</tr>
<tr>
<td>OCO</td>
<td>Overseas Contingency Operations</td>
</tr>
<tr>
<td>OMN</td>
<td>Operations and Maintenance, Navy</td>
</tr>
<tr>
<td>OPNAV</td>
<td>Chief of Naval Operations Staff</td>
</tr>
<tr>
<td>OPTAR</td>
<td>Operating Target</td>
</tr>
<tr>
<td>PPBES</td>
<td>Planning, Programming, Budgeting and Execution System</td>
</tr>
<tr>
<td>R&amp;D</td>
<td>Research and Development</td>
</tr>
<tr>
<td>RDT&amp;E</td>
<td>Research, Development, Testing and Evaluation</td>
</tr>
<tr>
<td>RR</td>
<td>Return Ratio = NPVLCC_candidate/NPVLCC_Magic</td>
</tr>
<tr>
<td>Abbreviation</td>
<td>Definition</td>
</tr>
<tr>
<td>--------------</td>
<td>--------------------------</td>
</tr>
<tr>
<td>ROI</td>
<td>Return on Investment</td>
</tr>
<tr>
<td>USAF</td>
<td>United States Air Force</td>
</tr>
<tr>
<td>UAS</td>
<td>Unmanned Aircraft System</td>
</tr>
<tr>
<td>UAV</td>
<td>Unmanned Air Vehicle</td>
</tr>
</tbody>
</table>
ACKNOWLEDGMENTS

It is said that for an endeavor to be successful, the human effort is necessary but not sufficient. I am thankful to the Grace for successful completion. I want to thank Professor Daniel Nussbaum for suggesting the thesis topic and guiding me through myriad stages with constant encouragement, insights, and wisdom. There were many challenges in the project, including formulating the problem appropriately, collecting relevant data, developing mathematical models, analyzing the results and framing recommendations. His perceptiveness and insights made the project go smoothly. My other advisor, Professor Raymond Franck, gave invaluable guidance in the advanced modeling in cost-benefit economics for decision-making and public policy and steering me through the whole MBA program with timely midcourse corrections. His thoughtful comments enhanced the quality of the report. The author is grateful to USAF and CENTCOM for sponsoring this research. My thanks go to my dear wife for continued support for continuous improvement; words and equations can neither model nor forecast my gratitude.
EXECUTIVE SUMMARY

The goal of this study is to conduct a business case analysis of a Medium Altitude Global ISR Communication (MAGIC) UAV system. The DoD has a number of UAVs both in operations as well as in various stages of research, development, production, and deployment. A brief survey of UAVs in the medium altitude ISR range is presented. The MAGIC platform is analyzed together with three other platforms. A cost model for RDT&E and O & S for the MAGIC is developed based on the available data for the other platforms. Cost estimates use key performance parameters from the published literature. Three scenarios are considered. Two parameters are developed as measures of effectiveness (MOE), namely, a Net Present Value of Life Cycle Cost (NPVLCC) and a return ratio defined as the ratio of NPVLCC of a platform to the NPVLCC of MAGIC.

A baseline case is developed with cost estimates for RDT&E, Average Production Unit Cost (APUC), discount factor (discount rate), dollar per flight hour ($/FH) and a scenario with a 500 nm range. Net present value (NPV) calculations use a 10-year time horizon. These values and sensitivity analysis parameters are shown in the Table 1.

<table>
<thead>
<tr>
<th></th>
<th>MAGIC RDTE</th>
<th>MAGIC APUC</th>
<th>Discount Rate (%)</th>
<th>$/FH</th>
<th>Range (nm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baseline</td>
<td>510*</td>
<td>17*</td>
<td>2.5</td>
<td>3.7*</td>
<td>500</td>
</tr>
<tr>
<td>Variation</td>
<td>300-510-1300</td>
<td>14-17-20</td>
<td>0.0-2.5-5.0</td>
<td>3.7</td>
<td>500-1000-2000-3000</td>
</tr>
</tbody>
</table>

Table 1. Baseline assumptions and sensitivity parameters. All costs are in FY10$M

*These values are estimated using historical data

The results shown in Table 2 indicate that MAGIC outperforms Reaper (MQ-9) and Global Hawk (RQ-4) for all reasonable values of input variables. Predator (MQ-1B) outperforms MAGIC under current MAGIC cost estimates. MAGIC becomes
competitive over Predator when the RDT&E cost is about $300M (approximately 40% lower than the baseline $510M) or unit production costs are under $14M (approximately 20% lower than the baseline $17M).

In the 1000 nm range, MAGIC outperforms Predator, Reaper, and Global Hawk platforms. MAGIC dominates Global Hawk in 2000 nm and 3000 nm ranges. Other platforms do not meet range requirements. The results for a payload of 1000 lbs and 450 lbs are presented in Tables 3 and 4. The results show that Reaper is marginally better than MAGIC for the 500 nm range. MAGIC is preferred over Global Hawk in this range. At the range of 1000 nm MAGIC outperforms Global Hawk and is indifferent compared to Reaper. MAGIC dominates Global Hawk and Reaper platforms for 2000 nm range. MAGIC outperforms Global Hawk at 3000 nm range for this payload. The results for MAGIC is compared to Predator with a payload of 450 lbs are shown in Table 4. MAGIC is preferred over Predator in the 500 nm and dominates at 1000 nm range. Predator cannot compete in the 2000 nm and 3000 nm range.

Summarizing, MAGIC platform outperforms Reaper and Global Hawk for ISR capabilities with reasonable input values in the 500 nm range. Predator is preferred at this range with the present cost estimates of MAGIC. MAGIC is preferred platform over Reaper and Global Hawk in 1000 nm range and dominates Global Hawk in the 2000 and 3000 nm range. Further refinements in the cost estimates of RDT&E and O &S for MAGIC would be helpful in the next milestone product decision-making process.
Table 2. Summary of Baseline case vs. Return Ratios (NPVLCC_CandidateUAV to NPVLCC_MAGIC) are given using DoD SAR data. CC - Cannot Compete

<table>
<thead>
<tr>
<th>Platforms</th>
<th>Range 500 nm</th>
<th>Range 1000 nm</th>
<th>Range 2000 nm</th>
<th>Range 3000 nm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Predator (MQ-1B)</td>
<td>0.88</td>
<td>1.24</td>
<td>CC</td>
<td>CC</td>
</tr>
<tr>
<td>MAGIC</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Global Hawk-MAGIC</td>
<td>4.91</td>
<td>4.92</td>
<td>5.07</td>
<td>8.25</td>
</tr>
<tr>
<td>MAGIC</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Reaper (MQ-9)</td>
<td>1.17</td>
<td>2.0</td>
<td>CC</td>
<td>CC</td>
</tr>
<tr>
<td>MAGIC</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Return Ratio Very High: Strongly Favors MAGIC*
*Return Ratio High: Favors MAGIC*
*Return Ratio Marginal: Borderline Case*

*Baseline Case: Average Production Unit Cost (APUC) = $17M; RDTE = $510M; Discount Factor = 0.025*
*Return Ratio = NPVLCC_candidate/NPVLCC_MAGIC > 1 Favors MAGIC*
*CC = Cannot Compete;*
Table 3. Summary of Baseline case vs. Return Ratios for 1000 lb payload

<table>
<thead>
<tr>
<th>Platforms</th>
<th>Range 500 nm</th>
<th>Range 1000 nm</th>
<th>Range 2000 nm</th>
<th>Range 3000 nm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Predator (MQ-1B)-MAGIC</td>
<td>DNA</td>
<td>DNA</td>
<td>DNA</td>
<td>DNA</td>
</tr>
<tr>
<td>Global Hawk-MAGIC</td>
<td>4.92</td>
<td>4.92</td>
<td>5.07</td>
<td>9.00</td>
</tr>
<tr>
<td>Reaper (MQ-9)-MAGIC</td>
<td>0.88</td>
<td>1.0</td>
<td>1.93</td>
<td>CC</td>
</tr>
</tbody>
</table>

**Baseline Case**: Average Production Unit Cost (APUC) = $17M; RDTE = $510M; Discount Factor = 0.025
**Return Ratio** = NPVLCC_cadidate/NPVLCC_MAGIC > 1 Favors MAGIC
**CC = Cannot Compete; DNA = Data Not Available**
**Data From USAF**
Table 4. Summary of Baseline case vs. Return Ratios for 450 lb payload

<table>
<thead>
<tr>
<th>Platforms</th>
<th>Range 500 nm</th>
<th>Range 1000 nm</th>
<th>Range 2000 nm</th>
<th>Range 3000 nm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Predator (MQ-1B) -MAGIC</td>
<td>1.24</td>
<td>3.53</td>
<td>CC</td>
<td>CC</td>
</tr>
<tr>
<td>Global Hawk -MAGIC</td>
<td>DNA</td>
<td>DNA</td>
<td>DNA</td>
<td>DNA</td>
</tr>
<tr>
<td>Reaper (MQ-9) -MAGIC</td>
<td>DNA</td>
<td>DNA</td>
<td>DNA</td>
<td>DNA</td>
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</tbody>
</table>

*Baseline Case: Average Production Unit Cost (APUC) = $17M; RDTE = $510M; Discount Factor = 0.025
• Return Ratio = NPVLCC_candidate/NPVLCC_MAGIC > 1 Favors MAGIC
• CC = Cannot Compete; DNA = Data Not Available;
• **Data From USAF
I. INTRODUCTION

A. MOTIVATION

The military has seen increased use of the Unmanned Systems in all environments, land, sea, and air. These unmanned aircraft systems (UAS) have logged over 500,000 flight hours, unmanned ground vehicles (UGVs) have performed over 30,000 missions, and unmanned maritime systems (UMSs) (defined as unmanned undersea vehicles—UUVs, and unmanned surface vehicles—USVs) have protected the ports. These versatile and persistent systems perform reconnaissance, mine detection, surveillance, precision target designation, signals intelligence and host of other combatant commanders’ tasks. Recognizing their value, OSD has issued a roadmap describing the future for the unmanned systems (OSD, 2009).

Pursuant to one of the goals presented in this roadmap (Goal 3), the USAF, U.S. Central Command (CENTCOM) and OSD have pursued a UAS for medium altitude deployment as a capabilities technology demonstrator. This is referred as the Medium Altitude Global ISR Communication (MAGIC) program with increased persistence and long endurance ISR capabilities. The USD (AT&L) approved and signed the Weapon Systems Acquisition Reform Product Support Assessment report (DoD, 2011). One of the recommendations of this report is to use analytical tools such as BCA in the life cycle product support decision making process. Accordingly, this thesis performs a business case analysis (BCA) of MAGIC to help support the decision making process.

B. BACKGROUND

The military has successfully leveraged the advances in the technology of UAS to counter the Global War on Terrorism as evidenced by their deployment in the Operations Enduring Freedom and Iraqi Freedom, and in Afghanistan. Reflecting the military strategy, DoD is committing more budget to develop and acquire unmanned systems. Table 1 shows the increasing role of UAS and resource allocation in the president’s budget (FY11).
Table 1. President’s Budget (FY2011) for Unmanned Systems($ Mil) (From DoD, 2011b)

<table>
<thead>
<tr>
<th>Fiscal Year Defense Prog</th>
<th>FY11</th>
<th>FY12</th>
<th>FY13</th>
<th>FY14</th>
<th>FY15</th>
<th>Total</th>
</tr>
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<tbody>
<tr>
<td>Air</td>
<td>RDTE</td>
<td>1,106.72</td>
<td>1,255.29</td>
<td>1,539.58</td>
<td>1,440.57</td>
<td>1,296.25</td>
</tr>
<tr>
<td></td>
<td>PROC</td>
<td>3,351.90</td>
<td>2,936.93</td>
<td>3,040.41</td>
<td>3,362.95</td>
<td>3,389.03</td>
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<tr>
<td></td>
<td>OM</td>
<td>1,596.74</td>
<td>1,631.38</td>
<td>1,469.49</td>
<td>1,577.65</td>
<td>1,825.45</td>
</tr>
<tr>
<td>Domain Total</td>
<td></td>
<td>6,055.36</td>
<td>5,823.59</td>
<td>6,049.48</td>
<td>6,381.17</td>
<td>6,510.72</td>
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<tr>
<td>Ground</td>
<td>RDTE</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td></td>
<td>PROC</td>
<td>20.03</td>
<td>26.25</td>
<td>24.07</td>
<td>7.66</td>
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<td>207.06</td>
<td>233.58</td>
<td>237.50</td>
<td>241.50</td>
<td>245.96</td>
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<td>259.83</td>
<td>261.57</td>
<td>249.16</td>
<td>245.96</td>
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<tr>
<td>Maritime</td>
<td>RDTE</td>
<td>29.69</td>
<td>62.92</td>
<td>65.72</td>
<td>48.60</td>
<td>47.26</td>
</tr>
<tr>
<td></td>
<td>PROC</td>
<td>11.93</td>
<td>45.45</td>
<td>84.85</td>
<td>108.35</td>
<td>114.33</td>
</tr>
<tr>
<td></td>
<td>OM</td>
<td>5.79</td>
<td>4.71</td>
<td>3.76</td>
<td>4.00</td>
<td>4.03</td>
</tr>
<tr>
<td>Domain Total</td>
<td></td>
<td>47.41</td>
<td>113.08</td>
<td>154.32</td>
<td>160.94</td>
<td>165.62</td>
</tr>
<tr>
<td>All Unmanned</td>
<td>RDTE</td>
<td>1,136.41</td>
<td>1,318.21</td>
<td>1,605.29</td>
<td>1,489.16</td>
<td>1,343.52</td>
</tr>
<tr>
<td></td>
<td>PROC</td>
<td>3,383.86</td>
<td>3,008.63</td>
<td>3,149.32</td>
<td>3,478.96</td>
<td>3,503.36</td>
</tr>
<tr>
<td></td>
<td>OM</td>
<td>1,809.59</td>
<td>1,869.67</td>
<td>1,710.75</td>
<td>1,823.15</td>
<td>2,075.44</td>
</tr>
<tr>
<td>Domain Total</td>
<td></td>
<td>6,329.86</td>
<td>6,196.50</td>
<td>6,465.36</td>
<td>6,791.27</td>
<td>6,922.31</td>
</tr>
</tbody>
</table>

Table 2 shows UAS platforms reported in the DoD UAS roadmap (DoD, 2011b). This document stresses the need for affordable and convergent systems and envisions DoD to acquire Joint and interoperable, software, architecture, payloads and sensors for UAS acquisitions. Unit cost is an important factor in enabling the commanders with risk taking in their tactics and techniques. As DoD goes ahead with acquiring these platforms, affordability is required additional KPP in the requirements for major weapons acquisitions (DoD, 2010b).
C. RESEARCH QUESTIONS

There are two research questions addressed in this study.

1. **Primary Research Question:**

   What is the business case for MAGIC compared to Predator (MQ-1B), Global Hawk (RQ-4 A/B), and Reaper (MQ-9)

2. **Secondary Research Question:**

   What are the competing platforms for MAGIC including current and planned?

---

Table 2. DoD Unmanned Capabilities by Program (From DoD, 2011b)
D. THESIS OUTLINE

Chapter I provides motivation, background and the purpose of the study. Chapter II describes the methodology adopted in this study; metrics developed and used in the analysis; and the assumptions used in the business case analysis. Chapter III presents unmanned ISR platforms that are available and planned. It also provides key system performance parameters. This chapter provides Cost Estimation Relationships (CERs) for the MAGIC platform. Chapter IV discusses the analysis of MAGIC and three other platforms for 500 nautical miles scenario. Chapter V describes the analyses for 1000 nm, 2000 nm and 3000 nm ranges. Chapter VI contains conclusions and recommendations.
II. METHODOLOGY, METRICS AND ASSUMPTIONS

A. INTRODUCTION

1. Overview

This chapter presents the methodology used in developing the BCA. It also contains the two metrics used in the assessment of alternatives. The assumptions used in developing the BCA and the metrics are in the next section.

B. METHODOLOGY

1. Business Case Analysis

As suggested in a DoD instruction (DoD, 2011), business case analysis helps in the product decision making process at different stages of its evolution. The analysis and approach is adopted from this guide and Lim’s thesis (Lim, 2007). The BCA is adapted from the recommended steps as presented in Figure 1 (DoD, 2011).

![Figure 1. Business Case Analysis Process Components (from DoD, 2011)]
2. **Life Cycle Costs**

Life Cycle Costs are defined as the sum of Research, Development, Test and Evaluation (RDT&E), procurement cost, O & S cost and disposal cost (DoD, 2011; Nussbaum, 2010).

### C. METRICS

1. **Net Present Value of Life Cycle Cost**

The formula for the Net Present Value (NPV) is (Brealey, 2008)

\[
NPV = \frac{FV}{(1 + r)^n}
\]

\(NPV = \text{Net Present Value}\)
\(FV = \text{future value}\)
\(r = \text{interest rate}\)
\(n = \text{number of periods}\)

Future Value, in the above formula, is the total cost per year in future years. NPV of the total cost per year over the assumed life of the asset is the Net Present Value of the Life Cycle Cost (NPVLCC).

2. **Return Ratio**

Return ratio is the ratio between the NPVLCC of a given platform to the NPVLCC of MAGIC platform, given by

\[
RR = \frac{NPVLCC_{platform}}{NPVLCC_{MAGIC}}
\]

\(RR = \text{Return Ratio}\)
\(NPVLCC_{platform} = \text{Net Present Value of Life Cycle Cost of a platform}\)
\(NPVLCC_{MAGIC} = \text{Net Present Value of Life Cycle Cost of MAGIC}\)
D. ASSUMPTIONS

The following assumptions are applicable in the development of the BCA.

- All costs are normalized to FY10 $M
- Baseline Case discount factor (discount rate) of 2.5% is used in the net present value (NPV) calculations per Office of Management & Business (OMB) guidance
- Time horizon is 10 years with 24/7 persistent ISR coverage
III. SCENARIOS, PLATFORMS AND COST ESTIMATE RELATIONSHIPS (CERS)

A. INTRODUCTION

In this chapter, the analyses is presented for different scenarios considered for the BCA. The base line considered is for 500 nm scenario with other parameters defined in the section. The last section describes CERs for RDT&E and O & S costs for MAGIC.

B. SCENARIOS

There are four scenarios that were adapted from previous studies (Lim, 2007). These scenarios are 500 nm (base line range), 1000 nm (short range), 2000 nm (medium range) and 3000 nm (long range). These ranges represent operational conditions in areas of operations (AO) such as Afghanistan, North Korea, and Trans-Sahara regions.

C. PLATFORMS WITH ISR CAPABILITY

The present BCA addresses the platforms with Intelligence, Surveillance and Reconnaissance (ISR) capabilities in the medium altitude defined as 15,000 feet to 60,000 feet. Medium Altitude Global ISR and Communications (MAGIC) platform is the proposed candidate analyzed with other platforms. Tables 5 and 6 present platforms and their key performance parameters (DoD, 2009b; DoD, 2009c; DoD, 2009d; DoD, 2010a; BAMS, 2003; GAO, 2009). Table 7 gives notional additional data provided by USAF for analysis.
<table>
<thead>
<tr>
<th>Platforms with ISR capability</th>
<th>Length, ft</th>
<th>Wingspan, ft</th>
<th>Speed, Knots</th>
<th>Endurance, hrs</th>
<th>Range, nm</th>
<th>Altitude, ft</th>
</tr>
</thead>
<tbody>
<tr>
<td>MQ-1 Predator A</td>
<td>27</td>
<td>49</td>
<td>70</td>
<td>40</td>
<td>400</td>
<td>25000</td>
</tr>
<tr>
<td>MQ-1B Predator</td>
<td>36</td>
<td>66</td>
<td>160</td>
<td>24</td>
<td>2000</td>
<td>45000</td>
</tr>
<tr>
<td>MQ-9 Reaper</td>
<td>36</td>
<td>66</td>
<td>240</td>
<td>14</td>
<td>3200</td>
<td>45000</td>
</tr>
<tr>
<td>ER/MP</td>
<td>28</td>
<td>56</td>
<td>135</td>
<td>36</td>
<td>200</td>
<td>29000</td>
</tr>
<tr>
<td>RQ-4 Global Hawk</td>
<td>48</td>
<td>131</td>
<td>330</td>
<td>31</td>
<td>9950</td>
<td>60000</td>
</tr>
<tr>
<td>BAMS</td>
<td>48</td>
<td>131</td>
<td>310</td>
<td>30</td>
<td>9950</td>
<td>60000</td>
</tr>
<tr>
<td>Magic</td>
<td></td>
<td>132</td>
<td>70</td>
<td>120</td>
<td></td>
<td>20000</td>
</tr>
</tbody>
</table>

Table 5. Platforms with ISR Capabilities vs. Key Performance Parameters
Table 6. Platforms with ISR Capabilities vs. Key Performance Parameters, contd.

### Platforms with ISR capability (Cont’d)

<table>
<thead>
<tr>
<th>Platform</th>
<th>GTOW, lbs</th>
<th>Ext Payload, lbs</th>
<th>Int Payload, lbs</th>
<th>Remarks</th>
<th>Power, hp</th>
</tr>
</thead>
<tbody>
<tr>
<td>MQ-1 Predator A</td>
<td>2300</td>
<td>200</td>
<td>450</td>
<td>Rotax 4 Cy Eng</td>
<td></td>
</tr>
<tr>
<td>MQ-1B Predator</td>
<td>10000</td>
<td>3000</td>
<td>800</td>
<td>Honeywell TPE-331-10T</td>
<td>115</td>
</tr>
<tr>
<td>MQ-9 Reaper</td>
<td>10500</td>
<td>3000</td>
<td></td>
<td>Allison-Garret</td>
<td>950</td>
</tr>
<tr>
<td>ER/MP</td>
<td>3200</td>
<td>800</td>
<td></td>
<td>Thielert Centurion</td>
<td>135</td>
</tr>
<tr>
<td>RQ-4 Global Hawk</td>
<td>32250</td>
<td>4500</td>
<td></td>
<td>Rolls-Royce</td>
<td>950</td>
</tr>
<tr>
<td>BAMS</td>
<td>32350</td>
<td>2400</td>
<td>3200</td>
<td>Rolls-Royce AE3007 TF</td>
<td></td>
</tr>
<tr>
<td>Magic</td>
<td>11000</td>
<td>1000</td>
<td></td>
<td></td>
<td>168</td>
</tr>
</tbody>
</table>

Table 7. Platforms with notional ISR capabilities vs. Key Performance parameters

### USAF Data

<table>
<thead>
<tr>
<th>Platform</th>
<th>Payload-old, lbs</th>
<th>Payload-new, lbs</th>
<th>Endurance-old, Hrs</th>
<th>Endurance-new, Hrs</th>
</tr>
</thead>
<tbody>
<tr>
<td>MQ-9 Reaper</td>
<td>3000</td>
<td>1000</td>
<td>14</td>
<td>21</td>
</tr>
<tr>
<td>RQ-4 GHawk</td>
<td>4500</td>
<td>1000</td>
<td>31</td>
<td>30</td>
</tr>
<tr>
<td>MAGIC</td>
<td>1000</td>
<td>1000</td>
<td>120</td>
<td>120</td>
</tr>
<tr>
<td>MQ-1B-Predator</td>
<td>800</td>
<td>450</td>
<td>24</td>
<td>16</td>
</tr>
<tr>
<td>MAGIC</td>
<td>1000</td>
<td>450</td>
<td>120</td>
<td>131</td>
</tr>
</tbody>
</table>
D. COST ESTIMATION RELATIONSHIPS (CERS) FOR MAGIC

1. Cost Estimates for RDT&E for MAGIC

This section develops CERs relating the two key parameters for UAVs and applies it to MAGIC based on its key performance parameters.

The cost of fuel per flight hour for available UAVs is extracted from Selected Acquisition Reports (SARs), Acquisition Program Baseline (APBs) and other published data. Two relationships are developed for estimating Operations & Support (O & S) costs for MAGIC. The first method develops dollar/flight hour/Average Production Unit Cost (APUC) as a function of engine power. The second method develops dollar/flight hour as a function of Gross Take Off Weight (GTOW). The data for the CER is presented in the Table 8 (DoD 2009b, DoD 2009c, DoD 2009d, DoD 2009e, BAMS 2003). The x-axis on the graph is the product of payload and endurance given by

\[
\text{Payload (thousands of lbs) } \times \text{ Endurance (Hours)}
\]

The RDT&E/APUC is related to the Kilo-pound-Payload-Hr and shown as a graph. The value of the ratio RDT&E/APUC for MAGIC from the graph is 26 and approximated conservatively to 30. This parameter is used in calculating the RDT&E cost for a chosen APUC.

2. Cost Estimates for O & S for MAGIC

Two methods present calculations of the CER for O & S for MAGIC. The O & S cost is the average of the two methods. The first method uses the ratio of dollar cost of fuel per APUC as a function of the horsepower. The second relation plots dollar cost of fuel for flight hour as a function of the GTOW. The values of KPP of the MAGIC in the graph gives $3.7M (FY10 $M) per year as O & S cost.
Figure 2. CER for O & S for MAGIC: Left graph is the fuel cost ratio vs power and Right graph is Cost per Flight Hour vs. GTOW
3. Summary

Summarizing, this chapter presented UAV platforms in the medium altitude with key performance parameters. Cost estimate relationships for MAGIC are developed based on historical data. Two Cost estimate relationships to determine O & S cost based on horse power and GTOW are developed. Further, a ratio defined as RDT&E/APUC for MAGIC is developed. This information is used in calculating annual costs and life cycle cost.
IV. ANALYSIS FOR 500 NM RANGE

This chapter provides analysis of MAGIC compared to other three platforms for a 500 nm scenario. The measures of effectiveness described earlier are calculated and presented for the baseline case. Sensitivity analysis is given by varying the key parameters.

A. MAGIC COMPARED WITH PREDATOR

This section describes the analysis of MAGIC and predator for 500 nm scenario. Table 9 gives the key performance parameters for the MAGIC and Predator.

![Analysis - Base Case](image)

Table 9. Key Performance Parameters for MAGIC and Predator (*Values are rounded up)
Table 10. Net Present Value of Life Cycle Costs for MAGIC and Predator for 500nm

The Table 10 shows the calculations for the NPVLCC for the 500 nm range. The return ratio of 1.11 favors MAGIC for this baseline case. Table 11 shows the values for sensitivity analysis using the perturbations from the baseline. The RDT&E, APUC, and discount factors are perturbed and NPVLCC and RR are computed.
Table 11. Sensitivity Analysis of MAGIC and Predator for 500 nm

<table>
<thead>
<tr>
<th>Parameter Variations</th>
<th>RDTE (FY10 $M)</th>
<th>APUC (FY10 $M)</th>
<th>Discount Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baseline</td>
<td>510</td>
<td>17</td>
<td>0.025</td>
</tr>
<tr>
<td>Parameter Variations</td>
<td>300-510-1300</td>
<td>14-17-20</td>
<td>0.0-0.025-0.05</td>
</tr>
</tbody>
</table>

Example: RDTE = 510, APUC = 17, df = 0.025

\[ \text{RR} = \frac{\text{Net Present Value LOC_Predator}}{\text{Net Present Value LOC_MAGIC}} = \frac{1249}{1415} = 0.88, \text{ Predator} \]

The baseline case uses the RDT&E cost of $510M, APUC value of $17M, and discount factor of 2.5%. The sensitivity values have three each for RDT&E, APUC, and discount rate as in the table.
The Figure 3 shows variation of APUC with breakeven RDTE. The breakeven RDTE is the RDTE value corresponding to a return ratio of 1. As an example, for an APUC value of $17M, the breakeven RDTE value is about $320M. The figure shows that for RDTE of less than $320M, MAGIC favors Predator.

B. MAGIC COMPARED WITH GLOBAL HAWK

This section describes the analysis of MAGIC and Global Hawk for 500 nm scenario. Table 12 presents the key parameters for the two platforms.
Table 12. Key Performance Parameters for MAGIC and Global Hawk

The Table 13 presents the NPVLCC for the two platforms. The return ratio favors MAGIC for the baseline case parameters. The RDT&E, APUC, and discount factors are perturbed and Figure 4 presents the results of APUC as breakeven RDT&E cost is varied. Pairs of values to the left of the curve favor MAGIC and to the right of the curve Global Hawk is favored. As an example, consider an APUC of $15M, and read the breakeven RDT&E value of $6.13B from the left graph. This indicates that MAGIC is favored over Global Hawk for all values of RDT&E less than $6.13B for an APUC cost of $15M. Similarly, for a discount factor of 0.03, the breakeven RDT&E is observed as $2.14B. This reading indicates MAGIC is preferred over Global Hawk for all values of RDT&E less than $2.14B for a discount factor of 0.03.
Table 13. NPVLCC analysis for the MAGIC and Global Hawk

Figure 4. Sensitivity Analysis for MAGIC and Global Hawk platforms
C. MAGIC COMPARED WITH REAPER

This section describes the analysis of MAGIC and Reaper for 500 nm scenario. Table 14 gives the key performance parameters for MAGIC and Reaper platforms.

Table 14. Key Performance Parameters for MAGIC and Reaper platforms

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Reaper</th>
<th>MAGIC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Endurance, Hrs</td>
<td>14</td>
<td>120</td>
</tr>
<tr>
<td>Speed, Knots</td>
<td>240</td>
<td>70</td>
</tr>
<tr>
<td>Range, nm</td>
<td>500</td>
<td>500</td>
</tr>
<tr>
<td>Payload, lb</td>
<td>3000</td>
<td>1000</td>
</tr>
<tr>
<td>GTOW, lbs</td>
<td>10,500</td>
<td>11,000</td>
</tr>
<tr>
<td>No. of UAVs Required</td>
<td>7</td>
<td>3</td>
</tr>
</tbody>
</table>

Calculations based on Cruise Speed, Endurance, Maintenance Time, No. of UAVs in the Area of Operations, No. of required spare UAVs.

Table 15 shows the calculations for NPVLCC and the Return Ratio for these platforms in. The RR favors MAGIC for the baseline case at 500 nm range. The RDT&E, APUC, and discount factors are perturbed to analyze sensitivity to these parameters. Figure 5 shows the variations of these parameters. The graph on the left shows the variation of APUC with breakeven RDT&E. The pairs of points to the left of the curve favor MAGIC and favor Reaper to the right of the curve. The graph on the right shows the variation of breakeven RDT&E with discount factor.
Table 15. NPVLCC and Return Ratio for the MAGIC and Reaper for the baseline case

<table>
<thead>
<tr>
<th></th>
<th>Reaper (MQ-9)</th>
<th>MAGIC</th>
<th>Return Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fleet Size Required</td>
<td>7</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>Sorties per Year</td>
<td>992</td>
<td>84</td>
<td></td>
</tr>
<tr>
<td>Investment Cost (FY10M)</td>
<td>$193</td>
<td>$51</td>
<td></td>
</tr>
<tr>
<td>Procurement</td>
<td>$193</td>
<td>$51</td>
<td></td>
</tr>
<tr>
<td>Total Investment</td>
<td>$193</td>
<td>$561</td>
<td></td>
</tr>
<tr>
<td>O &amp; S Cost (Annual)</td>
<td>$167</td>
<td>$98</td>
<td></td>
</tr>
<tr>
<td>10 Year NPV Life Cycle Cost</td>
<td>$1.654</td>
<td>$1.415</td>
<td>1.17</td>
</tr>
<tr>
<td></td>
<td>$193</td>
<td>$561</td>
<td></td>
</tr>
<tr>
<td></td>
<td>$1,461</td>
<td>$854</td>
<td></td>
</tr>
<tr>
<td>Total NPV-LCC (FY10M)</td>
<td>$1.654</td>
<td>$1.415</td>
<td>1.17</td>
</tr>
</tbody>
</table>

\[
\text{Return Ratio} = \frac{\text{Net Present Value LOO_Reaper}}{\text{Net Present Value LOO_Magic}} = 1.17
\]

\( >1 \), Favor MAGIC
D. SUMMARY OF BASELINE CASE FOR 500 NM RANGE

The baseline case has $510M for RDT&E, $17M for APUC, and a discount factor of 2.5% with a 10-year time horizon. MAGIC outperforms Global Hawk and Reaper for the baseline case with reasonable input values. Predator is preferred over MAGIC with the present cost estimates. The sensitivity analysis shows that if RDT&E costs are about $320M (40% reduced from $510M) then MAGIC is preferred. The sensitivity analyses also show that MAGIC is preferred over Global Hawk and Reaper platforms.
V. ANALYSIS FOR 1000, 2000, AND 3000 NM RANGE

This chapter presents analysis for the MAGIC compared with the three ISR platforms for the 1000, 2000, and 3000 nm scenarios. The baseline case assumptions of RDT&E, APUC, and O & S cost is same for these ranges. The sensitivity analysis parameters have the same variations as the 500 nm range.

A. MAGIC AND PREDATOR FOR 1000 NM RANGE

Figure 6 presents the results of the analysis for this range. The x-axis has the breakeven RDT&E (BE-RDT&E) plotted against APUC. The BE-RDT&E indicates the RDT&E cost that is indifferent to both the platforms. As an example, for an APUC cost of $15M, the BE-RDT&E value from the graph is seen to be $1B. MAGIC is favored for $15M APUC for all values of the RDT&E cost less than $1B.

Figure 6.  Design Trade Space with APUC vs. Breakeven RDT&E for MAGIC and Predator for 1000 nm range
B. MAGIC AND REAPER FOR 1000 NM RANGE

Figure 7 shows the design trade space for MAGIC and Reaper in this range. As an example, for an APUC value of $15M, the breakeven RDT&E is seen from the graph to be $1.98B. This indicates MAGIC is preferred over Reaper for RDT&E cost less than $1.98B for an APUC of $15M.

Figure 7. Design Trade Space for MAGIC and Reaper for 1000 nm range

C. ANALYSIS FOR MAGIC AND GLOBAL HAWK FOR 1000 NM RANGE

Figure 8 presents the results of the analysis for these platforms for the 1000 nm scenario. The left graph in the figure shows the design trade space with APUC and BE-RDT&E as parameters. As an example, an APUC value of $15M corresponds to a BE-RDT&E cost of $6.13B from the graph. This implies that MAGIC is preferred over Reaper for all values of RDT&E cost less than $6.13B for a chosen APUC value of $15M.
Figure 8. Trade space for MAGIC and Global Hawk for 1000 nm range

Figure 9. Trade space for MAGIC and Global Hawk for 1000 nm range with RDT&E vs discount factor
Figure 9 presents results with RDT&E and discount factor as parameters for these two platforms. As an example, for a discount factor of 0.03, MAGIC is favored over Global Hawk for all values of the RDT&E cost less than $2.13B.

D. ANALYSIS OF MAGIC FOR 2000 NM RANGE

This section presents analysis for MAGIC compared with Global Hawk platform. Other platforms cannot compete with the key performance parameters. Figure 10 presents the design trade space for MAGIC and Global Hawk. As an example, for an APUC of $15M, the graph provides a breakeven RDT&E of $7.56B. MAGIC is favored for all values of RDT&E under $7.56B for a selected APUC of $17M.

![Design Trade Space](image)

Figure 10. Design Trade Space for MAGIC and Global Hawk for 2000 nm range
E. ANALYSIS OF MAGIC FOR 3000 NM RANGE

This section provides analysis for MAGIC compared with Global Hawk. Other platforms cannot compete with the given key performance parameters. Figure 11 shows the resulting design trade space. As an example, for an APUC of $15M, the breakeven RDT&E is $17.42B. MAGIC is preferred for all values of RDT&E cost less than $17.32B for the selected APUC of $17M.

![Figure 11. Design Trade Space for MAGIC and Global Hawk for 3000 nm range](image)

F. ADDITIONAL DATA ANALYSIS

The sensitivity analyses for MAGIC with Predator, Reaper and Global Hawk for additional values are documented in Appendices A, B, and C.
VI. CONCLUSIONS AND RECOMMENDATIONS

This chapter presents conclusions and recommendations based on the data and analysis of MAGIC and other three platforms. The measures of effectiveness used in the comparisons are Net Present Value of Life Cycle Cost and the Return Ratio (RR), which is the ratio of NPVLCC_candidate and NPVLCC_MAGIC. The sensitivity analysis parameters are RDT&E cost, APUC, and discount factor.

A. CONCLUSIONS

1. Primary Research Question

The return ratio (RR) is used to compare the platform relative economic feasibility. The results indicate that MAGIC outperforms Reaper (MQ-9) and Global Hawk (RQ-4) for all reasonable values of input variables. Predator (MQ-1B) outperforms MAGIC under current MAGIC cost estimates. MAGIC becomes competitive over Predator when the RDT&E cost is about $300M (approximately 40% lower than baseline $510M) or unit production costs are under $14M (approximately 20% lower than baseline $17M).

In the 1000 nm range, MAGIC outperforms Predator, Reaper, and Global Hawk platforms. MAGIC dominates Global Hawk in 2000 nm and 3000 nm ranges. Other platforms do not meet range requirements. The results for a payload of 1000 lbs and 450 lbs show similar trends. The results show that Reaper is marginally better than MAGIC for the 500 nm range. MAGIC is preferred over Global Hawk in this range. At the range of 1000 nm MAGIC outperforms Global Hawk and is indifferent compared to Reaper. MAGIC dominates Global Hawk and Reaper platforms for 2000 nm range. MAGIC outperforms Global Hawk at 3000 nm range for this payload. The results for MAGIC compared to Predator with a payload of 450 lbs indicate that MAGIC is preferred over Predator in the 500 nm and dominates at 1000 nm range. Predator cannot compete in the 2000 nm and 3000 nm range.

Summarizing, MAGIC platform outperforms Reaper and Global Hawk for ISR capabilities with reasonable input values in the 500 nm range. Predator is preferred at this
range with the present cost estimates of MAGIC. MAGIC is preferred platform over Reaper and Global Hawk in 1000 nm range and dominates Global Hawk in the 2000 and 3000 nm range. Further refinements in the cost estimates of RDT&E and O &S for MAGIC would be helpful in the next milestone decision-making process.

2. Secondary Research Question

There are several UAV platforms under various stages acquisition cycle. Some salient ones besides the platforms considered in this study include BAMS, Hunter, ER/MP and Vulcan. Their characteristics and key performance parameters are given in the roadmap and other studies (DoD, 2009a; Bowman & Brown, 2008; GAO 2009; Drew et al., 2005).

B. RECOMMENDATIONS

The present study suggests that MAGIC is preferred over the other platforms for the ISR mission requirements with the assumptions of the baseline and the scenarios.
APPENDIX A. ADDITIONAL RESULTS FOR MAGIC AND PREDATOR

The following tables and graphs support the analysis of MAGIC compared with Predator platform. The tables and figures have the same meanings and interpretations as the main chapters.

Table 16. Return Ratio data for MAGIC and Predator for 500 nm
Figure 12. Trade space for MAGIC and Predator using RR, RDTE and APUC for 500 nm

- Observations: ALL VALUES ABOVE 1.0 FAVOR MAGIC.
- MAGIC is favored for RDTE less than $320M (Discount factor = 0.025, APUC=$17M)
- MAGIC is favored for RDTE less than $480M (Discount factor = 0.0, APUC = $14M)
- MAGIC is favored for RDTE less than $200M (Discount factor=0.025, APUC=$20M)
Figure 13. Design Trade Space for MAGIC and Predator using RR with RDTE varying discount factors for 500 nm range
Figure 14. Design Trade Space for MAGIC and Predator using RR vs. discount factor varying RDT&E cost for 500 nm range

- Observations: ALL VALUES ABOVE 1.0 FAVOR MAGIC.
- Magic is favored for APUC = $17M and RDTE = $300M; Predator is favored for RDTE = $510M and $1300M.
Figure 15. Design Trade Space for MAGIC and Predator using RR vs. APUC varying RDT&E for 500 nm range

- Observations: ALL VALUES ABOVE 1.0 FAVOR MAGIC.
- For RDTE=$300M, MAGIC is favored (APUC ranging from 14-19)
- For RDTE=$510M and $1300M, Predator is favored (APUC from $14-$19M)
APPENDIX B. ADDITIONAL RESULTS FOR MAGIC AND GLOBAL HAWK

This appendix presents additional results for MAGIC and Global Hawk platforms. The tables and graphs have the same interpretations as in the main chapters.

Table 17. Return Ratios for MAGIC and Global Hawk for 500 nm range
Figure 16. Design Trade Space for MAGIC and Global Hawk using RR vs. RDTE varying Discount factor for 500 nm range

- Observation: As the estimate of MAGIC RDTE increases, for a given discount rate, MAGIC is still favored, but less so than in the Base case.
Observations:
- For a given RDTE, as MAGIC’s APUC decreases, MAGIC is more favored.
- For a given APUC, as MAGIC’s RDTE decreases, MAGIC is more favored.

Figure 17. Design Trade Space for MAGIC and Global Hawk using RR vs. RDTE varying APUC for 500 nm range
Design Trade Space for MAGIC and Global Hawk using RR vs. df varying RDT&E and RR vs. APUC varying RDTE for 500 nm
Table 18. Return Ratios for MAGIC and Global Hawk for 2000 nm range
Figure 18. Design Trade Space for MAGIC and Global Hawk using RR vs. RDT&E varying df for 2000 nm range
Figure 19. Design Trade Space for MAGIC and Global Hawk using RR vs. RDTE varying df for 2000 nm range
Table 19. Return Ratios for MAGIC and Global Hawk for 3000 nm range
Figure 20. Design Trade Space for MAGIC and Global Hawk using RR vs. RDT&E varying df for 3000 nm range

Observation: As the estimate of MAGIC RDTE increases, for a given discount rate, MAGIC is still favored, but less so than in the Base case.
Figure 21. Design Trade Space for MAGIC and Global Hawk using RR vs. RDT&E varying APUC for 3000 nm range
APPENDIX C. ADDITIONAL RESULTS FOR MAGIC AND REAPER

This appendix presents additional tables and graphs for MAGIC and Reaper. The results and interpretations are similar to the results in the main chapters.

Table 20. Return Ratios for MAGIC and Reaper for 500 nm range
Figure 22. Design Trade Space for MAGIC and Reaper using RR vs. df varying RDT&E and RR vs. APUC varying RDTE for 500 nm range.

- Observations:
  - The return ratio decreases as discount rate increases; MAGIC is less favored (Left Figure).
  - The return ratio decreases as APUC increases; MAGIC is less favored (Right Figure).
Figure 23. Design Trade Space for MAGIC and Reaper using RR vs. RDT&E varying Discount Rate for 500 nm range

Observation:
- As the estimate of MAGIC RDTE increases, for a given discount rate, MAGIC is still favored, but less so than in the Base case.
Figure 24. Design Trade Space using RR vs. RDT&E varying APUC for 500 nm range
Table 21. Return Ratios for MAGIC vs Reaper for 1000 nm range
Figure 25. Design Trade Space for MAGIC vs Reaper using RR vs. Discount rate varying RDT&E and RR vs. APUC varying RDT&E for 1000 nm range
Figure 26. Design Trade Space for MAGIC and Reaper using RR vs. RDT&E varying Discount rate for 1000 nm range

- Observation:
- As the estimate of MAGIC RDTE increases, for a given discount rate, MAGIC is still favored, but less so than in the Base case.
Figure 27. Design Trade Space for MAGIC and Reaper using RR vs. RDT&E varying APUC for 1000 nm range

**Observations:**
- For a given RDTE, as MAGIC’s APUC decreases, MAGIC is more favored.
- For a given APUC, as MAGIC’s RDTE decreases, MAGIC is more favored.
LIST OF REFERENCES


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   Ft. Belvoir, VA

2. Dudley Knox Library  
   Naval Postgraduate School  
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