SYM-AM-16-023

PROCEEDINGS
OF THE
THIRTEENTH ANNUAL ACQUISITION RESEARCH SYMPOSIUM

WEDNESDAY SESSIONS
VOLUME I

Measuring the Return on Investment and Real Option Value of Weather Sensor Bundles for Air Force Unmanned Aerial Vehicles

Thomas Housel, Professor, NPS
Johnathan Mun, Research Professor, NPS
David Ford, Research Associate Professor, NPS
Sandra Hom, Research Associate, NPS
Dave Harris, NPS
Matt Cornachio, NPS

Published April 30, 2016

Prepared for the Naval Postgraduate School, Monterey, CA 93943.

ACQUISITION RESEARCH PROGRAM
GRADUATE SCHOOL OF BUSINESS & PUBLIC POLICY
NAVAL POSTGRADUATE SCHOOL

The research presented in this report was supported by the Acquisition Research Program of the Graduate School of Business & Public Policy at the Naval Postgraduate School.

Panel 2. Applications of Real Options Analysis in Defense Acquisition

Wednesday, May 4, 2016	
11:15 a.m. – 12:45 p.m.	**Chair: James E. Thomsen,** Former Principal Civilian Deputy, Assistant Secretary of the Navy for Research, Development, & Acquisition ***Acquiring Technical Data With Renewable Real Options*** Michael McGrath, ANSER Christopher Prather, Senior Associate Analyst, ANSER ***Incorporation of Outcome-Based Contract Requirements in a Real Options Approach for Maintenance Planning*** Xin Lei, Research Assistant, University of Maryland Navid Goudarzi, Postdoctoral Researcher, University of Maryland Amir Reza Kashani Pour, Research Assistant, University of Maryland Peter Sandborn, Professor, University of Maryland ***Measuring the Return on Investment and Real Option Value of Weather Sensor Bundles for Air Force Unmanned Aerial Vehicles*** Thomas Housel, Professor, NPS Johnathan Mun, Research Professor, NPS David Ford, Research Associate Professor, NPS Sandra Hom, Research Associate, NPS Dave Harris, NPS Matt Cornachio, NPS

Measuring the Return on Investment and Real Option Value of Weather Sensor Bundles for Air Force Unmanned Aerial Vehicles

Thomas J. Housel—specializes in valuing intellectual capital, knowledge management, telecommunications, information technology, value-based business process reengineering, and knowledge value measurement in profit and non-profit organizations. He is currently a tenured full professor for the Information Sciences (Systems) Department. He has conducted over 80 knowledge value added (KVA) projects within the non-profit, Department of Defense (DoD) sector for the Army, Navy, and Marines. He also completed over 100 KVA projects in the private sector. The results of these projects provided substantial performance improvement strategies and tactics for core processes throughout DoD organizations and private sector companies. He has managed a $3 million+ portfolio of field studies, educational initiatives, and industry relationships. His current research focuses on the use of KVA and "real options" models in identifying, valuing, maintaining, and exercising options in military decision-making. [tjhousel@nps.edu]

Johnathan Mun—is a research professor at the U.S. Naval Postgraduate School (Monterey, CA) and teaches executive seminars in quantitative risk analysis, decision sciences, real options, simulation, portfolio optimization, and other related concepts. He has also researched and consulted on many Department of Defense and Department of Navy projects and is considered a leading world expert on risk analysis and real options analysis. He has authored 12 books. He is the founder and CEO of Real Options Valuation Inc., a consulting, training, and software development firm specializing in strategic real options, financial valuation, Monte Carlo simulation, stochastic forecasting, optimization, and risk analysis located in northern California. [jcmun@realoptionsvaluation.com]

David Ford—received his BS and MS degrees from Tulane University and his PhD degree from MIT. He is an associate professor in the Construction Engineering and Management Program, Zachry Department of Civil Engineering, Texas A&M University, and the Urban/Beavers Development Professor. He also serves as a research associate professor of acquisition with the Graduate School of Business and Public Policy at the U.S. Naval Postgraduate School in Monterey, CA. Prior to joining Texas A&M, he was on the faculty of the Department of Information Science, University of Bergen, Norway. For over 14 years, he designed and managed the development of constructed facilities in industry and government. His current research investigates the dynamics of development supply chains, risk management with real options, and sustainability. [davidford@tamu.edu]

Sandra Hom—is a Research Associate at the Naval Postgraduate School (Monterey, CA) and specializes in market structures, industry benchmarking research, and knowledge value added analysis. [schom@nps.edu]

Dave Harris—Naval Postgraduate School

Matt Cornachio—Naval Postgraduate School

Measuring the Return on Investment and Real Options Valuation of a Weather Sensor Bundle in Mission Execution Processes

Weather-related losses of remotely piloted aircraft (RPA) have exceeded $100 million over the past 20 years (Preisser & Stutzreim, 2015). The growing ubiquity of RPAs in routine combat operations is driving fundamental changes to the nature of support for these unmanned aircraft. Support requirements such as bandwidth availability, data transmission capabilities, digital interoperability, and weather forecasting are being pushed to unprecedented limits to ensure they enhance RPA performance without imposing superfluous constraints. A persistent trend plaguing RPA operators has been poor environmental situational awareness degrading overall operational effectiveness.

The impact of suboptimal weather forecasting, especially regarding adverse weather conditions, on RPAs is significant, and it is driving an increasing need for fundamental changes to a system that has matured over several decades of proven operational success with manned aircraft. Without humans in the cockpit, the nature and frequency of weather forecasting processes and supporting technologies must evolve to enable optimized RPA operational performance by providing weather products that achieve high levels of resolution, accuracy, and timeliness.

This research supports Air Force A2I leadership by providing a comprehensive business case analysis that estimates the overall value of investing in, acquiring, and implementing WeatherNow technology. It provides a risk-based assessment for technology portfolio optimization. The WeatherNow technology in this research refers to an advanced weather forecasting software suite and an onboard weather sensor. The software suite collects, decodes, and processes space-based, airborne, and surface observations used in conjunction with numerical weather prediction models. Using advanced algorithms, data fusion techniques, and rapid update capability, it provides comprehensive environmental intelligence products, improved asset protection, and decreased operational risk. The onboard weather sensor provides real-time weather information about icing, humidity, and cloud top heights directly to RPA aircraft operators. The sensor also provides continuous weather data in otherwise data-deprived areas. The software suite and sensor were built to be integrated to provide timely, relevant, and mission-specific environmental intelligence, early threat detection for icing or instrument meteorological conditions (IMC), and overall enhanced ISR collection capability.

The study estimates the value of WeatherNow technology in terms of return on investment (ROI) and uses integrated risk management (IRM) to provide a way to value implementation options; both are indispensable tools that support informed decision-making for technology investment. The analysis and conclusions from this study will support development of effective policy and strategic investment decisions in the effort to transform the existing weather forecasting processes to meet modern demand for near real-time weather information to RPA operators.

To represent a typical mission execution process, this study focused on an RQ-4B Global Hawk squadron based at Beale Air Force Base (AFB). The mission execution process model (MEPM) describes how an RQ-4B squadron plans and executes a typical intelligence, surveillance, and reconnaissance (ISR) mission. The MEPM consists of five subprocesses that are further broken down into tasks. Each subprocess takes an input and changes it in some way to produce an output, which becomes the input for the next subprocess. This process flow continues until the final output is produced, the RPA mission itself. The MEPM in this study was verified by a number of SMEs to be an accurate representation while remaining generic enough to be extensible to a wide range of platforms and scenarios throughout the Air Force and the DoD at large. To ensure extensibility while conserving accuracy in the model, this study is driven by key assumptions that are explained in further detail in the study.

The quantitative framework for this research is known as ROI-IRM (return on investment with integrated risk management). This methodology measures the value added by the WeatherNow technology and by intangibles such as the people executing the process. Since traditional ROI calculation is inadequate for assessing the value of intangible assets such as embedded knowledge, this study uses the knowledge value added (KVA) methodology to estimate ROI. The benefit of using KVA is that a traditional metric such as ROI can be estimated without revenue, by using a surrogate by describing process outputs in common units of output (CUO). Another benefit of KVA is its ability to allocate value across the subprocesses and even down to the task level, a much improved granularity compared to traditional investment finance ROI estimates. To measure the intangible benefits, KVA uses a metric called return on knowledge (ROK). To determine ROI and ROK, KVA compares the As-Is MPEM, the current process, to the To-Be MPEM, the process with the WeatherNow technology included. ROI and ROK estimates are precisely comparable with regard to value for cost return estimates.

Integrated risk management (IRM) uses the KVA results to further develop the business case by forecasting the future value of technology options. IRM uses a methodology known as real options valuation (ROV) to provide leaders with a robust decision support tool to enable informed technology portfolio investment and implementation decisions based on future value estimates. ROI-IRM is an essential tool for supporting decisions on high level strategy and policy concerning new technology and its effective implementation and integration. KVA and IRM used together form a powerful and defensible analytical tool set for decision-making for technology investments.

KVA Analysis and Results

KVA produces two key metrics, ROI and ROK, both expressed as ratios. KVA takes the traditional ROI calculation used in finance and adapts it to non-revenue generating organizations such as the DoD. As in investment finance, a higher ROI indicates a better return for the money invested. For DoD applications, a surrogate value for revenue must be used to monetize the outputs for purposes of an ROI estimate that typically comes from a market comparable analysis. This research used a very conservative, putative value of $1 per unit of output. ROK is calculated as number of outputs (in common units) divided by the cost to produce the outputs. A higher ROK indicates a better use of knowledge assets, and therefore a better investment.

Overall, the results of the KVA analysis show that the use of WeatherNow technology in the RPA mission execution process will generate significantly higher returns and far better use of the WeatherNow technology over the current As-Is process. By comparing the As-Is MPEM to the To-Be MPEM, KVA not only reveals that the WeatherNow technology will add value, but exposes which tasks benefit the most and which benefit the least. Figure 1 displays the differences in returns between both models. With the WeatherNow technology included in the process, ROI increased by 69% and ROK is more than 2.8 times larger than the As-Is ROK. These gains are attributable to the large improvement within the Flight Brief/Outbrief/Weather Update subprocess, specifically the Weather Update task. The WeatherNow technology greatly improves the frequency at which RPA operators receive weather updates, from every four hours in the As-Is process, to every 15 minutes in the To-Be process. This increase means an ROK almost 300 times larger and an ROI over 1000 times larger than the As-Is model. These enormous improvements are due to the process recognizing the added value of the new technology many more times compared to the As-Is without WeatherNow.

	----- As-Is -----		----- To-Be -----			
Mission Execution Process Description (RQ-4B) Items in red are WX-related	**Return on Knowledge**	**Return on Investment**	**Return on Knowledge**	**Return on Investment**	**Change in Return on Knowledge as Ratios**	**Change in Return on Investment as Ratios**
TOTAL	**38%**	**-62%**	**107%**	**7%**	**2.8**	**1.1**
DAY PRIOR TO FLIGHT						
Data Extraction (mission study)	**35%**	**-65%**	35%	-65%	**1.0**	**1.0**
Confirm which mission you are flying (i.e. which COCOM, route, etc)	101%	1%	101%	1%	1.0	1.0
Confirm currency to fly in that theater and other currency items required for flight	169%	69%	169%	69%	1.0	1.0
Confirm aircraft assignment and status with maintenance	31%	-69%	31%	-69%	1.0	1.0
Review SPINS and classified regulations that pertain to your mission	23%	-77%	23%	-77%	1.0	1.0
Review en route procedures built by COCOM Flight Commander	31%	-69%	31%	-69%	1.0	1.0
File flight plan (DD-175 or 1801)	310%	210%	310%	210%	1.0	1.0
Disseminate products	62%	-38%	62%	-38%	1.0	1.0
Review Terminal Area Procedure brief (if doing TO/LDG and unfamiliar with local operations)	31%	-69%	31%	-69%	1.0	1.0
DAY OF FLIGHT						
Identify Showstoppers (determine and decide)	**78%**	**-22%**	**251%**	**151%**	**3.2**	**8.0**
Does the weather forecast support flight safety and tactical execution of the mission?	61%	-39%	434%	334%	7.1	9.6
Are appropriate aircraft available for the mission?	21%	-79%	21%	-79%	1.0	1.0
No prohibitive interference (GPS degraded/denied, SAM threat, red air, etc)	103%	3%	103%	3%	1.0	1.0
Can we mitigate expected threats en route and in the target area to an acceptable risk level?	123%	23%	434%	334%	3.5	14.7
Do we have satisfactory LOS comm/data link conditions?	62%	-38%	62%	-38%	1.0	1.0
Have the appropriate supporting agencies been assigned?	62%	-38%	62%	-38%	1.0	1.0
Simultaneous detailed mission planning (based on individual assignments and responsibilities)	**10%**	**-90%**	**10%**	**-90%**	**1.0**	**1.0**
All mission materials and products complete for mission commander review	10%	-90%	10%	-90%	1.0	1.0
Formal Intelligence update (receive intelligence analysis of the following considerations)	**124%**	**24%**	**124%**	**24%**	**1.0**	**1.0**
METT-TSL, EN tactics, EMLCOA, EMDCOA, Threats, Friendly situation	124%	24%	124%	24%	1.0	1.0
Flight Brief/Outbrief/Weather Update Brief	**79%**	**-21%**	**22659%**	**22559%**	**287.6**	**1064.7**
All mission participants understand the plan and their role in support	41%	-59%	41%	-59%	1.0	1.0
Outbrief with Operations Duty Officer (receive latest updates)	45%	-55%	45%	-55%	1.0	1.0
Weather update (icing, convection, lightning, IMC, threat mitigation, etc)	82%	-18%	41616%	41516%	506.7	2324.9
Safety brief/ORM considerations prior to execution	62%	-38%	62%	-38%	1.0	1.0

Figure 1. Impacts of WeatherNow Technology Use on Mission Execution (Differences in Returns as Ratios)

IRM Analysis and Results

The IRM portion of this research incorporates raw data and KVA results from a concurrent study concerned specifically with the weather forecasting process. Both studies use the ROI-IRM methodologies and serve as complementary works. Three deployment options were evaluated using IRM Analysis of Alternatives. The first option, Strategy A, is a phased implementation in which the WeatherNow technology is implemented incrementally over time. The second option, Strategy B, is a higher risk option in terms of capital investment and involves immediate implementation and quick returns. The third option, Strategy C, is to proceed with the existing plan of implementing the new technology on 50 Global Hawk aircraft and no more. Figure 2 displays the results from the ROV analysis. Based on IRM economic valuation forecasting, the highest value option is to deploy the WeatherNow technology immediately.

AS-IS Strategy

Asset Value	$ 270,707
Implementation Cost	$ 1,342,045
Maturity	0
Risk-Free Rate (Annualized %)	0.00%
Dividend Rate (Annualized %)	0.00%
Volatility (Annualized %)	9.85%
ROI %	-79.83%
Net Present Value	$ (1,071,338)
Option Value	$ -
Total Strategic Value	**$ (1,071,338)**

TO-BE Strategy: Immediate Implementation

Asset Value	$3,986,537,414
Implementation Cost	$ 5,198,024
Maturity	3
Risk-Free Rate (Annualized %)	0.92%
Dividend Rate (Annualized %)	0.00%
Volatility (Annualized %)	30.56%
Total Strategic Value	**$3,981,480,893**
Incremental Value-Added	**$3,982,552,231**

TO-BE Strategy: Sequential Implementation

Asset Value	$ 1,993,268,707
Implementation Cost: Phase I	$ 519,802
Implementation Cost: Phase II	$ 1,039,605
Implementation Cost: Phase III	$ 1,039,605
Maturity: Phase I	2
Maturity: Phase II	4
Maturity: Phase III	6
Risk-Free Rate (Annualized %)	1.56%
Dividend Rate (Annualized %)	0.00%
Volatility (Annualized %)	30.56%
Total Strategic Value	**$ 1,990,841,590**
Incremental Value-Added	**$ 1,991,912,928**

Real Options Valuation

Strategy A Phased Implementation	$ 1,990,841,590
Strategy B Immediate Execution	$ 3,981,480,893
Strategy C As-Is Base Case	$ (1,071,338)

Figure 2. ROV Results

Insights

Although enormous improvements in ROI and ROK were realized, there are still more unrealized benefits of using WeatherNow technology. These benefits include the improvement in the richness of information that RPA operators receive and the implications of this richness on the level of confidence that operators have in making critical go/no-go decisions during mission execution.

Recommendations

Based on the results of this analysis, the following recommendations are submitted. To reduce uncertainty and mitigate risks, leaders should consider total strategic value through sophisticated analytical techniques, such as those used in this study, to inform critical decision-making. Once selected, investments should be tracked and monitored over time and then adjusted as necessary based on observed performance. This study was designed around a mature analytical framework and is extensible to a wide range of services, technologies, and platforms. Similar economic valuation analyses should be performed on other aviation platforms that may benefit from the WeatherNow technology, particularly lower flying RPA platforms that are more limited by adverse weather than the high-flying Global Hawk.

Conclusion

This quantitative analysis has proven that implementation of WeatherNow technology will improve the current mission execution process and has provided risk-based decision support tools to assist with critical decisions. This research did not examine the socio-technical implications of implementing such sophisticated technology in the mature weather forecasting system. Thus, there is opportunity for further research to conduct a detailed examination of potential acceptance issues with WeatherNow and how policy should evolve to support the optimal integration and sustained success of WeatherNow technology. This is an important area for continued research, investment, and innovation, toward modernizing the weather forecasting system to complement the unique needs of RPAs, improving their operational effectiveness, and reducing their susceptibility to adverse weather conditions.

Measuring the Return on Investment and Real Options Value of a Weather Sensor Bundle in Weather Forecasting Processes

Remotely Piloted Aircraft (RPA) usage has grown exponentially both in ubiquity and utility over the past decade and a half. From their initial use as a purely tactical-level asset in providing ground troops with aerial reconnaissance and surveillance, RPAs have become a strategic-level asset with the precision strike capability to take out high-level targets anywhere in the world. Currently, the greatest threat to RPAs is not surface-to-air missiles, but rather their susceptibility to severe weather conditions (Preisser & Stutzreim, 2015). When Unmanned Aerial Vehicles (UAVs) conduct missions in austere and remote environments where little or no infrastructure exists, timely and accurate weather forecasts have become difficult and in some cases almost impossible to produce. Losses in the hundreds of millions of dollars can be attributed to UAV crashes caused by high winds, icing, lightning, and heavy turbulence (Preisser & Stutzreim, 2015). Unfortunately during the development and acquisition of many UAVs in use today, very little testing and analysis of environmental situational awareness was conducted in order to prepare for this threat. Furthermore, without a human present on the platform itself, it becomes even more difficult to determine current weather conditions throughout the mission, exacerbating the threat that severe weather creates. It is for these reasons that a need for increased weather situational awareness has arisen among the UAV community.

The current weather forecasting process for UAV missions reflects a high degree of uncertainty and is often based on hours-old and sometimes inaccurate information. WeatherNow technology will attempt to mitigate the risks presented by the current weather forecasting process by providing significantly improved environmental awareness to maximize mission effectiveness and platform survivability. The program consists of an on-board weather sensor referred to as an Atmospheric Sensing and Prediction System (ASAPS) as well as a software suite, called Nowcasting, that fuses together data from the sensor as well as from existing weather nodes (such as satellite imagery and ground-based radar) to create weather updates that are accurate, timely, and relevant to the RPA crew.

Unique to the WeatherNow technology is the method in which the sensor and software suite are able to interoperate and integrate with current RPA tactics, tools, and procedures (Preisser & Stutzreim, 2015). The WeatherNow program consists of three separate phases that together produce actionable, real time, and much improved environmental awareness. Part one, Mission Area Sensor Streaming (MASS) retrieves environmental data from several sources, both typical and atypical (such as overhead persistent infrared) for the area of interest. Part two, Dynamic Rapid Update Module (DRUM), fuses together the data from the MASS phase (as well as data retrieved from the ASAPS sensor) to create a 4-D view of the environmental situation in the targeted area. As the name suggests, updates are conducted at a high rate, but the system is able to maintain a low level of latency while still producing a high-resolution view. The third portion of the Nowcasting program is Fused, Integrated Representation of the Environment (FIRE). The goal of FIRE is to provide the RPA crew with near-real-time products that give them enhanced environmental awareness of the area of interest. The WeatherNow program has the potential to significantly enhance the weather intelligence gathered in support of unmanned platform missions, but more broadly, it could radically improve the weather forecasting process as it exists in the Air Force today.

In order to estimate the value added by purchasing and implementing the WeatherNow technology, it is necessary to conduct a thorough analysis of the costs and benefits of using both the ASAPS sensor and Nowcasting software suite. This research uses the Knowledge Value Added (KVA) methodology to quantify the benefits of introducing the Nowcasting program into the Air Force weather forecasting process, specifically for the RQ-4B Global Hawk UAV community. This study quantifies value in terms of a Return on Investment (ROI), as well as provides implementation options through the use of Integrated Risk Management (IRM) and Real Options Valuation (ROV) portfolio optimization strategy.

This research documents a process model of the current "as-is" weather forecasting procedures based on input from Subject Matter Experts (SMEs) in the 9th Reconnaissance Wing aboard Beale Air Force Base (AFB). The process model describes how a weather forecast is created for use by an RQ-4B Global Hawk squadron while remaining generic enough to be applied to any Air Force squadron in which weather forecasts are produced. The process is broken down into six main subprocesses, which are further disaggregated to capture the complex nature of weather forecasting. Each subprocess takes a given input and produces an output, which becomes the input to the subsequent subprocess. The final output of the process is an actionable weather forecast brief to be used by the Global Hawk aircrew.

KVA methodology estimates the productivity embedded in an organization by measuring the value of knowledge contained in its people, technology, and processes (Housel & Bell, 2001). In this study, KVA quantifies the value of each subprocess of weather forecasting in terms of a common unit of output. In a non-profit organization like the DoD, estimating the ROI of a technology investment in dollars is not possible in the traditional sense. KVA produces a measure known as Return on Knowledge (ROK) based on the knowledge that is embedded within the organization's people, technology, and processes. This study uses KVA to assess the value added to the weather forecasting process by implementing WeatherNow technology.

The IRM and ROV portions of this study determine the different pathways for the implementation of WeatherNow into the weather forecasting process. Due to the inherent volatility within the DoD acquisition of technology, Air Force leadership needs to have the flexibility to make changes to their adoption strategy. IRM and ROV provides those decision-makers with a tool that helps optimize the value of strategic decisions.

Knowledge Value Added Results

As in traditional financial investment return calculations, ROK is determined by dividing total output by total input. In this study the same ratio is applied to calculate the return on knowledge for each subprocess of weather forecasting and weather forecasting as a whole for both the as-is model and the to-be model (process with WeatherNow technology included). The numerator is calculated by multiplying the total learning time (time required to learn how to do that specific task) by the number of times that task is executed ("fired") per year, and the value of one hour's worth of learning time. In this case a value of $1.00 was used as a very conservative estimate (this is done in both the as-is and to-be models). The denominator is calculated by multiplying the labor cost by the number of people performing the task, the number of times the task is fired in one year, and the time required to perform the task. ROK values allow management to determine which subprocesses within their organization add more value to the process as a whole. Ultimately a higher ROK value for the to-be subprocesses (as well as the overall ROK value) would indicate that investing in WeatherNow technology adds value.

The results of the KVA analysis overwhelmingly support the adoption of WeatherNow technology into the Air Force weather forecasting process. The mission-watching subprocess received the greatest increase in return on knowledge from the as-is to the to-be scenario, as seen in Figure 3. The reason for this is because of the increase in the number of times the tasks within that sub-process are fired in one year. The Nowcasting software suite increases the number of weather updates by almost 20 times per Global Hawk flight mission. The knowledge embedded within the WeatherNow technology is another factor that contributes to the increase in ROK. The Nowcasting software and ASAPS sensor take thousands of hours of learning time and are able to fire at much higher rates than humans are capable. It is this central principle that explains the enormous increases in ROK and ROI. The return on knowledge in the to-be scenario is over 3,000 times greater than the as-is return on knowledge.

RQ-4 Weather Forecasting Process: Comparison of As-Is and To-Be ScenarioResults	As-Is Return on Knowledge	As-Is Return on Investment	To-Be Return on Knowledge	To-Be Return on Investment	Change in Return on Knowledgeas Ratio	Change in Return on Investment as Ratio
TOTAL	20%	-80%	76693%	76593%	3,802.1	612.1
Conduct Annual Cross Talk Between Forecasters and RPA Operators	276%	176%	276%	176%	1.0	1.0
Data Collection	322%	222%	3213%	3113%	10.0	14.0
sensitivities to determine mission-critical weather information	1084%	984%	148349%	148249%	136.9	150.7
Assemble the weather brief, tailoring the collected data to suit the specific mission set	274%	174%	274%	174%	1.0	1.0
Conduct mssion-watching	16%	-84%	366054%	365954%	23,386.8	3,087.5
Conduct debrief	45%	-55%	45%	-55%	1.0	1.0

Figure 3. Changes in Return on Knowledge and Return on Investment Due to WeatherNow Sensor (Differences in Returns as Ratios)

Integrated Risk Management and Real Options Valuation Analysis and Results

The IRM and ROV portions of this study evaluated three different strategies for adopting the WeatherNow Technology. Strategy A implements both the Nowcasting software and the ASAPS sensors over time in a phased approach. This is done with the intent to limit potential risks of failure early in adoption, as technology and software acquisition programs are prone to do. Phase I will outfit 10 Global Hawks with the ASAPS sensor within two years, Phase II will outfit another 20 Global Hawks in the next two years, and Phase III will outfit another 20 aircraft within the last two years. Strategy B is an approach that incurs very high capital investments early in order to reap the returns as quickly as possible. It calls for the implementation of the ASAPS sensor on 100 Global Hawks within three years. Strategy C adopts the technology to only 50 Global Hawks to be outfitted with the sensors, with no specific time constraint. The strategic option strategies are seen in Figure 4. As a result of the ROV calculations, the most optimal solution is Strategy B, immediate execution. It produces a total strategic value of just under $4 billion, as compared to a negative strategic value of $1.07 million for the as-is strategy. These results are seen in Figure 5.

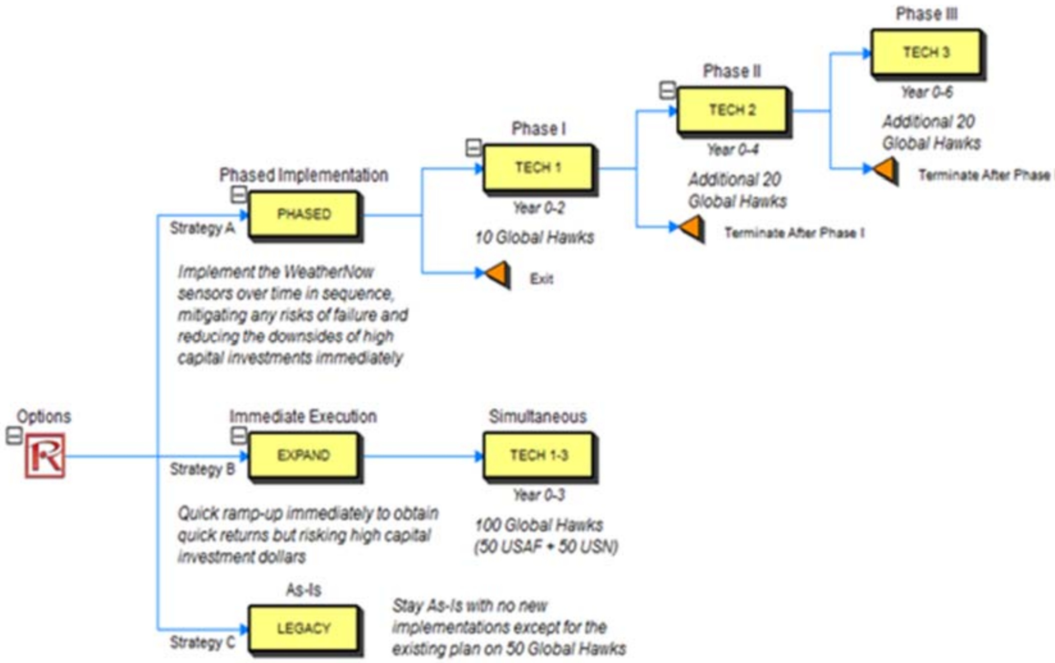

Figure 4. Adoption Strategies for WeatherNow

AS-IS Strategy

Asset Value	$ 270,707
Implementation Cost	$ 1,342,045
Maturity	0
Risk-Free Rate (Annualized %)	0.00%
Dividend Rate (Annualized %)	0.00%
Volatility (Annualized %)	9.85%
ROI %	-79.83%
Net Present Value	$ (1,071,338)
Option Value	$ -
Total Strategic Value	**$ (1,071,338)**

TO-BE Strategy: Immediate Implementation

Asset Value	$3,986,537,414
Implementation Cost	$ 5,198,024
Maturity	3
Risk-Free Rate (Annualized %)	0.92%
Dividend Rate (Annualized %)	0.00%
Volatility (Annualized %)	30.56%
Total Strategic Value	**$3,981,480,893**
Incremental Value-Added	**$3,982,552,231**

TO-BE Strategy: Sequential Implementation

Asset Value	$ 1,993,268,707
Implementation Cost: Phase I	$ 519,802
Implementation Cost: Phase II	$ 1,039,605
Implementation Cost: Phase III	$ 1,039,605
Maturity: Phase I	2
Maturity: Phase II	4
Maturity: Phase III	6
Risk-Free Rate (Annualized %)	1.56%
Dividend Rate (Annualized %)	0.00%
Volatility (Annualized %)	30.56%
Total Strategic Value	**$ 1,990,841,590**
Incremental Value-Added	**$ 1,991,912,928**

Real Options Valuation

Strategy A Phased Implementation	$ 1,990,841,590
Strategy B Immediate Execution	$ 3,981,480,893
Strategy C As-Is Base Case	$ (1,071,338)

Figure 5. Real Options Valuation Results

Insights, Recommendations, and Conclusions

The KVA analysis conducted in this research indicates a favorable return should the DoD decide to invest in WeatherNow technology. Return on knowledge and cost savings aside, WeatherNow has potential benefits in several other areas as well. This study has only looked at implementation on the Global Hawk platform. Today there are over 10 different RPA platforms in use by the DoD, all of which are susceptible to adverse weather conditions. This study is generic enough to be extensible to not just Air Force weather forecasting in support of Air Force only RPA platforms. Army, Navy, and Marine Corps forces are potential benefactors of WeatherNow technology as well. Furthermore, the accurate weather forecasts produced by the Nowcasting software suite are not necessarily for use by RPA aircrews only. Manned aircraft have the potential to benefit from the increased environmental awareness afforded by WeatherNow. Additionally, ground units, specifically those that fire long-range rockets like the High Mobility Artillery Rocket System (HIMARS) and Guided Multiple Launch Rocket System (GMLRS) rely on timely and accurate weather forecasts. Improved weather intelligence would help those units improve the accuracy and lethality of their strike missions. As with most technological innovations that may disrupt current practices, however, appropriate care and time must be taken to train personnel in the operations and implications of WeatherNow technology. The relevant publications and doctrine would also have to reflect the use of WeatherNow as well. It is the recommendation of this study, however, that Air Force leadership adopts this technology and implements it rapidly.

Conclusion

This quantitative analysis supports the conclusion that implementation of the WeatherNow technology that was examined for this study will improve the current mission execution process and real time weather forecasting process. The results also have provided a risk-based decision support framework and supporting tool set to assist with future investment in technology decisions by treating such decisions as a portfolio of options with varying future quantitative values and risks.

The focus of this research precluded examining the socio-technical implications of implementing such sophisticated weather forecasting technology in the current weather forecasting system. Thus, there is opportunity for further research to conduct a detailed examination of potential acceptance issues with WeatherNow and how policy should evolve to support the optimal integration and sustained success of WeatherNow technology. This is an important area for continued research, investment, and innovation, all in the course of modernizing the weather forecasting system to complement the unique needs of RPA pilots. By improving their operational effectiveness and reducing their susceptibility to adverse weather conditions, the number of successful missions will increase over time.

Recommendations

The results clearly indicate that the immediate option to deploy the WeatherNow technology RAP fleet-wide are warranted. Delays in acquiring and implementing this technology will likely result in reduced value added and lower than possible mission success. The effect of this technology on mission success should be tracked over time so that options, risks, and ROIs can be adjusted to reflect real usage of the technology.

The performance analytical framework used in this study is extensible to a wide range of services, technologies, and platforms beyond its use in evaluating the potential value added of the WeatherNow technology. Similar economic valuation analyses should be performed on other aviation platforms that may benefit from the WeatherNow technology, particularly lower flying RPA platforms that are more limited by adverse weather than the high-flying Global Hawk.

References

557th Weather Wing Flight Plan 2015. (2015). Retrieved from http://www.557weatherwing.af.mil/shared/media/document/AFD-150325-016.pdf

Air Weather Association (AFWA). (2012, July). *Air Force weather: Our heritage 1937–2012*.

Beckwith, R., Teibel, D., & Bowen, P. (2004, November). Report from the field: Results from an agricultural wireless sensor network. In *Proceedings of the 29th Annual IEEE International Conference on Local Computer Networks* (pp. 471–478).

Boon, C. B., & Cluett, C. (2002). Road weather information systems: Enabling proactive maintenance practices in Washington state (No. WA-RD 529.1). Washington State Department of Transportation.

Boselly, S. E., III, Doore, G. S., Thornes, J. E., Ulberg, C., & Ernst, D. (1993). *Road weather information systems, volume 1: Research report* (Strategic Highway Research Program Publication-SHRP-H-350). Washington, DC: National Research Council, 90–93.

Capital Staff. (2015, February 10). The 60-second interview: Tony Dokoupil, author of "Send in the Weathermen." Retrieved from http://www.capitalnewyork.com/article/media/2015/02/8561982/60-second-interview-tony-dokoupil-author-send-weathermen

Crawford, B. (2015, January/February). Own the weather: Flying in degraded visual environments. *Army Technology Magazine, 3*(1), 7.

Dokoupil, T. (2015, July). Forecasting war: The military's weathermen heroes you never knew about. *Reader's Digest*. Retrieved from http://www.rd.com/true-stories/survival/military-weathermen-gray-berets/

Federal Coordinator for Meteorological Services and Supporting Research (OFCM). (2013, November). *The federal role in meteorological services and supporting research: A half-century of multi-agency collaboration* (FCM-17-2013). Retrieved from http://www.ofcm.gov/i-7/fcm-i7.pdf

Fleisch, E. (2010). What is the internet of things? An economic perspective. Economics, Management, and *Financial Markets, 5*(2), 125–157. [Note: see p. 13.]

George C. Marshall Institute. (2015). *Connecting climate and national security*. Retrieved from http://marshall.org/wp-content/uploads/2015/09/Climate-Security0915final.pdf

Kauffmann, P., Ozan, E., & Sireli, Y. (2004). Feasibility of TAMDAR: An aircraft-based weather data collection system. *Journal of Air Transport Management, 10*(3), 207–215.

Krishnamurthy, L., Adler, R., Buonadonna, P., Chhabra, J., Flanigan, M., Kushalnagar, N., & Yarvis, M. (2005, November). Design and deployment of industrial sensor networks: Experiences from a semiconductor plant and the North Sea. In *Proceedings of the 3rd International Conference on Embedded Networked Sensor Systems* (pp. 64–75). ACM.

Jensen, D. (2014). Ensuring and quantifying return on investment through the development of winter maintenance performance measures.

Johnson, S. R., & Holt, M. T. (2005). The value of weather information. *Economic Value of Weather and Climate Forecasts,* 75. Retrieved from https://books.google.com/books?hl=en&lr=&id=FnTVdEfsY2oC&oi=fnd&pg=PA75&dq=Measuring+the+economic+Value+of+weather+sensors&ots=diuAziFx_H&sig=f-Cr5y8HSS2GuyvRi8odg3acQts#v=onepage&q&f=false

Mathews, A. J. (2013). Applying geospatial tools and techniques to viticulture. *Geography Compass, 7*(1), 22–34.

National Climate Data Center (NCDC). (2013). Billion dollar U.S. weather/climate disasters, 1980–2012. Asheville, NC: National Climate Data Center. Retrieved from http://www.ncdc.noaa.gov/billions/events.pdf

O'Reilly, T., & Battelle, J. (2009). Web squared: Web 2.0 five years on. O'Reilly Media.

Panasonic Weather Solutions. (2013, November 15). Response to request for information by the Office of Science and Technology policy with regard to the national plan for civil earth observations.

Samenow, J. (2015, April 20). Air Force's plan to drop U.S. forecast system for U.K. model draws criticism. *Washington Post*. Retrieved from https://www.washingtonpost.com/news/capital-weather-gang/wp/2015/04/20/air-force-to-cut-ties-with-u-s-weather-forecast-system-in-favor-of-uk-model/

Shultz, M. D., Unruh, C. R., Williamson, D., & Anttonen, C. J. (2010). Colony: A new business model for research and development.

Stewart, T. R., Katz, R. W., & Murphy, A. H. (1984). Value of weather information: A descriptive study of the fruit-frost problem*. Bulletin of the American Meteorological Society, 65*(2), 126–137.

U.S. Army Research, Development, and Engineering Command (USARDE). (2015, January/February). Future of Army sensors. *Army Technology Magazine, 3*(1).

U.S. Department of Commerce/National Oceanic and Atmospheric Administration. (2015, September). *The federal plan for meteorological services and supporting research: Fiscal year 2016* (FCM-P1-2015). Office of the Federal Coordinator for Meteorological Services and Supporting Research (OFCM).

ACQUISITION RESEARCH PROGRAM
GRADUATE SCHOOL OF BUSINESS & PUBLIC POLICY
NAVAL POSTGRADUATE SCHOOL
555 DYER ROAD, INGERSOLL HALL
MONTEREY, CA 93943

www.acquisitionresearch.net