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**A Business Case Analysis for Upgrading the Current Aerial Reconnaissance Fleet to the Q400 Aircraft**

**25 November 2011**

**by**


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# ABSTRACT

This report identifies the potential benefits and costs of upgrading the current fleet of DHC-7 aircraft to the Q400. We accomplish this through conducting an analysis of the Army's current operational mission sets, the projected life cycle costs of each aircraft, and the alternative courses of action. In addition, we utilize value engineering and feedback analysis tools to support the recommendations and findings. Once complete, the final product from this research could become part of a future aerial requirements packet for the Aerial Common Sensors (ACS) program. The Aerial Reconnaissance and Exploitation Sensors (ARES) program office, located at the Aberdeen Proving Grounds, MD, will receive the results of the research identifying the financial and performance benefits of purchasing the Q400.

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# TABLE OF CONTENTS

I. INTRODUCTION........................................................................................1

II. BACKGROUND ........................................................................................3
   A. KEY ISSUES WITH THE CURRENT ARL SYSTEM..............................3
   B. BACKGROUND OF THE AIRBORNE RECONNAISSANCE LOW (ARL) ........................................................................................5
   C. A TYPICAL ARL MISSION........................................................................6
   D. THE DHC-7........................................................................................7
   E. THE Q400........................................................................................8
   F. THE FUTURE OF THE AIRBORNE RECONNAISSANCE LOW PROGRAM ........................................................................................11

III. DHC-7 AND Q400 COMPARISON........................................................15

IV. ANALYSIS ........................................................................................17
   A. ASSUMPTIONS AND CONSTRAINTS ..............................................17
   B. PERFORMANCE AND CAPABILITY ................................................19
   C. STANDARD MISSION PROFILE COSTS ..........................................33
   D. RETURN ON INVESTMENT (ROI)......................................................38

V. CONCLUSION ........................................................................................51

APPENDICES A–I........................................................................................53

LIST OF REFERENCES ................................................................................81

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# LIST OF FIGURES

Figure 1. DHC-7 External Dimensions ... 7
Figure 2. Countries Using Versions of the DHC-8 ... 9
Figure 3. Q400 External Dimensions ... 10
Figure 4. Operational View of JDSAISR ... 13
Figure 5. Q400 Range and Endurance Advantage Over the DHC-7 ... 23
Figure 6. Modular Payload Bay Concept on the LEMV ... 26
Figure 7. Operating Restrictions Due to the Andes Mountain Range ... 32
Figure 8. DHC-7 Versus Q400 Performance Comparison ... 33
Figure 9. Standard Mission Scenario ... 34
Figure 10. DHC-7 Versus Q400 Standard Mission Efficiencies ... 37
Figure 11. DHC-7 and Q400 Cumulative Life Cycle Costs (in 2011 Dollars) and Payback Period ... 43
Figure 12. Cumulative Life Cycle Costs (in 2011 Dollars) and Payback Period ... 44
Figure 13. Per Aircraft 10,560 Annual Hour LCC using 2% through 8% O&S Increase Adjustment ... 46
Figure 14. Per Aircraft 12,000 Annual Hour LCC Using 2% Through 8% O&S Increase Adjustment ... 47
Figure 15. ARL Fleet LCC Range With Various Assumptions ... 48
Figure 16. IRR on Q400 Investment With Various Assumptions ... 49

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# LIST OF TABLES

Table 1. Aircraft Dimensions ........ 15
Table 2. Cabin Dimensions ........ 15
Table 3. Weights and Payload Capability ........ 16
Table 4. Aircraft Performance ........ 16

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# LIST OF ACRONYMS AND ABBREVIATIONS

| | |
|---|---|
| AO | Area of Operations |
| ACS | Aerial Common Sensors |
| ARDF | Airborne Radio Direction Finding |
| ARES | Airborne Reconnaissance and Exploitation Sensors |
| ARL | Airborne Reconnaissance Low |
| BCA | Business Case Analysis |
| BCT | Brigade Combat Team |
| BN | Battalion |
| CAD | Computer-Aided Drawing |
| CAM | Computer-Aided Manufacturing |
| CDD | Charge Coupled Device |
| CCIR | Commander's Critical Information Requirements |
| CdD | Conklin and de Decker |
| CENTCOM | U.S. Central Command |
| COL | Colonel |
| COTS | Commercial Off-the-Shelf |
| DF | Direction Finding |
| DIS | Daylight Imaging System |
| DMTI | Dismounted Moving Target Indicator |
| DoD | Department of Defense |
| EMARSS | Enhanced Medium Altitude Reconnaissance and Surveillance System |
| EO | Electro-Optical |
| ESM | Electronic Support Measures |
| EW | Electronic Warfare |
| F2T2EA | Find, Fix, Track, Target, Engage, Assess |
| F3EAD | Find, Fix, Finish, Exploit, Assess and Disseminate |
| FAA | Federal Aviation Administration |
| FBI | Federal Bureau of Investigation |

| | |
|---|---|
| FLIR | Forward Looking Infrared |
| FMC | Fully Mission Capable |
| FMV | Full Motion Video (provided by EO/IR sensors) |
| FOPEN | Foliage Penetration |
| FY | Fiscal Year |
| GMTI | Ground Moving Target Indicator |
| ICD | Initial Capabilities Document |
| ICM | Intelligence Capabilities Manager |
| IMINT | Imagery Intelligence |
| INSCOM | Intelligence and Securities Command |
| IR | Infrared |
| IRLS | Infrared Line Scanner |
| IRR | Internal Rate of Return |
| ISA | International Standard Atmosphere |
| ISCA | Integrated Sensor Coverage Area |
| ISR | Intelligence, Surveillance and Reconnaissance |
| JDSAISR | Joint Direct-Support Airborne Intelligence Surveillance and Reconnaissance |
| JUONS | Joint Urgent Operational Needs Statement |
| KIAS | Knots Indicated Air Speed |
| Lb | Pound (weight) |
| LCC | Life Cycle Costs |
| LEMV | Long Endurance Multi-Intelligence Vehicle |
| LIDAR | Light Detection and Ranging |
| MC | Mission Capable |
| MI | Military Intelligence |
| MO | Mission Overwatch |
| MOCA | Minimum Obstruction Clearance Altitude |
| MTI SAR | Moving Target Indicator/Synthetic Aperture Radar |
| MTOW | Maximum Take-Off Weight |
| NAI | Named Area of Interest |

| | |
|---|---|
| NDI | Non-Developmental Item |
| NM | Nautical Mile |
| NPV | Net Present Value |
| NVS | Noise and Vibrations Suppression |
| O & S | Operations and Support |
| OPTEMPO | Operations Tempo |
| OWE | Operating Weight Empty |
| PAA | Persistent Area Assessment |
| PACOM | Pacific Command |
| PM | Program Manager |
| POM | Program Objective Memorandum |
| ROI | Return on Investment |
| SATCOM | Satellite Communications |
| SAR | Synthetic-Aperture Radar |
| SHP | Shaft Horse Power |
| SID | Situation Development |
| SIGINT | Signals Intelligence |
| SOUTHCOM | Southern Command |
| STC | Supplemental Type Certificate |
| STOL | Short Take-Off and Landing |
| SWIR | Short Wave Infrared |
| TAI | Targeted Area of Interest |
| TAT | Tactical Action Team |
| TBO | Time Between Overhauls |
| TCM-IS | TRADOC Capability Manager for Intelligence Systems |
| TIC | Troops in Contact |
| TOS | Time On Station |
| TRADOC | Training and Doctrine Command |
| UAS | Unmanned Aerial System |
| UHF | Ultra-High Frequency |

| | |
|---|---|
| VHF | Very-High Frequency |
| VTOL | Vertical Take-Off and Landing |

# EXECUTIVE SUMMARY

## Project Title

A Business Case Analysis for Upgrading the Current Aerial Reconnaissance Low (ARL) Fleet to the Q400 Aircraft

## Project Report

This report identifies the potential benefits and costs of upgrading the current fleet of DHC-7 aircraft to the Q400. We accomplish this through conducting an analysis of the Army's current operational mission sets, the projected life cycle costs of each aircraft, and the alternative courses of action. In addition, we utilize value engineering and feedback analysis tools to support the recommendations and findings. Once complete, the final product from this research could be used as part of a future aerial requirements packet for the Aerial Common Sensors (ACS) program. The Aerial Reconnaissance and Exploitation Sensors (ARES) program office, located at the Aberdeen Proving Grounds, MD, will receive the results of the research identifying the financial and performance benefits of purchasing the Q400.

## Background

The DHC-7 currently conducts manned aerial reconnaissance missions for the U.S. Army. The DHC-7s have limited operational usefulness due to their lack of power and payload capacity and their limited supply chain. These limitations drive up maintenance costs and make this aircraft expensive to support through the year 2017. A potential replacement for the DHC-7 is the newer Q400 Bombardier aircraft. Our primary research objective was to conduct a side-by-side comparison of these aircraft to confirm or deny the following hypotheses:

- After the upfront investment, the Q400 is a more efficient aircraft concerning the associated operating cost savings over its life cycle.
- As a newer aircraft, the Q400 will be more reliable and capable.

## Project Objectives

The following objectives shaped our research methodology and ensured that the relevant alternatives received consideration and analysis:

- clearly identify the costs and benefits of replacing the existing aircraft with the newer Q400 aircraft from monetary and nonmonetary points of views,
- apply value-engineering techniques to analyze the case for the Army purchase of newer aircraft,
    a. replace the current fleet of DHC-7s with fewer Q400s to maintain the same mission capability or
    b. replace the current fleet of DHC-7s with the same number of Q400s to increase mission capability, and
- provide recommendations to the ACS program on the available courses of action to assist with their decision-making on the future of the program.

## Recommendation

The Army would realize cost, performance, future capability, and upgradability benefits by replacing its aging DHC-7 ARL fleet with the new Q400 aircraft. In a one-for-one comparison of performance, the Q400 equates to at least 1.3 DHC-7s and can perform the same mission objectives at 68% of the cost. In terms of overall value to the Army and the intelligence user, the Q400 delivers almost twice the value of a DHC-7.

Upgrading the ARL fleet to Q400s will save the Army almost a half billion dollars over the next 20 years and an upgrade will pay for itself after just 13 years. The net present value (NPV) of the Q400 investment is a positive $268 million with an internal rate of return (IRR) of 6.9%.

Therefore, it does not make economic sense for the Army to continue spending money on the DHC-7; it is an old and inefficient aircraft that the Army should consider retiring due to rising operations and support (O&S) costs.

# I. INTRODUCTION

Intelligence, surveillance, and reconnaissance (ISR) products are crucial to the success of Department of Defense (DoD) operational missions. The creation of these ISR products comes from a variety of complex sensors that are part of the airborne platforms. One such system employed by the U.S. Army is the Airborne Reconnaissance Low (ARL).

The Army requires multifunction day-or-night, all-weather ISR systems. In an effort to keep acquisition and development costs to a minimum, the Army purchased used De Havilland of Canada (DHC) DHC-7s in 1991, and modified them to create a new ARL platform (Niemiec, 1996). The ARL's imagery and signals intelligence (IMINT and SIGINT) capability originally provided support to U.S. Southern Command (SOUTHCOM). Due to its success in supporting SOUTHCOM, and the inability of the United States Air Force to meet standing commitments to provide radar coverage on the Korean peninsula, the Army continued to develop the ARL to support operations in U.S. Pacific Command (PACOM). In 1996, United States Forces Korea (USFK) received three ARLs. Their primary mission was to observe North Korean military activities and to replace the retiring OV-1D Mohawk fleet (Goebel, 2011). The ARL systems currently support the areas of responsibility for U.S. Central Command (CENTCOM) and U.S. European Command.

Production of the DHC-7s began in 1975 and ended in 1988. The production timeframe of the aircraft means that the Army's fleet of ARLs is approaching an average age of 30 years per aircraft. The operations and support (O&S) costs are high and are continuing to increase as the aircraft ages. Spare parts are difficult to obtain, and, as a result, contracted mechanics must obtain and install individually milled parts, which is an expensive process. Although the ARL's design supports product improvements and upgrades, the aging DHC-7 platform is experiencing increased costs to maintain full mission capability. The bottom line is that trying to do payload upgrades on an aging platform may not be the most cost-effective solution for the Army.

As the DoD and the Army implement their strategy for providing better intelligence capabilities to support the warfighter, the Army is reviewing current ISR platforms and deciding what future capabilities they need to retain. In keeping with a low-cost and minimal-development acquisition plan, the Army should consider other commercial off-the-shelf (COTS) aircraft as possible DHC-7 replacements. In addition to retaining the capability to execute the current ARL mission, a replacement aircraft should have the ability to host an upgraded ISR sensor suite.

The estimated expiration year date of the DHC-7 ARL fleet is 2020; however, the fact that they can still fly does not necessarily make them a wise use of resources. This business case analysis (BCA) compares the DHC-7 to the Bombardier Q400 and examines the possible performance benefits obtained with newer, more reliable, more efficient, and more capable aircraft. This BCA also reviews and highlights the life cycle costs (LCC) and the economic value of making a decision to upgrade the fleet on a one-for-one basis.

## II. BACKGROUND

### A. KEY ISSUES WITH THE CURRENT ARL SYSTEM

As stated in the introduction, the Army faces ongoing maintenance issues and increasing O&S costs with the current ARL platform. Due to these rising O&S costs, the Army is considering a potential replacement for the DHC-7. In addition to rising costs, the Army should also consider the DHC-7's performance issues. The following section highlights in more detail the key concerns that the Army has with the DHC-7.

Loiter Time. The loiter duration for the DHC-7 is generally seven to eight hours, while the preferred duration is 10 hours (Cook, 2011). During combat operations, units might be required to surge 24 hours a day, which cannot be done with three DHC-7 aircraft.

Maintenance. One Army unit that operates the DHC-7 recently reported an average maintenance cancellation rate of 15–20% (Cook, 2011). This high cancellation rate results from the age of the aircraft and the aviation problems associated with older aircraft and from limited repair and maintenance resources. Additionally, a 2001 case study on the ARL's life cycle logistics highlighted the difficulty in recruiting qualified mechanics for the DHC-7. The study stated that the "DHC-7 mechanics are aging along with the airframes. Many of the contractor's technical personnel have retired … or simply have chosen not to undergo the hardships that are currently associated with the ARL program" (Maples, 2001, p. 31). According to this report, the Aviation and Missile Life Cycle Management Command had to reduce DHC-7 specific experience requirements to expand the pool of potential mechanics. The selection of mechanics relied on whether or not they had equivalent aircraft maintenance experience and on their ability to receive on-the-job training to qualify them as DHC-7 mechanics (Maples, 2001, p. 32).

The Maples (2001) study also reported on the struggle to keep the aircraft's components up-to-date. The ARL underwent multiple, expensive modifications in order to update its technology. These modifications "often complicate[d] wiring and interface connections to the aircraft" (Maples, 2001, p. 32), in effect making the process more costly.

These maintenance issues are systemic and inherent to the aging DHC-7. The older the aircraft, the more difficult (and more expensive) it is to maintain the aircraft and increase its reliability. For the Army to increase the ARL's reliability and, in effect, its operational availability, the Army must be willing to pay higher O&S costs.

Engine Service Ceiling. The service ceiling of the DHC-7 is 18,000 feet, but if one of its four engines fails, the pilot must drift down significantly in altitude to 13,000 feet. As a result, the aircraft cannot operate in warm locations with mountains above 8,000 feet due to its one-engine-out service ceiling. DHC-7s operating in Afghanistan can only fly in the flat southern desert due to the low minimum obstruction clearance altitude (MOCA) and the immediate vicinity of Kandahar. The low one-engine-out service ceiling marginalizes the potential impact on targeting operations because the aircraft cannot operate where the majority of the target deck flights are located. When supporting SOUTHCOM operations, the DHC-7 can only fly on the eastern side of the Andes Mountains.

In addition, because of its operating weight of 44,000 pounds, an ARL takes almost an hour to climb to 18,000 feet (Viking Air, 2001). The service ceiling decrease can be a critical constraint when planning missions in mountainous areas.

Noise. The noise of the aircraft can disrupt missions, particularly those that require lower altitude reconnaissance so that the cameras can operate below cloud decks. The noise of the aircraft could potentially identify its location to ground elements. In addition, multiple noise-level-related airspace prohibitions exist in densely populated areas.

Overall Aircraft Service Life. The age of the aircraft, the fact that DHC-7s are no longer in production and that only a small number are still in operation globally, directly affects the ability of the aircraft to remain mission capable.

Few Operational DHC-7s Worldwide. As of 2004, approximately 60 serviceable DHC-7s were in operation. The case study of the ARL's life cycle logistics identified DHC-7 "obsolescence" (Maples, 2001, p. 32) as a problem for the Department of the Army. At the time of the publication of that study, the Army was the primary user of the aircraft. The study also reported that “the original equipment manufacturer and other civilian contractors who work with the aircraft [were] making attempts to re-engineer, re-manufacture and/or redesign parts that are no longer available” (Maples, 2001, p. 33).

## B. BACKGROUND OF THE AIRBORNE RECONNAISSANCE LOW (ARL)

The Development. The Army developed the ARL system (also referred to as the O-5, EO-5A/B/C, RC-7, and DHC-7) in response to joint urgent operational needs statements (JUONS) and the requirement to establish a platform for common aerial sensors. The need to sustain and build an enduring ARL capability is a requirement identified by the Joint Direct-Support Airborne Intelligence, Surveillance, and Reconnaissance (JDSAISR) Initial Capabilities Document (ICD).

History. The ARL system developed from a SOUTHCOM requirement for a manned aviation platform that could provide an IMINT and SIGINT collection capability. The ARL program officially began in November 1990 when the Army purchased used DHC-7s from civilian carriers. The Army converted these aircraft into the ARL-Communication (C) version in 1993. De Havilland of Canada developed the DHC-7 and the Army chose it as the platform for ARL because of its ability to carry the necessary sensors, its endurance and short take-off and landing (STOL) performance, and its multi-engine configuration. It is an extensively modified aircraft; in particular, a higher maximum gross weight and extended range capability were additions during the ARL conversions. It has the ability to pressurize and can operate at up to 18,000 feet with a full mission crew. Mission duration can be up to eight hours with a range of 1,100 nautical miles at a maximum cruising speed of 231 knots, and the aircraft can loiter at a speed as low as 110 knots.

The design requirements stated that ARL should support nation building, counter-narcotics operations, missions to promote democracy and stability, and support operations in SOUTHCOM's area of responsibility. The ARL systems began their support missions with SOUTHCOM in 1993 to assist in counter-drug surveillance operations and later deployed to Haiti in support of U.S. peacekeeping operations. In 1996, an ARL deployed to Bosnia-Herzegovina to support the North Atlantic Treaty Organization’s peacekeeping force.

Two different ARL configurations also deployed to SOUTHCOM. The ARL-C configuration has a conventional communication-intercept and direction-finding payload. The ARL-I, configuration has an imagery payload consisting of a forward-looking infrared (FLIR) sensor, an infrared line scanner (IRLS), and a daylight imagery system (DIS). The RC-7 met SOUTHCOM's requirements very well, and the Army soon requested a more advanced version, designated RC-7B or ARL-M, which merged the functionality of the ARL-C and the ARL-I.

In November 1995, in response to a USFK and PACOM requirement, the Army directed the additions of moving target indicator (MTI) and synthetic aperture radar (SAR) capabilities to the ARL-M so that it could replace the OV-1D Mohawk aircraft. The procurement of the MTI/SAR subsystem was successful and fielded two ARL-Ms in less than 10 months.

Operational Functions of the ARL. The ARL program has three primary operational functions. The first is to *find* enemy activity through broad-area searches within Named Area of Interests (NAI). The second function is to *fix* on a target by providing more resolution of a specific target area, known as a Targeted Area of Interest (TAI). The third operational function is to *finish* on the target through high-resolution imagery before and during mission execution.

ISR Capabilities. Due to airframe age and dated technology, the ARL must rely on major modifications to accommodate new and diverse mission requirements. The SIGINT subsystem uses an Electronic Support Measures (ESM) system that has a high frequency (HF), very-high frequency (VHF), and ultra-high frequency (UHF) intercept and direction-finding (DF) capabilities. The IMINT subsystem equipment includes infrared-sensitive charge-coupled devices (CCD) embedded in the sensor ball, FLIR, and DIS.

## C. A TYPICAL ARL MISSION

All of the Army's ARL aircraft have the ARL-M modifications with multifunction capabilities, which allow it to conduct both the SIGINT and IMINT missions. The ARL-M has the capability to conduct several types of DF operations, including HF, VHF, and UHF. Dissemination is through secure UHF (line-of-sight and

SATCOM) or VHF modulation communications. In addition, ARL-M can support three separate imagery systems on board through a first-generation, forward-looking infrared (IR) camera turret; a DIS camera turret; and an infrared-sensitive CCD embedded in the sensor ball. The system can send RS-170 video imagery via downlink to COTS systems such as TACLINK II, which is a portable video receiver. Two onboard operators can record information on eight-millimeter videotape or transmit near-real-time data to the ground forces commander. The aircraft also has a suite of Aircraft Survivability Equipment (ASE) suitable for countering enemy threats.

## D. THE DHC-7

Commercial Usage of DHC-7. The DHC-7 originally flew as a commercial regional airliner, operating on intercity routes between major metropolitan areas from small local airports. This requirement dictated good short-field capability and a low noise signature. The DHC-7 met with only limited commercial success. Most turboprop operators used these aircraft as feeders into large airports, where STOL performance was not a priority. In comparison to other feeder liners, the DHC-7's four engines required twice the maintenance of a twin-engine model, thereby driving up operational costs. Figure 1 shows the dimensions of the DHC-7.

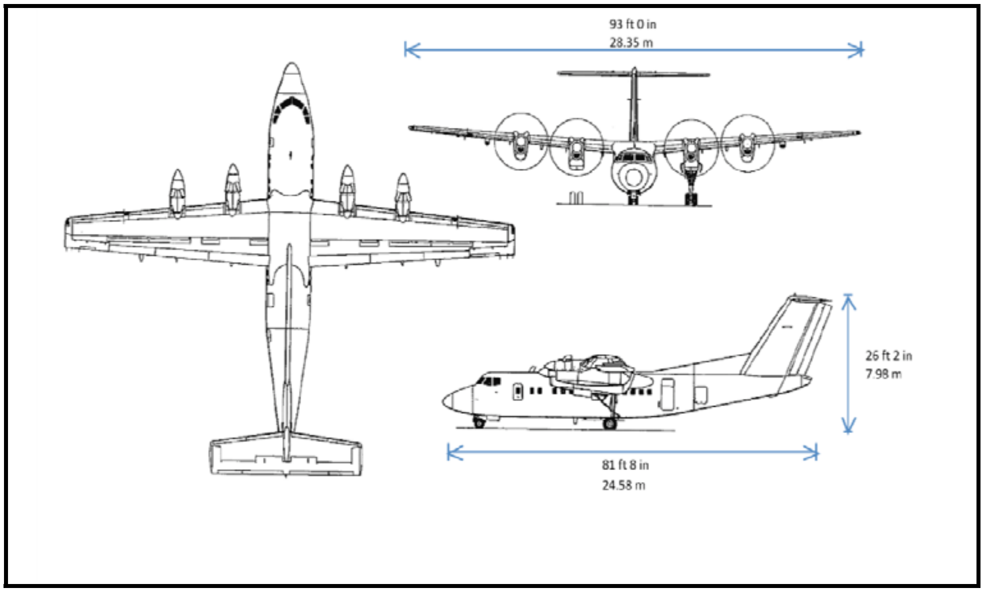



**Figure 1. DHC-7 External Dimensions**

(Aviastar, 1975)

Current Situation. As of 2011, eight ARL systems are flying and are in the ARL-M configuration as well as a DHC-7 training aircraft. Four ARL-Ms are at Fort Bliss, Texas, and primarily support SOUTHCOM requirements; three ARL-Ms are in Korea supporting PACOM. One additional aircraft is supporting CENTCOM.

## E. THE Q400

Commercial Usage of the Q400. During the 1970s, De Havilland Canada officials began development of a commuter airliner with 30 to 40 seats called the DHC-8 and used the DHC-7 as its basis. The DHC-8 featured a larger airframe and twin engines. Bombardier has since bought out De Havilland Canada. Currently over 1,000 DHC-8s of all models (-100 to -400) are in service, with Bombardier forecasting a total production run of 1,192 units of all variants through 2016. The DHC-8-400, commonly referred to as the Q400, has the ability to conduct STOL operations. With the Q400, Bombardier also focused on improving cruise performance and lowering operational costs.

The Q400s are less expensive to maintain due to only having two engines and being newer (in both airframe age and design). In fact, the Q400 has one of the lowest costs per passenger mile when compared to its direct competitors. The Q400 is able to operate from small airports with 3,000-foot (910 meter) runways.

The Selection of the Q400 as the Alternative Aircraft. The DHC-8 and Q400 are already in service globally with other governments (see Figure 2). The Aerial Reconnaissance and Exploitation Systems (ARES) program considered the Casa C-295, which is comparable to the DHC-7, but saw that the Casa C-295 sat too low to the ground for one of the required payloads (L. Ilse, personal communication, April 20, 2011). The following paragraphs offer a brief view as to why the Q400 appears to be superior to the DHC-7. Subsequent chapters will go into more detail and analysis.


**Figure 2. Countries Using Versions of the DHC-8**
(Bombardier, 2011)

Engine Power. The Q400 has a higher payload capacity, more power, and more endurance in the ARES configuration. The Q400 has the Pratt & Whitney PW150A engine, which allows for lower fuel consumption and emissions, new technology materials and cooling, and a low parts count for reduced complexity and ease of maintenance. The Q400 supports the DoD's current financial goal of acquiring more efficient equipment (Weisgerber, 2011).

Length of Aircraft. Compared to the DHC-7, the Q400 has an additional 20 feet of fuselage length usable for cargo. This additional space should be able to accommodate more sensor payloads than three for the DHC-7. In addition, this extra space could accommodate future niche sensors such as light detection and ranging (LIDAR) and foliage penetration (FOPEN) that are not currently part of the ARL program (see Figure 3 for the Q400 external dimensions).

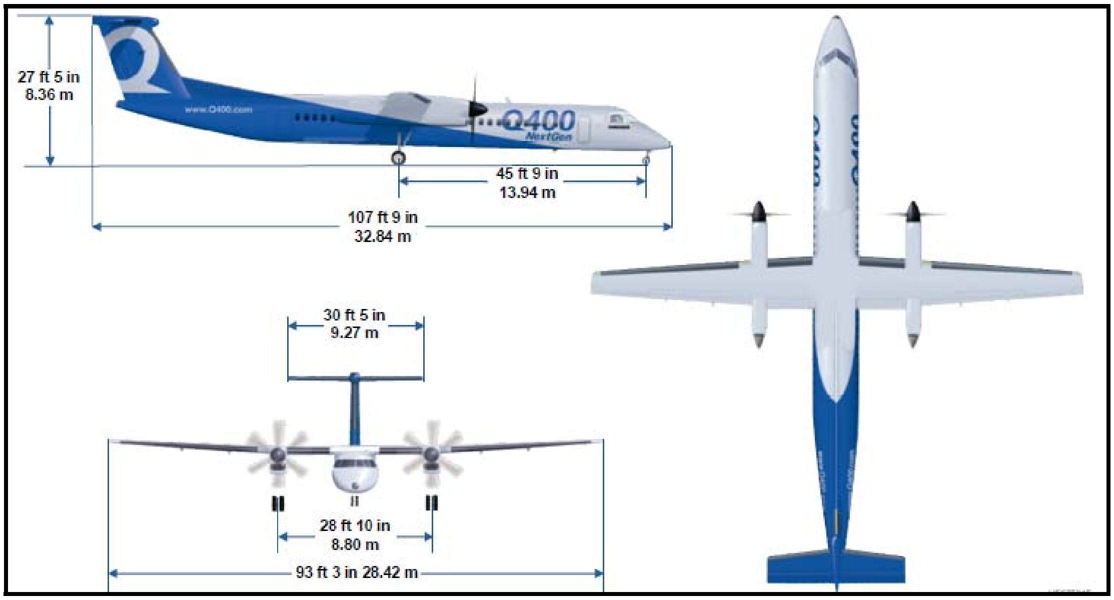



**Figure 3. Q400 External Dimensions**
(Bombardier, 2011)

### 1. Potential Advantages of the Q400

Noise Improvement. The Q in Q400 stands for *quiet*. The Q400 has a proprietary sound-reduction system called the active noise and vibration suppression (NVS) system. This system makes the interior of the aircraft extremely quiet compared to other turboprop aircraft, potentially improving the performance of on-board operators. The Q400 is also quieter from the outside. An aircraft with reduced signatures enhances their survivability and increases their probability of detecting and observing target activity. Concerning training, aircraft quietness might facilitate training operations by reducing noise complaints that could help ensure that local communities do not deny training and mission airspace.

Life Expectancy. The design life of the Q400 is 80,000 flight cycles, but Bombardier recently extended the lives of its aircraft, including some early Q400 aircraft. No Q400s are close to this cycle limit at present, but the potential for life extension exists. Aircraft that use up-to-date technology lower operating costs, a factor that the DoD is currently pushing for in future acquisitions in order to save more money in the long term (Weisgerber, 2011).

Payload Capability. From the start, the Q400's design will have the capability to facilitate modular sensor bays, which will allow operators to switch out of payloads quickly and tailor them to specific missions.

Still in Production. As of April 28, 2011, the production numbers of the Q400s stood at 352 aircraft. Bombardier no longer produces their Q200 and Q300 models due to the success of the Q400. This allows them to concentrate their production resources on the Q400 line.

Engine power. The Q400 is a two-engine aircraft, with a single-engine service ceiling that is 19,000 feet at 95% of max gross weight.

Heads-Up Guidance System. The Q400 has CAT-IIIa capability for increased operational ability in inclement weather and has the approval of the Federal Aviation Agency (FAA).

Existing Modification Strategy. All modifications to the Q400 must meet military specifications and have Supplemental Type Certificates (STC) from the FAA. An STC, issued by the FAA, approves a product (aircraft, engine, or propeller) change.
More important to the U.S. Army, the STCs will be applicable to all Q400s modified for ISR missions. In addition, Q300 STCs will receive updates for use on the Q400 with only minor rework for the installation of radome, electro-optical (EO) and IR sensors. This adaptability will lower overall program risk and reduce schedule impact.

Single-Engine Service Ceiling. One of the Q400's engines is capable of providing more significant lift and speed capacity than similar aircraft. For example, if the Q400 were operating at its maximum altitude of 25,000 feet, the service ceiling would decrease to 21,374 feet with one engine failure. In comparison, if the DHC-7 operated at its maximum altitude of 18,000 feet, its service ceiling would decrease to 13,000 feet if one engine failed (Intelligence and Security Command [INSCOM], 2002).

## F. THE FUTURE OF THE AIRBORNE RECONNAISSANCE LOW PROGRAM

Joint Direct-Support Airborne Intelligence Surveillance and Reconnaissance (JDSAISR). According to the recently published ICD for the JDSAISR, the desired outcome of JDSAISR is the operational synchronization of military actions in time and space to produce maximum relative combat power at a decisive point (Training and Doctrine Command [TRADOC], 2010, p. 1). The ICD will provide a set of capabilities that will enable timely, assured, persistent, and responsive airborne ISR support to tactical commanders at the Brigade Combat Team/Regimental Combat Team level and below (TRADOC, 2010, p. 1).

JDSAISR's Concept of Operation. The JDSAISR's capabilities will allow tactical commanders to focus on their commander's critical information requirements "for the purpose of driving operational synergy … to the lowest appropriate level" (TRADOC, 2010, p. 1). In addition, JDSAISR will contribute to the commander's situational understanding through its "unique characteristics of range, flexibility … and other key capability attributes" (TRADOC, 2010, p. 2). More specifically, the aerial platforms must be able to attack the network by focusing ISR support on the enemy's abilities to move, shoot, communicate, plan, supply, and sustain.

JDSAISR must be able to integrate capabilities to conduct find, fix, and finish support operations in supporting the tactical commander "to attack the threat" (TRADOC, 2010, p. 2). The sensors, as part of the ISR package, must provide sufficient resolution over desired coverage areas, and they must appropriately match their host platform. In addition, these host platforms (manned and unmanned) must be able to provide the requisite attributes for altitude, duration, payload capacity, and infrastructure demands.

Capabilities Enabled by JDSAISR. JDSAISR's capabilities contribute directly to answering the commander's critical information requirements in various scenarios to include irregular warfare and major combat operations (TRADOC, 2010, p. 1). The following are the specific enabling capabilities planned under JDSAISR:

- synchronization of processes, equipment, and training that eliminates gaps and provides the right information to the right place at the right time;
- networking of an interoperable network that will transport voice, text, data, video, and other information;
- analytical support that effectively leverages national to tactical tasking, processing, exploitation, and dissemination resources; and

- interdependency of ground-based, operational/theater, and strategic/national ISR capabilities that provide the necessary foundational and contextual information to maximize JDSAISR capabilities (TRADOC, 2010, p. 3).

JDSAISR Operational View. The JDSAISR capabilities are a synchronized layer of airborne capabilities that include the ARL as an asset that helps the commander answer his critical information requirements. Individual JDSAISR capabilities cannot alone achieve the desired level of performance. Layering and integrating all ISR capabilities to focus on a given problem set helps meet the commander's mission needs (TRADOC, 2010).

JDSAISR capabilities allow the tactical commanders "to attack the threat network in the context of the find, fix, finish, exploit, assess, and disseminate (F3EAD) and find, fix, track, target, engage, assess (F2T2EA) effects-based targeting process" (TRADOC, 2010).

Figure 4 shows the operational view for JDSAISR.

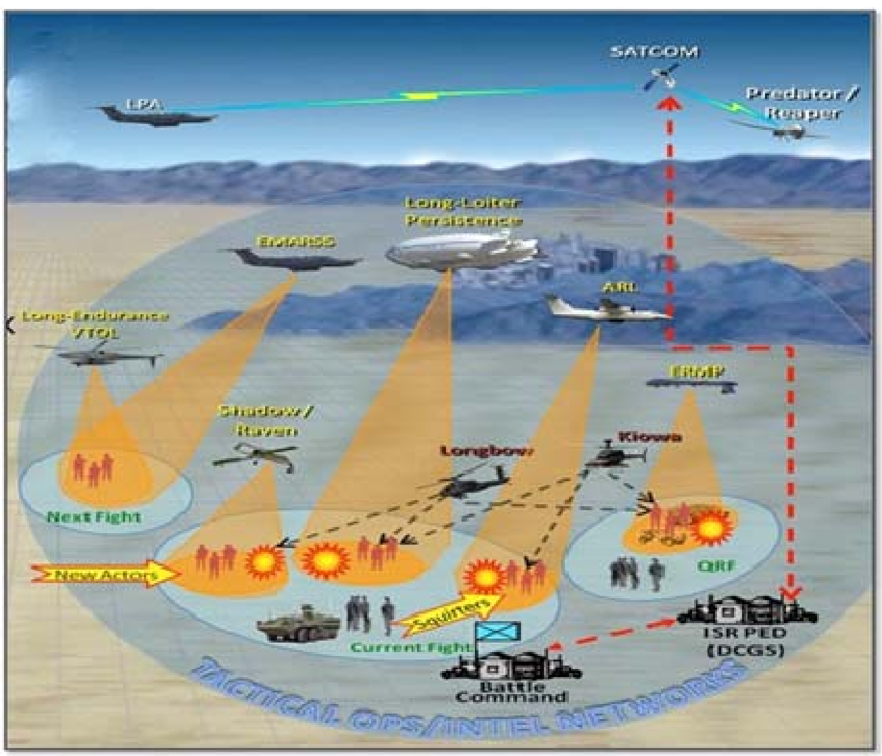



**Figure 4. Operational View of JDSAISR**
(TRADOC, 2010, p. 16)

Aerial ISR Layer Strategy. According to Joint Requirements Oversight Council Memorandum 157-09, all Services will continue to focus on the integration and optimization of sensor capabilities and platforms that possess the attributes of persistence and flexibility. In Figure 4, the various aircraft at the top of the blue circle represent the Army's Aerial Layer of Platforms and Sensors (ALPS) strategy that integrates with foundational, ground, other aerial (joint and nontraditional ISR) assets, and space capabilities. The four aerial assets that compose the ALPS strategy include the Enhanced Medium-Altitude Reconnaissance Surveillance System (EMARSS), a vertical take-off and landing (VTOL) unmanned aerial system (UAS), the Long Endurance Multi-Intelligence Vehicle (LEMV) UAS system, and the ARL (TRADOC, 2011).

# III. DHC-7 AND Q400 COMPARISON

The focus of this chapter is to do a side-by-side comparison of technical characteristics of the two aircraft. More analytical comparisons come later. For example, Chapter 4 contains the performance and cost comparison analyses. Tables 1–4 present the physical differences between the DHC-7 and the Q400.

**Table 1. Aircraft Dimensions**

| Aircraft Dimensions | DHC-7 | Q400 |
|---|---|---|
| Overall Length | 81.75 feet | 107.7 feet |
| Overall Height | 26.2 feet | 27.4 feet |
| Overall Wingspan | 93 feet | 93.25 feet |
| Wing Area | 860 $feet^3$ | 679 $feet^3$ |
| Wing Aspect Ratio | 10 | 12.8 |

*Note*. Data taken from Viking Air (2001) and Bombardier (2011).

**Table 2. Cabin Dimensions**

| Cabin Dimensions | DHC-7 | Q400 |
|---|---|---|
| Cabin Length | 39.5 feet | 72.5 feet |
| Max Cabin Height | 6.4 feet | 6.4 feet |
| Max Cabin Width | 8.5 feet | 8.2 feet |
| Cabin Volume | 1910 $feet^3$ | 2730 $feet^3$ |
| Cargo Compartment | 240 $feet^3$ | 411 $feet^3$ |

*Note*. Data taken from Viking Air (2001) and Bombardier (2011).

Table 3. Weights and Payload Capability

| Weights and Payload | DHC-7 | Q400 |
|---|---|---|
| Max Take-Off Weight (MTOW) | 44,000 lbs | 65,200 lbs |
| Max Landing Weight (MLW) | 42,000 lbs | 62,000 lbs |
| Typical Operating Weight Empty (OWE) | 27,570 lbs | 39,284 lbs |
| Max Zero Fuel Weight (MZFW) | 39,000 lbs | 58,000 lbs |
| Max Fuel (with auxiliary tanks) | 27,570 lbs | 21,724 lbs |
| Max Payload | 6,275 lbs | 18,716 lbs |
| Max Passengers (civilian) | 54 | 78 |

*Note*. Data taken from TRADOC (2002) and Bombardier (2011).

Table 4. Aircraft Performance

| Aircraft Performance | DHC-7 | Q400 |
|---|---|---|
| Engines | 4 x Pratt & Whitney PT6A-50 | 2 x Pratt & Whitney PW150A |
| Total Shaft Horsepower (all engines) | 4,480 SHP | 10,142 SHP |
| Time Between Overhauls (TBO) | 5500 hours | 10000 hours |
| Take-off Distance(ISA, SL, MTOW) | 2,240 feet | 4580 feet |
| Landing Distance (ISA, SL, MLW) | 2,160 feet | 4,221 feet |
| Max Range (ARL payload: max fuel & 45-minute reserve) | 1,096 nm | 3,152 nm |
| Max Cruise Speed | 231 knots | 352 knots |
| Max Endurance Speed (ARL Payload, max fuel & 45 min reserve) | 140 knots | 222 knots |
| Max Endurance Time (ARL Payload, max fuel & 45 min reserve) | 7.8 hours | 14.2 hours |
| Max Operating Altitude | 18,000 feet | 25,000 feet |
| Enroute Rate of Climb (MTOW) | 1,510 fpm | 2,280 fpm |
| One-Engine-Out Rate of Climb (ISA, SL, MTOW) | 820 fpm | 780 fpm |

*Note*. Data taken from TRADOC (2002) and Bombardier (2011).

# IV. ANALYSIS

## A. ASSUMPTIONS AND CONSTRAINTS

### 1. Assumptions Background

In general, we assumed that none of the parameters considered in the analysis change over the life cycle of the aircraft. Annual flight hours, fuel costs, and payloads are constant because there is no high-confidence method to determine these parameters in 2020, much less in 2031.

#### *a. Assumption 1*

Because the Army has the opportunity to buy brand new Q400s configured to its exact specifications, we assumed that the Army would purchase the Enhanced High Gross Weight (EHGW) version. The EHGW version maximizes payload capability and maximizes performance in high and hot altitudes. All Q400 specifications in this BCA show the EHGW version.

#### *b. Assumption 2*

The cost per flight hour is the basis for O&S costs. The figure for the DHC-7 came from a 2010 Science Applications International Corporation (SAIC) EO-5 BCA and adjusted data from a Conklin & de Decker (CdD) report (CdD, 2011). The SAIC analysis used data from the Fixed Wing Program Office (FWPO), the Program Objective Memorandum (POM), CdD, and from their own calculations. The cost per flying hour ranged from $2,340 to $4,269; for this BCA, we calculated the average to be $3,338. We used this figure for all subsequent calculations using O&S. This calculation represents an accurate figure because it is close to the median of the data points ($3,295; see Appendix A for more information). Crew costs are not a consideration in this BCA.

#### *c. Assumption 3*

The data that was used to calculate the cost per flight hour to operate the Q400 was from the Bombardier (2011) and CdD (2011) documents. The average figure from Bombardier was $2,069, with the adjusted CdD figure of $2,076. With this data we calculated the figure to be $2,072. For all subsequent calculations using O&S, we used $2,072 (see Appendix A for more information). Crew costs are not a consideration in this BCA because they would likely be similar, if not the same.

#### *d. Assumption 4*

The current Operations Tempo (OPTEMPO) of the ARL fleet will not change. Program Manager Fixed Wing (PM FW) forecasted annual hours at 110 hours per aircraft per month for the ARL fleet. This monthly forecast results in 10,560 total annual hours for the fleet.

#### *e. Assumption 5*

The term *mission payload* includes the weight of the sensors, the infrastructure changes and additions made to the aircraft to support the sensors (including wiring, workstations, monitors, and antennas), and personnel operating the mission equipment, excluding pilots.

The DHC-7 mission payload is 6,275 pounds; in its current configuration, it operates at its MTOW specification.

| MTOW – *Operating Weight Empty (*OWE) – Maximum Useable Fuel = Mission payload |
|---|

The theoretical Q400 mission payload is 6,000 pounds. We found this by determining the weight of the proposed standard sensor packages and then added in infrastructure and support weights. This calculation probably overestimates the Q400's ARL payload weight, but it ensures a fair comparison to the DHC-7.

### 2. Constraints Background

In an effort to limit the scope of this BCA, we only considered one aircraft to compare cost and performance against the DHC-7.

#### *a. Constraint 1*

Discussions with members of the PM ARES program office and the TRADOC Capability Manager for Intelligence Sensors (TCM-IS) led to the conclusion that the Q400 was the most competitive aircraft for the ARL mission and, therefore we selected it as the focus of this BCA.

## B. PERFORMANCE AND CAPABILITY

### 1. Operational Availability

Operational availability, also referred to as *operational readiness* or *combat readiness*, of military equipment is important to ensuring the success of military operations. Operational readiness is the number of days that the equipment is available and fully mission capable (FMC) or mission capable (MC), divided by the number of days in the reporting period. The Army's goal for aircraft is 75% FMC (Department of the Army [DoA], 2004). Commanders must be able to forecast the availability of their equipment with a high degree of certainty in order to plan and execute military operations. The current ARL on the DHC-7 airframe has poor reliability, resulting in unexecuted missions and the potential denial of warfighter support and crucial decision-making intelligence for commanders. The actual impacts of these coverage gaps are difficult to quantify.

United States Army Intelligence and Security Command (INSCOM) has the overall responsibility for the ARL fleet of eight aircraft. The 3rd Military Intelligence (MI) Battalion (BN) has three aircraft and the 204th MI BN has four. CENTCOM controls the eighth aircraft (D. Keshel, personal communication, August 16, 2011). The ARL fleet shows recent operational readiness rates of approximately 71% MC from February 2011 through July 2011 and 30% FMC from November 2010 through July 2011 (Cook, 2011). The rate of 30% FMC is well below the Army's goal of 75% FMC for aircraft. From November 2010 through July 2011, the 3rd MI BN reported 0% FMC. Although the airframes and engines were mission capable, the 3rd MI BN could not complete its mission due to difficulties with some of the newer mission equipment. This information equates to the ARL fleet being FMC approximately three out of every 10 flying days and being able to fly a mission about seven of every 10 days. The poor readiness rate severely influences operations. The 3rd MI BN annually flies only 2,846 of the 3,900 hours that they plan to fly, resulting in a 73% mission-accomplishment rate (Cook, 2011). The small size of the fleet means that as aircraft receive scheduled and unscheduled maintenance, only 10% of missions have a backup aircraft available. If the primary aircraft also goes down for unscheduled maintenance, the possibility of mission failure increases, potentially affecting the intelligence customer's decision-making ability (Cook, 2011).

The small fleet and operational readiness issues also affect flight training. Both the 3rd MI BN and the 204th MI BN report that their crews would be more proficient at their duties if the aircraft had better operational readiness rates or if there were more aircraft available. Additionally, the 3rd MI BN also reports having to deny mission support requests and joint training opportunities with the Republic of Korea's military forces due to a lack of available aircraft (Cook, 2011).

The Q400 is already in limited use by the government. The organizations that operate them have small fleets, usually consisting of just one or two aircraft. The Federal Bureau of Investigation (FBI) currently maintains a transport fleet that includes an older series-100 Dash-8 and a newer Q400. The FBI reports that their Q400 is an extremely reliable aircraft with an operational readiness rate of 95.5% (W. Lacy, personal communication, August 16, 2011).

A Bombardier representative also reports that other Q400 fleet operators are achieving 98.5% dispatch reliability (J. Gonsalves, personal communication, May 3, 2011). Dispatch reliability is the percentage of revenue departures that do not incur a delay greater than 15 minutes or a cancellation for technical reasons. Although there is no direct comparison between Army FMC rates and the civilian Q400's operating rates, dispatch reliability is a close indicator. The MC rate is more accurate than the FMC rate in these circumstances. Either the aircraft flies the mission or it does not. Unfortunately, there is still likely to be a small margin of error that is impossible to account for because the civilian Q400 does not have electronic mission equipment to consider in the dispatch reliability rates.

A DHC-7 with a 71% MC readiness rate is available only 260 days out of every year. On the other hand, a Q400 with an operational readiness rate of 95.6% (a number based on the most restrictive Q400 readiness data points) is available 349 days—an increase of 89 days, or about 34%. Based on these numbers between the aircraft, 1.3 DHC-7s per one Q400 are needed to achieve equivalent capabilities. If the Army replaced the existing ARL fleet on a one-for-one basis, based on operational readiness alone, a Q400 fleet of eight aircraft could do the work of almost 11 (10.7) DHC-7 ARL's, a benefit of nearly three additional aircraft (see Appendix B for detailed calculations).

An alternative interpretation of this data shows that the 34% additional capability based on readiness of the Q400 fleet could provide approximately 34% more hours of time on station (TOS) than the current ARL fleet.

### 2. Capability—Range and Endurance

Range and loiter time are both performance measures that are a function of both the amount of fuel an aircraft can carry and the aircraft's efficiency. An aircraft that can carry a large amount of fuel inefficiently is no more useful than a highly efficient aircraft that can carry only a small amount of fuel. The DHC-7-based ARL utilizes its regular fuel tanks and has auxiliary tanks called *wet wings* because they utilize space in the wings to carry extra fuel. The most efficient fuel burn comes at approximately 140 knots, allowing the ARL to fly for up to eight hours and travel approximately 1,100 nautical miles. In an effort to maximize their TOS, or loiter time, INSCOM ARL operators currently must modify their flying technique and operations, including sacrificing speed to the target area, to maximize their flight time. ARL operators in Korea would like to be able to cover an entire period of darkness, but cannot do so with the currently configured DHC-7 ARL (Cook, 2011). Because the current ARL operates at its MTOW, it is unable to carry additional fuel, even if it had the space.

A new Q400 has the ability to use additional internal or external fuel tanks that weigh up to 10,000 pounds, giving it a total of over 21,000 pounds of fuel. The additional 20 feet of interior space allows for the mounting of fuel tanks in the interior of the aircraft without sacrificing much mission space. Another advantage of internal fuel tanks is that they minimize drag-producing extrusions on the aircraft and maximize range and loiter time. A Q400 in this configuration, carrying one of the proposed future 6,000-pound ARL payloads, has a range of over 3,100 nautical miles and a total endurance time of 14.2 hours. This performance almost triples the aircraft's range capability and is an improvement of over 75% in endurance over the current DHC-7-based ARL.

This additional range and endurance has immediate, positive mission implications. With sensitive international political alliances and certain countries denying the basing of U.S. aircraft in their countries, the Q400 becomes an even more attractive option. Its additional range and endurance allow it to operate in areas where a DHC-7 cannot.

As Figure 5 shows, a Q400 based in Afghanistan has the range and endurance to operate in Iraq, whereas the DHC-7 ARL does not. This means that if the ARL platform were required in both countries simultaneously, the Army would have to establish and maintain an ARL logistical capability in each country. Similarly, a Q400 in the same situation could set their base in either country and operate with the efficiency that comes with logistical consolidation. Note that Figure 5 does not take into account the political considerations of overflying sovereign territories; it merely illustrates the potential benefit that the increased range of the Q400 might have in a given theater.


**Figure 5. Q400 Range and Endurance Advantage Over the DHC-7**

*Note.* DHC-7 (red circle) = 1,096 nm = 1,261 miles / 2 = 631 mile range; Q400 (blue circle) = 3,152 nm = 3,625 miles / 2 = 1,812 mile range. The data for this figure was taken from Bombardier (2011) and TRADOC (2002).

### 3. Capability—Maximum Cruise Speed

Another capability that additional horsepower provides is cruise speed. Currently, the DHC-7 ARLs operate out of Texas and Korea, and are generally executing *steady-state* operations. However, the units that operate the ARL are a globally deployable asset that must be ready to respond to warfighter needs for the ARL's ISR capabilities (Cook, 2011). When these units deploy to support a Brigade Combat Team (BCT), Division, or Corps, the maximum cruise speed becomes an important factor. Regularly planned missions do not require excessive speed because the operators conduct planning that allows them to account for the required TOS to ensure maximum fuel efficiency. A re-tasking is usually for an urgent and developing situation where speed is crucial. The DHC-7 can cruise at up to 231 knots, but it does so at an extreme cost to fuel efficiency. The Q400 has a maximum cruise speed of 360 knots, which is approximately 56% faster than the DHC-7 and with less impact on its fuel efficiency.

### *a. Operational Mission Scenario*

The following operational mission scenario highlights the importance of speed. An INSCOM unit deploys to Afghanistan and flies regularly scheduled missions in and around Regional Command South. It is currently over the city of Kandahar in Kandahar Province. A situation develops in Helmand Province just to the west with Troops in Contact (TIC), meaning that soldiers are in a direct engagement with the enemy. No other ISR assets are currently in the area. The ARL receives the task to support the TIC and must fly approximately 100 miles (86 nautical miles). The current DHC-7 ARL will take over 22 minutes to get to the target area, but a Q400 would take just 14 minutes, an improvement of eight minutes. When minutes and seconds count, eight minutes is an exceptional improvement to the warfighter. Although this example is simple, its message is important. If the Army continues to conduct operations in varied locations, it will always need aerial assets with increased capabilities, such as those of the Q400 in this scenario.

## 4. Capability—Payload

The current ARL payload on the DHC-7 is approximately 6,275 pounds, which puts it at its maximum capability and minimizes the possibilities for sensor enhancements (L. Ilse, personal communication, April 20, 2011). The Q400 is capable of payloads of over 18,700 pounds, which give it almost 300% more capability than the DHC-7.[1] The Q400's additional payload comes with an increase of only 36% in operating weight empty (OWE), which shows its improved efficiency over the DHC-7 (see Appendix C for detailed payload figures).

The Q400s are able to carry an additional 10,000(+) pounds of payload more than the DHC-7 and they have an extra length of 27 feet (8.23 meters) to carry more items. As described in the JDSAISR document, warfighters are looking for flexibility and enhanced capabilities to fill gaps in current ISR collection methods (TRADOC, 2010). A larger and more capable setup within the aircraft provides much more room for future enhancements and upgrades. Obtaining the Q400 is an excellent example of how the

[1] If the Army were to completely utilize the 18,000(+) pounds of payload on a Q400, they would sacrifice some of the range and endurance advantage.

Army could do value engineering. In value engineering (VE), *value* is defined as *function* divided by *cost*:

$$\text{Value} = \frac{\text{Function}}{\text{Cost}}$$

To increase value, function must increase and/or cost must decrease. One concept that offers such increased value is the modular payload bay, already in use by aircraft manufacturers, which provides a sensor-dedicated area in the vehicle that allows for plug-and-play capability. In the case of the Army's Long Endurance Multi-Intelligence Vehicle (LEMV; a large hybrid air vehicle that can stay on station for weeks at an altitude of 20,000 feet), the modular payload bay provides a 24-foot long bay with housings for 12 individual payload modules. Each module uses an Internet-protocol-based interface for easy integration without modification to the mission computer. This interface allows the LEMV to carry different modular payloads that can switch out quickly for different operational missions. In addition, the modular payloads would allow for quick modifications upgrades without modifying the platform itself (Heaney, 2011). Figure 6 is an example of a modular payload bay. Note that the actual implementation of the modular payload bay onto a Q400 would likely look different and would essentially be three to four individual payload bays cut into the underside of the aircraft.

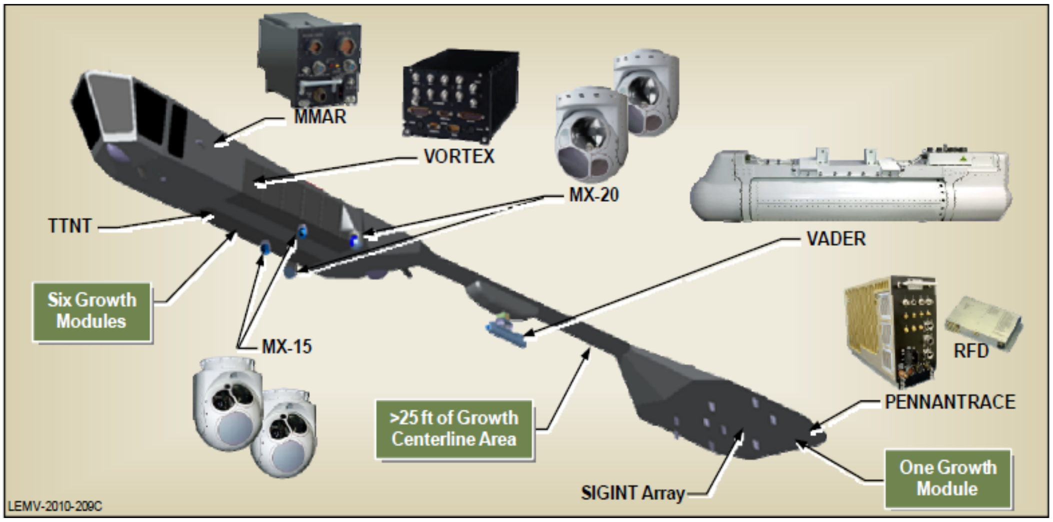



**Figure 6. Modular Payload Bay Concept on the LEMV**
(Heaney, 2011)

The current DHC-7 ARL-M has three different sensor configurations in payload: MTI/SAR, IMINT, and SIGINT. A possible future Q400-based ARL would have enough room to enhance the ARL's capability by building in the modular payload bay concept from the beginning. Given the added space and performance of the Q400, it should provide enough room for up to four or more sensors versus the three available on the DHC-7. These additional sensors would provide users with another asset and support the ARL's flexibility to adjust payloads for specific mission sets within hours not days (L. Ilse, personal communication, April 20, 2011)

The program manager for ARES, COL Keith Hirschman, envisions the future ARL replacement being able to carry large, niche sensors that the other previously mentioned platforms within the JDSAISR concept cannot (K. Hirschman, personal communication, April 20, 2011). In addition to allowing the rapid change out of an existing suite of sensors, the modular payload bay concept also facilitates rapid integration of new sensors (M. Popovich, personal communication, April 20, 2011).

#### *a. Possible Future Payload Configurations*

The Army TCM-IS office offered three possible payloads for consideration for an upgraded ARL platform. Each of these proposed payloads implement sensors that already exist and require minimal additional development. The sensors will also allow for easy integration in future platforms. The sensors are tailored to a specific mission set defined within the JDSAISR ICD and represent capabilities that the current ARL does not have, while also enhancing its existing capabilities. The sensors have all received approval as part of the ARL requirements document (Director, Capabilities Integration, Prioritization and Analysis, 2011). All of these payloads weigh less than the 6,275-pound suite of sensors and equipment currently onboard the ARL. To ensure a fair comparison between DHC-7 and Q400 capabilities we estimated 6,000 pounds to include aircraft modifications, workstations, operators, wiring, and antennas. This is likely an overestimation of a new Q400 ARL payload, but it ensures a realistic comparison by not overstating the performance of the Q400. The following section contains more details on proposed payloads A, B, and C.

Payload A. This payload is suitable for a find mission, also known as a persistent area assessment (PAA) mission, which works well with high-endurance platforms and provides broad-area sensing to develop enemy communications networks, activity, and movement. These are the potential components of Payload A:

- Ground Moving Target Indication (GMTI)—Phoenix Eye
    - This synthetic-aperture radar (SAR) shows the operator moving vehicles in a large area.
- Conventional SIGINT—Diamondback or Pennantrace
    - This sensor gives the operator the ability to penetrate communications networks.
- Wide-Area Airborne Surveillance Sensor—Constant Hawk, MASIV, or ARGUS-IS/IR
    - This sensor is similar in operation to a full motion video (FMV), but looks at much larger areas with a lower refresh rate and gives the operator the ability to store, rewind, and fast-forward imagery to detect patterns in movement.

Payload B. This payload is suitable for the fix mission, also known as the situation development (SID) mission, which receives cues from a variety of sources to develop situation and target understanding. These are the potential components of Payload B:

- DMTI Radar—VADER
    - This sensor is similar to GMTI, but has the resolution necessary to detect objects smaller than vehicles, such as personnel.
- LIDAR or High Resolution Color Image Mapping Sensor—PeARL Camera
    - This sensor is an optical remote-sensing technology that can measure the distance to, or other properties of, a target by illuminating the target with light.
- Hyperspectral Sensor
    - This sensor is similar in theory to the human eye in that it separates visible light; however, hyperspectral imagery divides the spectrum into many more bands and allows the operator to see beyond what is visible to the human eye. It increases the ability of the operator to identify certain materials that make up a scanned object.

Payload C. This payload is suitable for finish operations, also known as mission overwatch (MO) operations, which conduct multi-sensor ISR overwatch to current operations and can provide direct support to the warfighter on the ground. These are the potential components of Payload C:

- Dual EO/IR FMV with Shortwave IR (SWIR)
    - EO/IR cameras allow the operator to see during the day and night. SWIR allows the operator to see in even darker conditions than IR. Warfighters frequently request the dual EO/IR camera because it provides them with redundant coverage during operations (L. Ilse, personal communication, April 20, 2011). It provides the warfighter the capability to have observation on an objective and to have another

asset scanning the perimeter of the objective, for example. Most operations currently require two separate platforms to achieve this capability.

- Penetrating Radars—FOPEN, TRACER, Desert Owl, Copperhead
  - These sensors allow the operator to see through obstructions, such as dense jungle foliage.
- Aerial Precision Geo-Location (SIGINT)
  - This sensor gives the operator the ability to determine an exact location for enemy communications devices.

Using the modular payload bay design's plug-and-play concept, commanders can request assets from three basic payloads in numerous possible combinations of sensors. This gives the commanders a wide selection of assets to use in intelligence-gathering and observation missions. Although the weight of proposed future ARL payloads is similar to that of the current generation payload, the Q400 can carry this payload farther, faster, and more efficiently. The Q400's 10,000 pounds of additional payload capability provides the Army with a great deal of future flexibility, including modification and upgrade options.

### 5. Capability—Short Take-Off and Landing (STOL)

The design of the DHC-7 was developed in the 1970s at a time when the airline industry believed that regional city centers would build short take-off fields. This never materialized and there existed limited routes to remote airfields with short runways to generate enough traffic to justify the use of a 50-seater (Lenz, 2009). The DHC-7 can take off from fields as short as 689 meters (2,260 feet) and can land on runaways as short as 594 meters (1,950 feet). Although it is a great capability, STOL is not commonly used by commercial airlines and will likely not be a requirement for a future ARL (K. Hirschman, personal communication, April 20, 2011). The STOL capability was a SOUTHCOM request and is not part of the standard Army mission set. The DHC-7 is capable of operations on unprepared airfields; however, the Army has yet to use this capability (D. Keshel, personal communication, August 16, 2011).

The Q400 is not as capable in this respect; it needs 1,469 meters (4,819 feet) at MTOW to take off and 1,290 meters (4,232 feet) to land. This data makes the Q400 appear less useful due to the limited number of airfields at which it will be able to take off and land; however, the Q400 can operate from all Army Class A runways in accordance with *Army Field Manual 3-04.300,* (DoA, 2008). The Q400 is also capable of operations on unprepared airfields, which means that it has the ability to deploy and operate alongside Army expeditionary forces as missions dictate. In short, the Q400's short field capability is not as good as the DHC-7's, but it is sufficient for Army operations.

#### 6. Capability—Normal Ceiling and One-Engine-Out Ceiling

The DHC-7, when compared to similar aircraft, has power issues. Its four Pratt & Whitney PT6A-50 engines produce 1,120 shaft horsepower (SHP) for a total of 4,480 SHP at maximum power for take-off. The Q400 has only two Pratt & Whitney PT150-A engines, yet they have a rating of over 5,000 SHP at maximum power for take-off, yielding a total of over 10,000 SHP (Bombardier, 2011). A single PT150-A has more horsepower than all four PT6A-50s.

The horsepower numbers are meaningful in the context of operating capability. Aircraft performance limitations often require drift-down procedures in the existing ARL platform. At an ARL operating weight of 44,000 pounds and in International Standard Atmosphere (ISA) conditions, the ARL platform will descend to approximately 13,000 feet before it is able to maintain altitude (Viking Air, 2001). This gradual descent would take place over a period of approximately 38 minutes, during which time the aircraft would fly close to 86 nautical miles. The mission must be planned so that the aircraft can safely descend without encountering obstacles during the descent or after leveling off at 13,000 feet. In operating environments that have large mountain ranges, like Afghanistan and South America, certain areas are off limits because the aircraft must remain close enough to mountain passes so that it can descend through them if an engine fails. Failure to account for drift-down procedures in mission planning places the safety of the aircraft and its crew at high risk.

Using the Q400's drift-down procedures, Bombardier (2001) calculates that the single-engine ceiling of the future theoretical Q400 with an ARL payload at 6,000 pounds and fueled for a 10-hour mission would be 20,347 feet (56,000 pounds and ISA). The Q400's mission-configured, single-engine service ceiling is projected to be higher than the four-engine, mission-configured ceiling of the existing ARL platform.[2] This enhanced capability allows the Q400 significantly more flexibility in mission planning.

In an AO such as SOUTHCOM, planners currently face significant limitations because they can plan missions only on the east side of the Andes mountain range due to its lower altitude. Anything to the west is off-limits because if an engine issue were to occur, the aircraft and crew would likely be unable to return to the east side of the mountain range to make an emergency landing. This constraint prevents the Army from planning ARL operations along almost the entire west coast of South America. Figure 7 highlights the limitation of the DHC-7 on a map of South America, and the benefit of the Q400 in comparison. Aircraft performance is restricted in the red areas and unrestricted in the green areas. If the Q400 loses an engine, the aircraft can still fly through most mountain passes in the Andes. Only 46 peaks are above the Q400's 20,347-foot single-engine service ceiling, which greatly extends the ISR collection range for the aircraft and maximizes the platform's ability to collect intelligence.

[2] Increasing the Q400's payload above 6,000 lbs and/or adding additional fuel will decrease the engine-out ceiling.

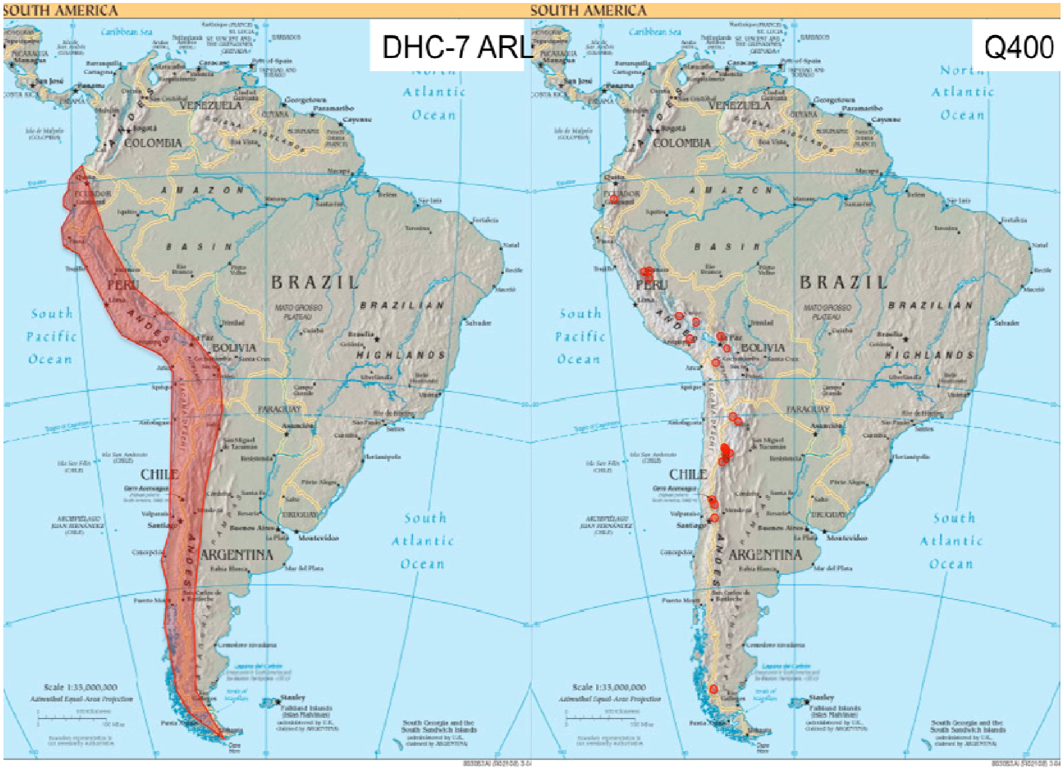



**Figure 7. Operating Restrictions Due to the Andes Mountain Range**

*Note.* Red shows areas that the platform is unable to operate. DHC-7 is shown on the left and Q400 on the right. The data for this figure was taken from Bombardier (2001), TRADOC (2002), and Viking Air (2001).

### 7. Overall DHC-7 to Q400 Performance and Capability Comparison

Figure 8 compares performance metrics for the DHC-7 and the Q400. To make this comparison meaningful, Figure 8 depicts the DHC-7 as the baseline against which to compare the Q400. Therefore, all of the DHC-7's performances equal *one*. The Q400 performance metrics were compared and displayed as a ratio (see Appendix E for detailed calculations). Based on the performance measures and capabilities identified in this BCA, the Q400 is up to three times the aircraft that the DHC-7 is. The average and the median of the performance ratios are 1.84 and 1.53 respectively. Even the most conservative performance measures indicate that one Q400 is equivalent to 1.3 DHC-7s. Replacing the eight DHC-7s in the Army's ARL fleet with eight Q400s would net the same performance as approximately 10.4 DHC-7s—a capability increase equivalent to adding two aircraft to the ARL fleet.

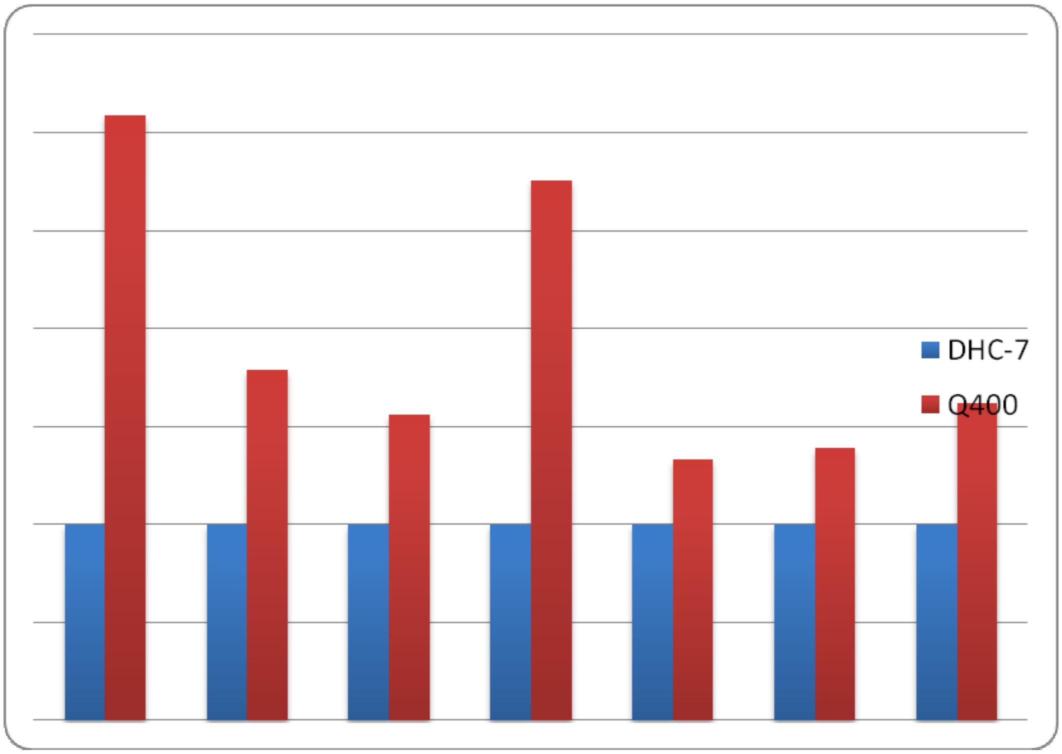



**Figure 8. DHC-7 Versus Q400 Performance Comparison**

## C. STANDARD MISSION PROFILE COSTS

This BCA examined quantitative and qualitative data from the ARL operators within INSCOM. The units involved included the 204th MI BN stationed at Fort Bliss, TX, and the 3rd MI BN stationed in Korea. Because of their combined feedback, a standard mission scenario emerged that allowed for a comparison between the Q400 and the DHC-7. The standard mission for this study consisted of a take-off from a station and a transit of 130 nautical miles (150 miles) to the mission area. The aircraft will operate at a maximum loiter TOS (based on available fuel), and will transit back to the station at 130-nautical miles with a 45-minute fuel reserve. This means that the pilots plan to land the aircraft with 45 minutes of fuel remaining. Figure 9 shows the standard mission scenario overlaid on a theoretical Army AO (see Appendix D for detailed calculations).

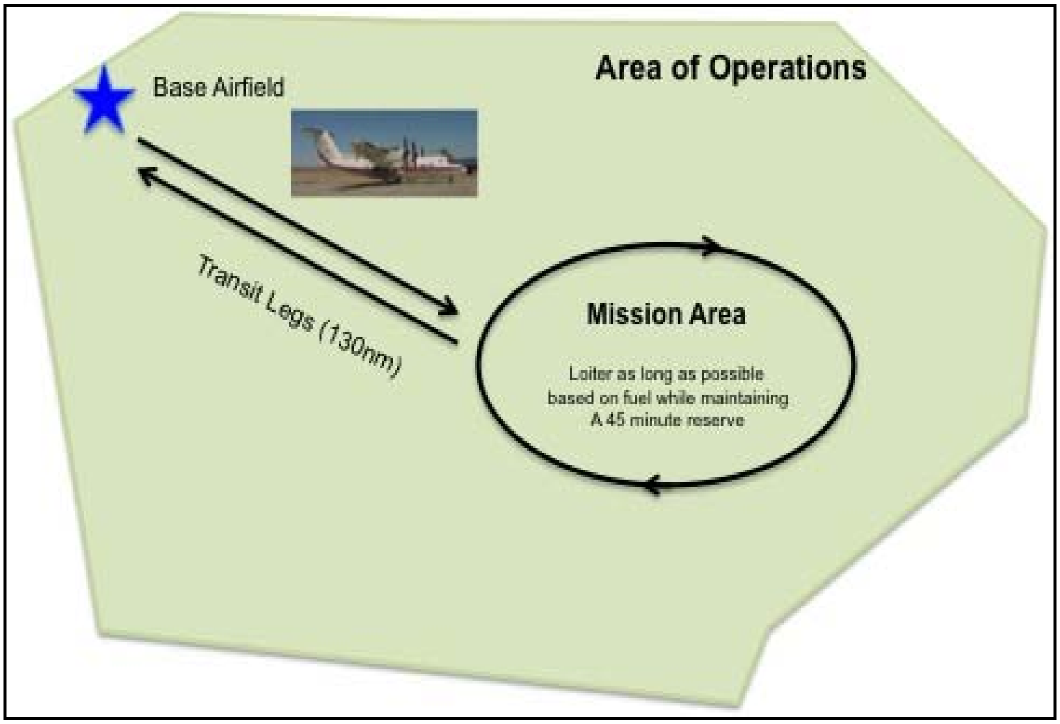



**Figure 9. Standard Mission Scenario**

*Note.* The data for this scenario was taken from Cook (2011).

### 1. DHC-7 Standard Mission Profile Cost

Although the DHC-7 is capable of faster cruising speeds, real-world units (3rd MI BN and 204th MI BN) travel their transit legs at approximately 140 knots and conduct their missions at this same speed when they are on station. The mission speeds flown reflect these units' direct effort to maximize fuel efficiency in order to maximize station time. With a 45-minute reserve, the DHC-7 can stay aloft for approximately seven hours and 50 minutes. The 130-nautical mile transit legs take 55 minutes each at 140 knots so the actual TOS is six hours, and it covers 836 nautical miles (for a total of 1,096 nautical miles per mission). The total cost per mission at $3,388 per hour comes to $26,140. The cost per nautical mile in the mission area is $31.26.

### 2. Q400 Standard Mission Profile Cost—Max Endurance

When placed into the same mission profile, the Q400 fared significantly better with its enhanced performance and fuel economy. The Q400 burns fuel most efficiently at 222 knots, allowing it to arrive at the target area more quickly, while also covering more area while on station. It is useful to look at the Q400's capability in a maximum-endurance scenario because the INSCOM operators would like more TOS than what the DHC-7 can correctly provide at its maximum. When configured for maximum endurance using internal auxiliary tanks with a 45-minute reserve, the Q400 can remain airborne for approximately 14.2 hours. The Q400 can complete the 130-nautical mile transit legs in only 35 minutes, saving over 40 minutes of transit time per mission. With its increased range, the Q400 has close to 13 hours TOS, which means it can cover a whole period of darkness. This endurance is important to flight operators and intelligence customers (Cook, 2011).

At $2,072 per hour, the total mission cost comes to $29,427, which is more expensive than a DHC-7 mission; however, when broken down further, the cost per nautical mile is $10.17, less than one-third of the DHC-7's cost. Another metric to consider is the actual cost per mission hour, which is the cost of the entire mission divided by the actual number of hours the ARL is conducting its intelligence mission, or TOS. This metric removes transit time from the equation and gives a more accurate look at what the intelligence actually costs. In this metric, the Q400 costs $2,259 per mission hour, which is almost half of the DHC-7's cost of $4,377 per mission hour.

### 3. Q400 Standard Mission Profile Cost—Most Likely Use Scenario

The maximum endurance configuration allows for potential surge capability, but an aircraft is rarely used to its maximum capability. For pilots and operators conducting regular missions, a 14-hour flight, plus pre-brief time, preparation time, and de-brief time, could disrupt mandatory crew rest time and is likely unsustainable for long periods. Therefore, it is important for this BCA to establish a most-likely-use scenario to compare the DHC-7 against the Q400.

Feedback from INSCOM operators helped develop this scenario, who said an ideal total mission time would be 10 hours (Cook, 2011). Given the same 130-nautical mile transit legs used in the DHC-7 scenario, the flight time of 10 hours leaves almost nine hours of TOS, which makes use of the Q400's enhanced capabilities and allows it to cover a period of darkness. A 10-hour mission costs $20,723, which is over $5,000 less per mission than the DHC-7. The Q400 costs just $2,347 per mission hour versus $4,377, and just $10.57 per nautical mile covered versus $31.26.

### 4. INSCOM Demand for TOS and Number of Sorties Required

The current demand for ARL use helps identify how the increased performance and capability of the Q400 translates into fleet-wide efficiencies. The subsequent paragraphs compare the TOS of the DHC-7 and Q-400.

PM FW predicts that the ARL fleet will fly 110 hours per aircraft per month, which equates to 10,560 hours annually (Lee, 2011). Given current transit times with the DHC-7, the 10,560 hours flown delivers approximately 8,055 hours of TOS and requires 1,349 sorties. As stated earlier, we define TOS as actual mission hours where the ARL is performing an intelligence mission.

Using the most-probable-use scenario and the current INSCOM demand for TOS, this BCA found that with a fleet of Q400s, the Army could accomplish the demand for 8,055 hours of TOS in just 912 sorties for a total of 9,124 annual flight hours (see Appendix F for calculations). This potential reduction in flight hours means more savings in O&S costs.

### 5. Results

Beyond performance metrics, we also considered overall efficiency differences. As with the capability and performance metrics above, we used the same methodology to analyze the efficiencies of the Q400 against the baseline of the DHC-7. The DHC-7's performance is represented as one with the Q400 displayed as a ratio. The most-probable-use scenario performances prevent the skewing of results and provide an accurate and realistic view of the possible Q400 advantages (see Appendix E for detailed calculations). As shown in Figure 10, the Q400 can complete the current ARL mission, including INSCOM's TOS requirements, in just 68% of the sorties that the DHC-7 requires. 110 flying hours per month per aircraft means that each ARL unit is able to provide daily coverage to intelligence users.

The Q400's hourly operating cost is 62% of the DHC-7's, and its cost per nautical mile covered is just 34% of the DHC-7's. Finally, to cover the same INSCOM demand, the Q400's 2011 annual O&S cost would be approximately 54% of the DHC-7's. The Q400 brings multiple efficiencies to the operator and is overall a more affordable aircraft to operate, even without its enhanced capabilities. Even the most conservative estimates of the Q400's efficiency show that the Q400 does the job at 68% of the cost of the DHC-7.

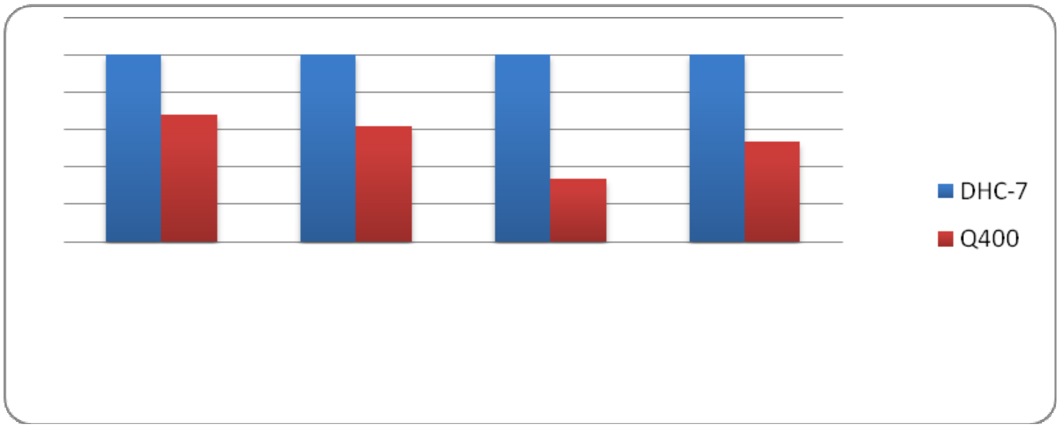



**Figure 10. DHC-7 Versus Q400 Standard Mission Efficiencies**

Using the VE model to examine performance and cost, the same performance and cost findings can be input into the value equation (Value = Function/Cost), as displayed in this section. We used the increased performance number as our metric for function, and the cost ratio as our metric for cost. Even using the most conservative figures, the results show that the Q400 is 1.3 times the aircraft that the DHC-7 is and does the job at 68% of the cost.

$$\text{Value} = \frac{\text{Function}}{\text{Cost}}$$

$$\text{The Q400's Value} = \frac{\text{1.30 x the performance of the DHC-7}}{\text{.68 x the operating cost of the DHC-7}}$$

The Q400's Value = *1.91* times the value of the DHC-7

This BCA concludes that in terms of value, the Q400 is almost twice the aircraft of the DHC-7. By replacing its DHC-7s with Q400s, the Army would essentially double the value of the current ARL fleet.

## D. RETURN ON INVESTMENT (ROI)

### 1. ROI 1

#### *a. One-Off Repair Parts and Cannibalization*

Increasing maintenance costs for spare parts are a major concern facing DHC-7 fleet operators. Two factors influence these high maintenance costs. First, the production line for the aircraft stopped in 1988; and second, De Havilland Canada only produced 113 total aircraft and approximately half of these aircraft are still flying (CH-Aviation, 2011). These factors make spare parts hard to find and, therefore, expensive. In addition, De Havilland Canada no longer exists so it is difficult to obtain digital drawings that are transferrable to Computer-Aided Drawing (CAD) and Computer-Aided Manufacturing (CAM). If a third party vendor must make a part for the DHC-7, the vendor will have to reverse engineer that part into CAD/CAM, which, again, will make it expensive to produce (C. Wantuck, personal communication, May 2, 2011).

Approximately 10 years ago, the ARL PM faced the issue of buying parts, specifically propeller hubs that were no longer in production. As a result, the ARL PM approached a civilian contractor to make these parts as a special order. The contractor would not consider producing these parts unless the purchase was for a bulk order of at least 65 units. The ARL PM then approached every civilian DHC-7 operator in the world in an attempt to spread the cost of buying so many propeller hubs. Although this was a creative attempt to solve the DHC-7's maintenance problem, the Army still had to purchase 40 propeller hubs when they only needed a "handful" (D. Keshel, personal communication, August 16, 2011).

The Army is facing this same scenario again in 2011. The analog gauges found in the DHC-7 cockpits are no longer available and are becoming extremely expensive and time consuming to repair. As a result, the Army may have to modernize all of the DHC-7 cockpits in its ARL fleet with new digital gauges. The approximate cost is $2.8 million (D. Keshel, personal communication, August 16, 2011).

An alternative method of obtaining parts is by sourcing them from other identical aircraft, a process commonly referred to as *cannibalization*. The small production numbers for the DHC-7 mean that the pool of source aircraft is shallow, making the practice of cannibalization difficult, time consuming, and expensive. Another challenge of maintaining the DHC-7 is that there is competition with other DHC-7 operators to obtain the same limited pool of repair parts.

A Scandinavian entity recently purchased an Israeli DHC-7 just for its parts. When a product line resorts to cannibalization to keep it running, it is essentially at the end of its life and the sustainment costs begin to peak (C. Wantuck, personal communication, May 4, 2011). Since 1996, the inefficiency of cannibalization has added millions of hours to maintenance personnel's workload (Government Accounting Office [GAO], 2001). Instead of a two-step process of removing the old part and replacing it with a new part, cannibalization requires three steps: remove the old part from the operational aircraft, remove the donor part from the donor aircraft, and then install the donor part on the operational aircraft.

If the donor aircraft is also an operational aircraft, there is the need for a fourth step, the installation of the new part onto the donor aircraft to make it operational again. Cannibalization can literally take twice the amount of time as a regular repair because there is the removal of the part and then the re-installation of that part twice, once into the nonmission capable aircraft and then eventually the cannibalized aircraft (GAO, 2001). In addition, because broken parts are replaced with used parts, cannibalizations do not restore a component to its full projected life expectancy, but instead, increase the chance that the same component will again break down prematurely (Worra, 2000).

The problems with the DHC-7 fleet have real-world implications. In 2010, the autopilot controller failed on one of the 3rd MI BN ARLs. The maintenance contractor that works with the Army maintenance team was able to source a previously used controller from a DHC-7 that operated in Yemen. The part did not have a traceable maintenance history and, as a result, it was not serviceable. The unit's only other option was to send out the original, failed controller for repair (Swickard, 2011). There was no projected date of return and as a result, the aircraft was unable to fly for an extended period, leaving their intelligence customers without service.

The Q400 does not have, and is not likely to have, the same problems as the DHC-7. There are over 1,000 Dash-8s in operation and over 350 of them are Q400s.

Additionally, the production line for the Q400 remains open. It is important to note that Bombardier no longer produces its Q200 and Q300 (smaller versions of the Q400), devoting its production resources to the more popular Q400 (J. Gonsalves, personal communication, May 5, 2011). The Army has the opportunity to buy new aircraft as opposed to buying used.

#### *b. Life Cycle Landings and Time Between Overhaul (TBO)*

The Q400 appears to be a better design that uses modern technology, materials, and construction methods. The DHC-7 has a rating of 60,000 life cycle landings compared to the Q400's rating of 80,000 (Bombardier, 2011). The engines on the DHC-7 have a time between overhaul (TBO) of 5,500 hours, at which time each of the four engines must receive inspection and overhauling. The Q400 has a TBO of 10,000 hours (Bombardier, 2011). With almost double the time between overhauls and with only two engines, the Q400 requires just 27.5% of the DHC-7 overhaul workload, equating to reduced maintenance costs.

#### *c. DHC-7 20-Year Life Cycle Costs*

The life cycle costs (LCC) calculation in this BCA looks at the per-hour flying cost of each aircraft, which is the basis for future O&S costs. Within the DoD, O&S costs account for approximately two-thirds of the overall defense budget (Congressional Budget Office [CBO], 2007). Due to the O&S costs being such a large portion of the DoD budget, serious consideration must be made to find ways to decrease unnecessary spending. For the DHC-7 ARL, these costs include operational fuel, airframe maintenance, and engine maintenance. For future budget planning, the Army should factor in increases to O&S costs associated with the life cycle of the aircraft.

To determine whether it would be prudent to calculate increases to DHC-7 O&S costs, we looked to the aging KC-135 Stratotanker for a comparison. The Air Force's KC-135 fleet is approaching an average service-life age of 45 years, a figure that is well beyond its initial design life. During the height of the Cold War, the replacement of most aircraft fleets occurred at approximately 20 years, but today the fleets have a life expectancy beyond this 20-year mark (Dixon, 2005). Although modifications and refurbishments to the fleets assist in maintaining their reliability, no one knows the sustainability and maintainability implications of operating aircraft that are this old (Bryant, 2007). Estimates on the increasing costs, over and above inflation, for the KC-135 range from 1% to 6.5% annually and come from different agencies, including the United States Air Force and the Defense Science Board. Given the fact that the average age of an Army DHC-7 is over 28 years and that the number of KC-135s and Boeing 707s (the KC-135's civilian equivalent) is far greater than the number of DHC-7s that were ever in service, it is likely that the ARL might incur similar, if not more, O&S cost increases.

In this case, the LCC calculation looked at the current year, 2011, and calculated the cost of maintaining the DHC-7 ARL over the next 20 years. We used a figure of 5% over and above inflation to calculate DHC-7 ARL O&S cost increases. Five percent is a conservative number given the small fleet size compared to the KC-135/Boeing 707.

Using the 10,560 annual hours as the basis for our calculation, we found an LCC of $157 million per ARL, for a total fleet LCC of approximately $1.26 billion (Appendix G). The $157 million figure per aircraft is similar to the number reported in an SAIC (2010) EO-5 study, which concluded that the status quo 20-year LCC of the DHC-7 was $126 million per aircraft. SAIC used a different method to calculate the LCC, yet both of these studies concluded with similar figures, confirming the results of this BCA. A 2.5% inflation rate included in the calculation increases O&S costs by 7.5% per year in future dollars. The result is that the fleet's LCC is over $1.67 billion, or $209 million per aircraft in future dollars.

#### *d. Q400 20-Year Life Cycle Costs*

This BCA then examined the Q400 with slightly different assumptions than the DHC-7. First, the increase for O&S costs stayed at zero because the Army would be purchasing brand-new aircraft. Assuming that the Army replaced each DHC-7 ARL with a Q400 at a cost of $31 million per aircraft and outfitted each with a customized ISR suite costing $19 million, the total cost of each aircraft was $50 million. Replaced on a one-for-one basis, the total acquisition cost, or investment cost, for the new Q400 ARL fleet would be $400 million. The acquisition cost is also part of the O&S costs for the Q400, which is approximately 38% cheaper to operate per flight hour due to its more efficient engines and design.

We also accounted for the number of annual required flight hours. Based on the current OPTEMPO forecast for a demand of 8,055 TOS hours, and using the 10-hour mission assumption, the Q400 requires only 9,124 flight hours annually. The calculations produced an LCC total of $797 million, or just over $99 million per aircraft in 2011 dollars (see Appendix G for detailed calculations).

#### *e. 20-Year Life Cycle Cost Results*

The results of these calculations of 20-year LCC means that replacing the current ARL fleet with Q400s is 18% cheaper than staying with the DHC-7 fleet and yields a cost avoidance savings of over $462 million over the next 20 years. This figure also assumed that the DHC-7 would receive no additional upgrades in the next two decades. Figure 11 is a break-even analysis graph and shows that by year 13 (2024), the upfront investment cost of eight new Q400s will be paid off and the fleet will continue to be less expensive to operate than the current DHC-7 fleet.

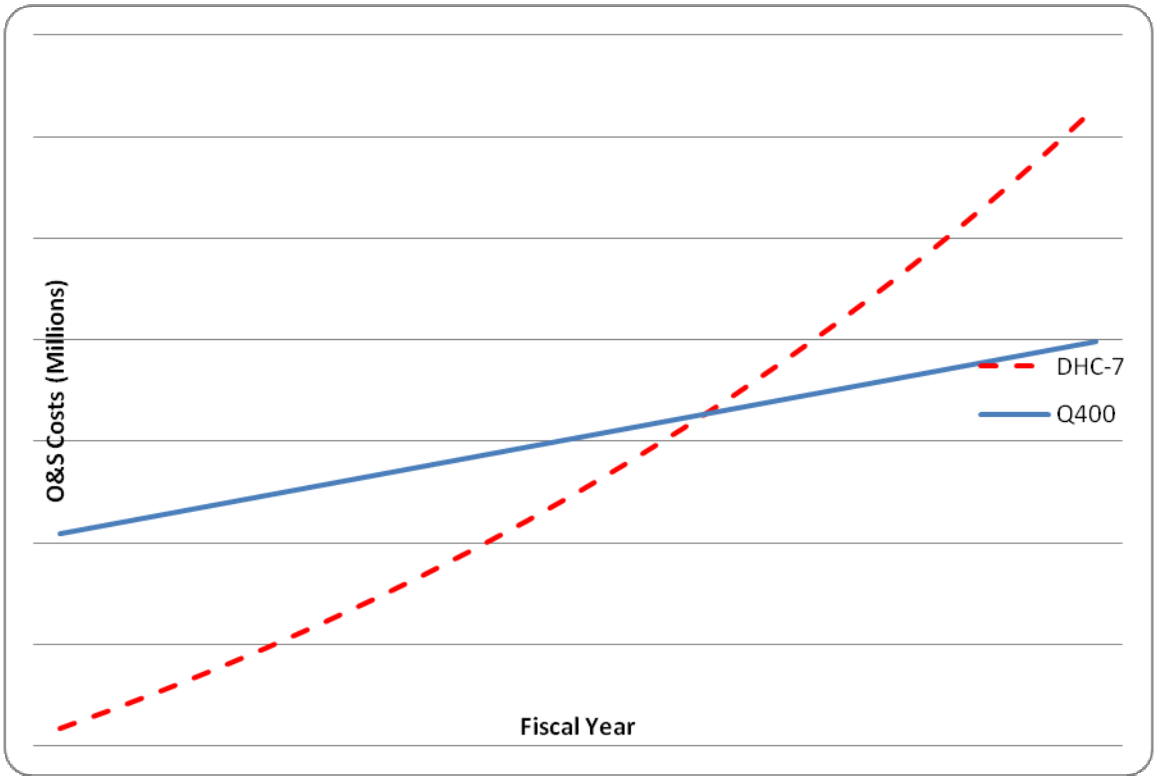



**Figure 11. DHC-7 and Q400 Cumulative Life Cycle Costs (in 2011 Dollars) and Payback Period**

*Note.* The data for this figure was taken from Bombardier (2011), CdD (2011), and SAIC (2010). See Appendix G for the calculations.

#### *f. 20-Year Life Cycle Costs With Additional Annual Flying Hours*

The Army has contracted out the maintenance of the ARL fleet to a private contractor and pays for services required to keep the aircraft flying for up to 125 hours per month, per aircraft (D. Keshel, personal communication, August 16, 2011), which adds up to 12,000 hours per year. Presumably, the Army would like the capability to fly up to 12,000 hours a year because that is what they are paying for. By assuming 12,000 annual flying hours, which is more than the forecasted OPTEMPO, the LCC structure changes. An estimate of 12,000 annual flying hours for the DHC-7 equates to 9,154 hours of TOS delivered. The Q400 can deliver the same amount of TOS in just 10,368 annual hours, versus the 12,000 hours for the DHC-7.

The DHC-7 has an LCC of over $1.43 billion, or over $178 million per aircraft in 2011 dollars. The Q400 fleet's LCC is $851 million, or approximately $106 million per aircraft. Upgrading the fleet to the Q400 saves the Army over half a billion dollars over 20 years and costs less than 60% of the LCC the Army would pay to maintain the current DHC-7 fleet. In this situation, we calculated the break-even point to occur in just 12 years, based on what the Army is currently paying for in contract support. When the calculation is made based on the number of annual hours that the Army currently pays for, the break-even point occurs in just 12 years (2023), as shown in Figure 12 (see Appendix H for detailed calculations).

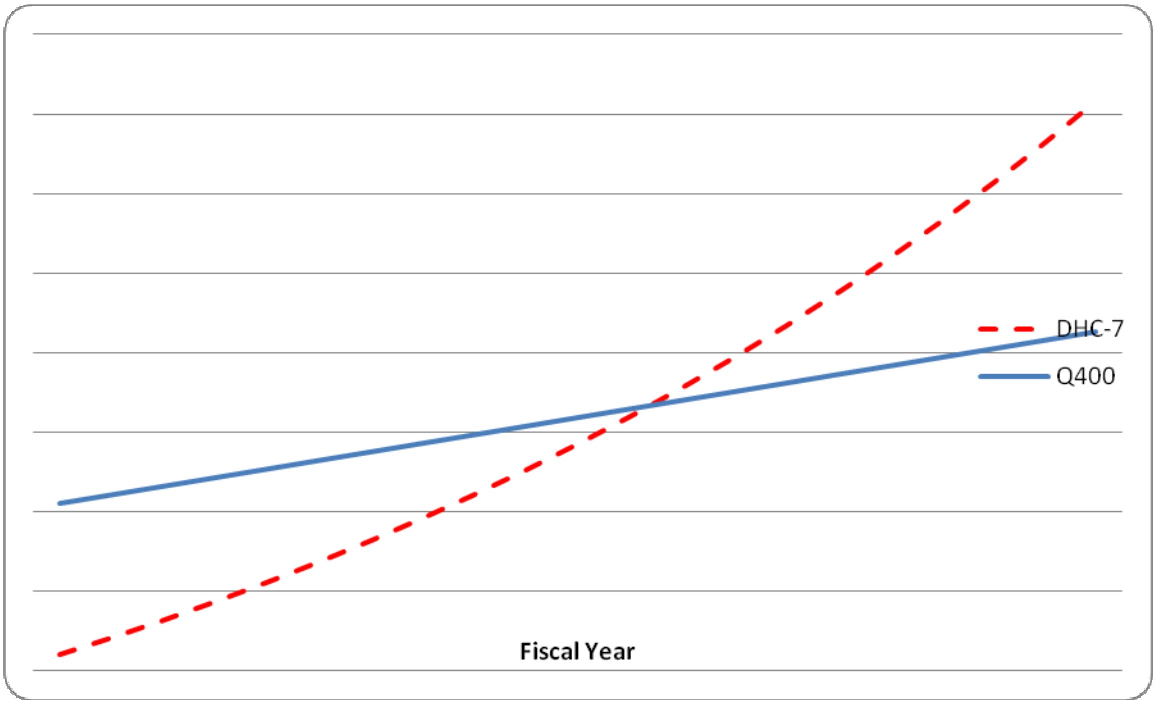



**Figure 12. Cumulative Life Cycle Costs (in 2011 Dollars) and Payback Period**
*Note*. The data for this figure was taken from Bombardier (2011), CdD (2011), and SAIC (2010). See Appendix H for the calculations.

### 2. ROI 2—Net-Present Value and Internal Rate of Return

In addition to analyzing the life cycle costs and break-even points, this BCA also analyzed the potential net present value (NPV) and internal rate of return (IRR) of purchasing the Q400s. The NPV looks at future cash flows and uses the time value of money to appraise the present value of long-term projects. This method requires the use of a discount rate, which represents the opportunity cost. This BCA used a discount rate of 2.1%, which is recommended by the Office of Management and Budget for a 20-year project (The White House, 2011).

Using the assumption of 110 hours per month per aircraft, the NPV of the 2011 $400 million Q400 investment is over $268 million. Due to the positive NPV, we recommend that the DoD accept this investment. In addition, the IRR is a positive 6.9%, which represents the Army's potential return on this investment.

Using the estimate of 125 hours per month per aircraft, there is an even larger positive NPV. Based on this estimate, the NPV is almost $360 million, and the IRR is 8.3%. If the newly acquired aircraft flew additional hours, the value of this potential investment would increase, making it more fiscally sound and prudent.

### 3. Sensitivity Analysis

Two major assumptions made earlier in this BCA are the annual number of hours flown and the percentage at which O&S costs will increase. Using these assumptions, we conducted a sensitivity analysis to see how the calculations would change if we adjusted these assumptions. In this section we present a series of figures that highlight the results of the sensitivity analysis.

For Figures 13 and 14, we retained the original assumptions of annual hours staying at the PM FW's estimate of 10,560 hours and used the upper bound of 12,000 hours, the amount of hours the Army is paying for through contractor support. We present a low estimate using an O&S increase assumption of just 2%, as well as the base case of 5% and then the upper bound of 8%. For Figures 15 and 16, we used a range of annual fleet hours down to 6,000 hours and compared the total fleet LCC of each platform, as well as the IRRs.

Figure 13 shows that using the 10,560-hour assumption, an O&S increase assumption of 2% for the DHC-7 still yields LCC savings. The Q400 LCC per aircraft at 10,560 hours is $99.6 million, while the LCC for the DHC-7 is $113.6 million. At the upper bound of an 8% O&S cost increase, because we assume that the O&S costs will not increase for the new Q400, its LCC stays the same at $99.6 million, whereas the DHC-7 is $222.2 million, almost double the cost.

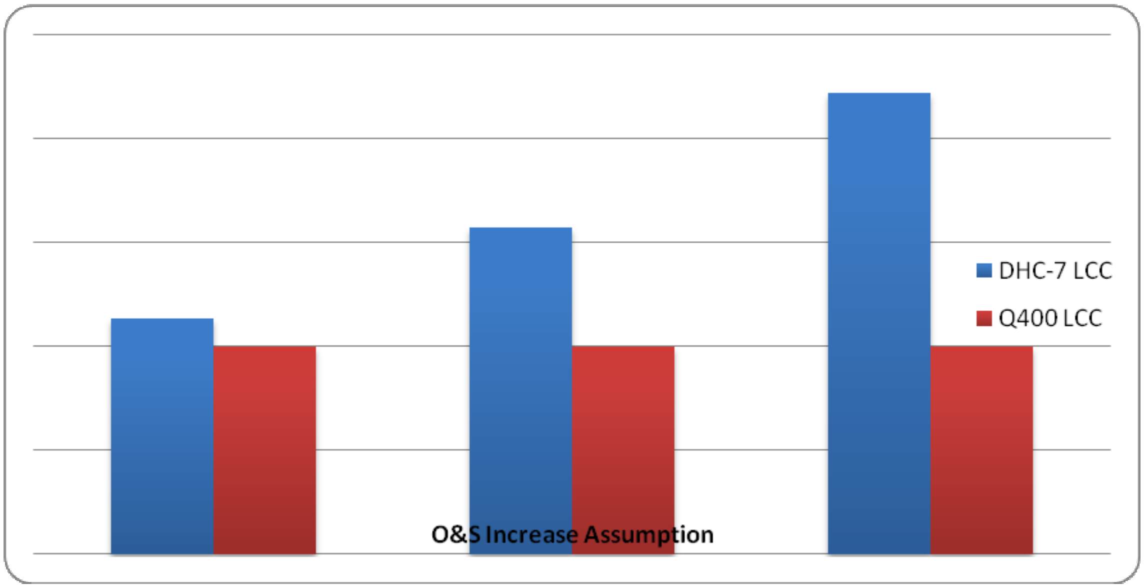



**Figure 13. Per Aircraft 10,560 Annual Hour LCC using 2% through 8% O&S Increase Adjustment**

*Note*. The data for this figure was taken from Bombardier (2011), CdD (2011), and SAIC (2010). See Appendix I for the calculations.

Figure 14 shows the same trend, when using the upper bound of annual flight hours to 12,000. At the low end of the 2% increase in O&S costs, the Q400 LCC is $106.4 million, whereas the DHC-7 is $129.1 million. At the high-end, assuming an 8% increase, the Q400 LCC remains at $106.4 million, and the DHC-7 increases significantly to $252.5 million, over double the LCC in 2011 dollars.

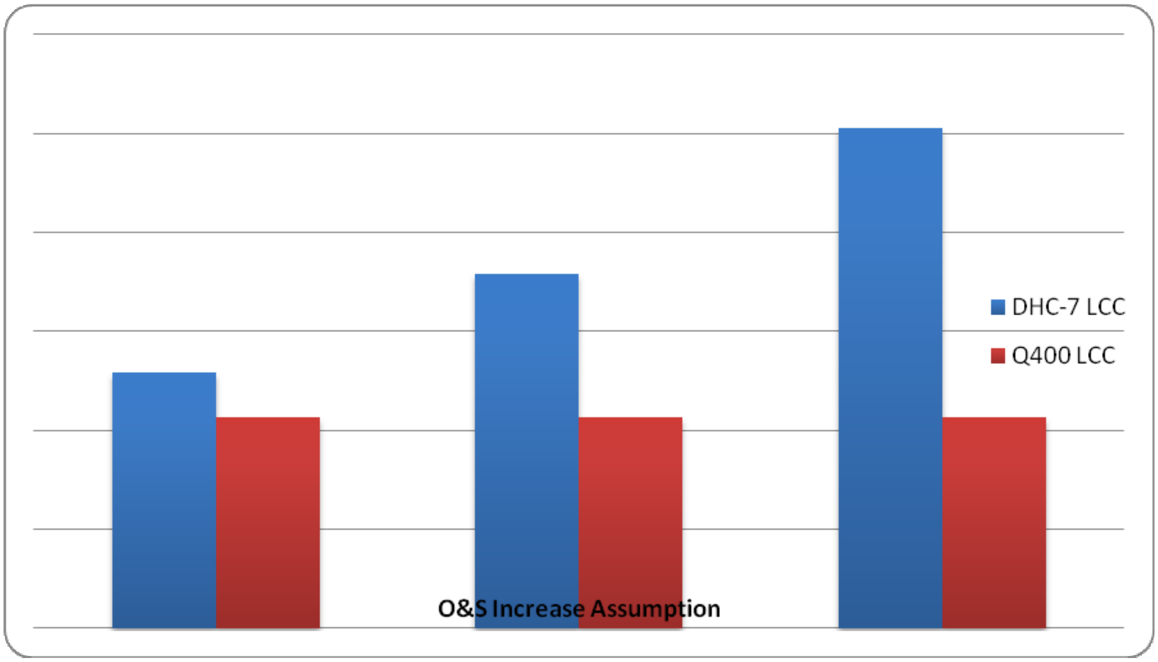



**Figure 14. Per Aircraft 12,000 Annual Hour LCC Using 2% Through 8% O&S Increase Adjustment**

*Note*. The data for this figure was taken from Bombardier (2011), CdD (2011), and SAIC (2010). See Appendix I for the calculations.

Figure 15 presents the entire fleet costs using a complete range of assumptions; from 6,000 annual flight hours and a 2% O&S cost increase to 12,000 flight hours and an 8% O&S increase. On the low end, if the Army believes that it will fly the ARL about half as much as it does now, and uses a 2% increase in O&S, continuing to fly the DHC-7 would make sense economically because the fleet LCC of the DHC-7 is $516.4 million versus the Q400's LCC of $625.5 million. However, at 7,000 annual hours and using an O&S assumption of 3%, the Q400 investment begins to be a better investment. The Q400's fleet LCC would now be $663.1 million versus the DHC-7's $670.1 million. Also displayed in Figure 15 are the BCA's base case scenarios of 10,560 and 12,000 hours using a 5% O&S increase. On the high end, using 12,000 hours and an 8% O&S cost increase assumption, the Q400 advantage becomes more pronounced. The DHC-7's fleet LCC would be over $2.02 billion, while the Q400's would be $851.2 million.

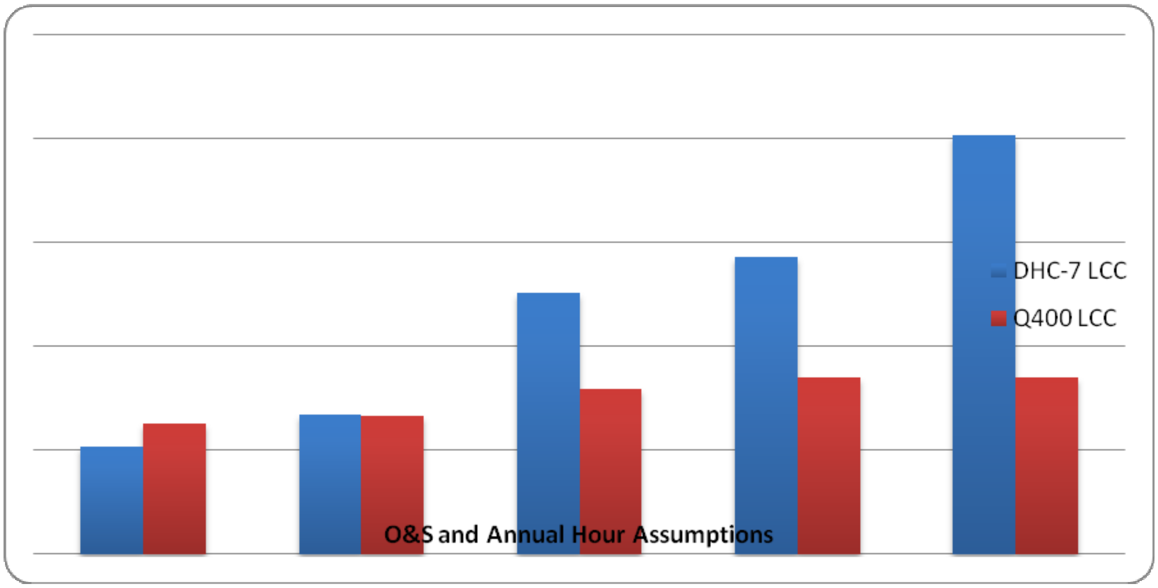
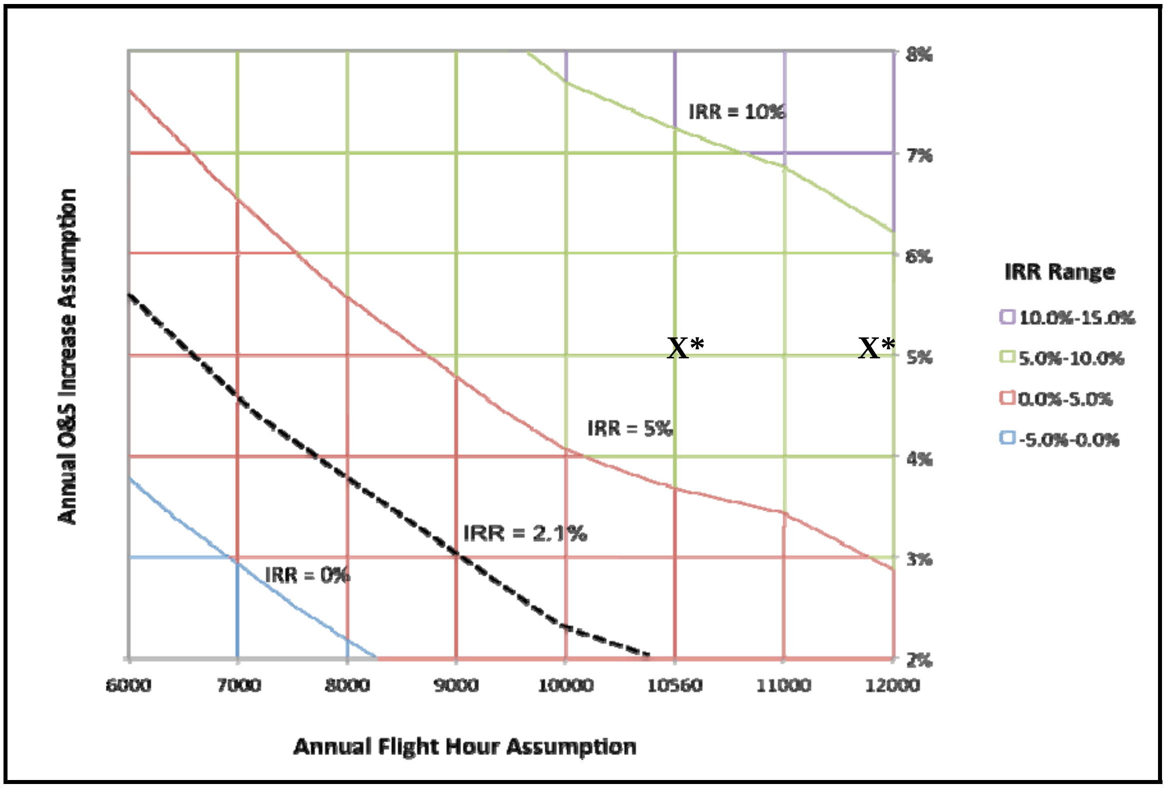



**Figure 15. ARL Fleet LCC Range With Various Assumptions**

*Note*. The data for this figure was taken from Bombardier (2011), CdD (2011), and SAIC (2010). See Appendix I for the calculations.

Figure 16 takes into account the time-value of money and shows the IRR of the Q400 investment using a complete sensitivity analysis. On the lower left-hand side of the graph, we see that using the assumptions of 6,000 annual flight hours with O&S increases of 2% to 3%, the IRR is low and in some instances negative. 2011 OMB guidance states that a 20-year project should use 2.1% as the discount rate, which means IRR must be 2.1% or greater to show a positive NPV project and is represented on the graph by a dotted line. Anything less than 2.1% is a poor investment and anything greater is a good investment. For example, when assuming 10,000 annual flight hours and a 4% O&S cost increase, this would net the Army with a positive 5% IRR. The 5% IRR would also occur with 8,000 annual flight hours and a 5.5% O&S cost increase. Given that PM FW uses the figure of 110 hours per month per aircraft (10,560 total hours annually), using the vertical 10,560 hours line is sensible. From Figure 16, we can conclude that any combination of O&S and annual hour assumptions that yield an IRR 2.1% or greater represents a positive NPV for the Army, making the Q400 a worthwhile investment.




***** Baseline Assumptions

**Figure 16. IRR on Q400 Investment With Various Assumptions**

*Note*. The data for this figure was taken from Bombardier (2011), CdD (2011), and SAIC (2010). See Appendix I for the calculations.

In conclusion, the Q400 is a good investment unless the Army believes that the DHC-7 fleet will remain supportable and that there will be relatively modest ARL OPTEMPOs in the years to come. If we add the superior performance of the Q400, the case for the new aircraft is even stronger.

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# V. CONCLUSION

The Army would gain cost, performance, future capability, and upgradability benefits if it replaced its aging DHC-7 ARL fleet with the new Q400 aircraft. In terms of readiness rates alone, a newer aircraft makes sense due to its increase in operational availability. In a one-for-one comparison of performance, the Q400 equates to at least 1.3 DHC-7s and performs at just 68% of the cost. In terms of overall value to the Army and the intelligence user, the Q400 delivers almost twice the value of a DHC-7.

It does not make economic sense for the Army to continue spending money on the DHC-7. The DHC-7 is an old and inefficient aircraft that the Army should consider retiring due to rising O&S costs. Although there are upfront investment costs associated with replacing the ARL fleet, the Army will experience significant O&S savings in future years. Using conservative estimates based on the DHC-7's current average of 10,560 flight hours per year and the TOS that it delivers, the Army will save almost a half billion dollars over the next 20 years if it upgrades the ARL fleet to Q400s. The investment will pay for itself after just 13 years. After conducting a sensitivity analysis, we conclude that unless the Army significantly decreases annual flight hours and uses a very low O&S increase assumption, the Q400 provides a positive NPV and therefore represents an excellent investment.

Using the baseline assumptions, the positive NPV of the Q400 investment has a value of over $268 million and would produce a 6.9% IRR. In addition to the economic advantages of the Q400, the Army would also gain huge performance benefits. The Q400 is faster, can carry more, and can fly longer in a better flight envelope than the current ARL.

Finally, if the Army is going to continue upgrading its ISR sensor suites, it does not make sense to continue upgrading yesterday's technology. The Army, and, therefore, the warfighter, would benefit more from an investment in new sensors that provide the latest levels of capability, modularity, and upgradeability. These sensors will provide immediate benefits to the warfighter and to intelligence customers in the form of customizable payloads. The next logical argument might be that the Army could save even more money by buying fewer Q400-based ARLs. However, as former Chairman of the Joint Chiefs of Staff, Admiral Mike Mullen, stated as a guest lecturer at the Naval Postgraduate School in 2010, "Performance versus numbers logic only goes so far—the Services should be extremely careful with significant reductions in their fleets, because one platform can only be in one place at one time" (M. A. Mullen, September 8, 2010).

The Army should be careful, if it decides to reduce the ARL fleet, because this fleet must continue to support two major commands (SOUTHCOM and PACOM) in two separate parts of the world, while also still being able to execute its mission as a globally deployable ISR asset. The JDSAISR ICD identifies the future of airborne ISR, and the Q400 appears to be an excellent match for enabling the success of the JDSAISR's future missions. The Q400's economic benefits and performance advantages make it a sound investment for the Army.

# APPENDICES A–I

## Appendix A - Per Flight Hour Costs (Q400)

**Q400 - 10,000 lb Payload (Maximum Endurance)**

| Fuel | | Fuel Costs |
|---|---|---|
| Block Fuel (lb) | 1656.14 | |
| Block Fuel (USG) | 243.55 | |
| Fuel Price ($/USG) | $6.03 | |
| **Total ($/FH)** | **$1,468.61** | |

| 10-Year | | Mature | | Direct Maintenance Costs |
|---|---|---|---|---|
| **Airframe** | | **Airframe** | | |
| Labour ($/FH) | $65.81 | Labour ($/FH) | $98.49 | |
| Material ($/FH) | $185.11 | Material ($/FH) | $275.51 | |
| **Engines** | | **Engines** | | |
| PW150A ($/FH) | $269.83 | PW150A ($/FH) | $305.21 | |
| **Combined** | | **Combined** | | |
| **Total ($/FH)** | **$520.75** | **Total ($/FH)** | **$679.21** | |

| 10-Year | | Mature (Over 10-Years) | | Total Costs |
|---|---|---|---|---|
| **TOTAL ($/FH)** | **$1,989.36** | **TOTAL ($/FH)** | **$2,147.82** | |

| | |
|---|---|
| 20 Year average cost (1-10 year + Mature) = | **$2,069** |
| Conklin de Decker Adjusted = | **$2,076** |
| Average PHFC = | **$2,072** |

**Assumptions:**

All airframe and engine figures in Jan 2011 USD
10 Year Cost: Average cost per hour over the first 10 years of the aircraft's life, post new delivery
Mature Cost: Average cost per hour between 10 and 20 years of the aircraft's life
Average Flight Length of 60 min/FC
Sector performance based on 10,000 lb payload scenario
Cruise altitude 25,000 ft
Enroute temperature ISA + 10°
Budgetary estimates for planning purposes only, no overhead or burden applied -
Does not constitute offer of cost guarantee
Costs given on a per aircraft basis
All labour performed in-house at $65/MH
Costs based on Low Utilization Maintenance Program for operators flying less than 1,500 FH/yr
Costs presented as per the term stated above
Labour includes scheduled & unscheduled routine labour tasks with efficiency
Engine costs based on shop visit and LLP stack time & material rates

**Fuel price of $6.03 calculated from 204th MI RFI Response ($47,000 / 7,800 gallons)**

**Conklin de Decker adjusted figure includes: adjusted fuel burn, maintenance labor, parts, engine restoration, propeller allowance and APU allowance**

| | | |
|---|---|---|
| | 1 | gallon = 6.79 pounds |
| Q400 burn rate (242 knots/hour) = | 1430 | pounds per hour |
| | 211 | gallons per hour |

A-2

## Appendix A - Per Flight Hour Costs (DHC-7)

| | | |
|---|---|---|
| | Conklin de Decker adjusted = | $2,997 |
| 2 | SAIC EO-5 Study (OMA Maint Cost vs Linear Cost) = | $4,269 |
| 3 | SAIC EO-5 Study (Fixed Wing Service Life Study 2002 $ | $2,340 |
| 4 | SAIC EO-5 Study (POM+Actuals+Conklin) = | $3,295 |
| 5 | SAOC EO-5 Study (POM+Actuals+Conklin Straight Line | $3,791 |
| | Average PHFC = | $3,338 |
| | Median PHFC = | $3,295 |

**Assumptions:**

All figures in 2011 USD
Conklin de Decker estimates 323 gallons per hour
#2 - this is the linear equation of the Actual OMA Maintenance Cost - projected for 2011
#3 = based on FY02 figure provided by Fixed Wing Service Life Study in FY02 $, then converted to FY11 $ by using OMA Appropriations composite index (.8507)
#4 - FY10-18 Program Objective Memorandum budgeted dollars combined with actual data from 2002-2008 plus CdD data
#5 - FY10-18 Program Objective Memorandum budgeted dollars combined with actual data from 2002-2008 plus linearly expressed CdD data

A-3

## Appendix B - Operational Availability

**Calculation 1**

Source: INSCOM RFI replies from 3rd MI Group (USFK) and 204th MI (SOUTHCOM)

| DHC-7 Operator | # of aircraft | FMC | MC |
|---|---|---|---|
| 204th MI (SOUTHCOM) | 4 | UNK | 88% |
| 3rd MI Group (USFK) | 3 | 19% | 61% |
| Total Aircraft | 7 | | |
| | 5.35 | | |
| Combined Readiness (MC) | 76.4% | | |

**Calculation 2**

Source: Donald Cook, INSCOM G3 Aviation, NOV 2010 through JUL 2011 data

| DHC-7 Operator | # of aircraft | FMC | MC |
|---|---|---|---|
| 204th MI (SOUTHCOM) | 4 | 53% | 82% |
| 3rd MI Group (USFK) | 3 | 0% | 56% |
| Total Aircraft | 7 | | |
| | | 2.12 | 4.9811 |
| Combined Readiness | | 30.3% | 71.2% |

*data for the 8th aircraft (on loan to CENTCOM) is unavailable

**FMC Data**

NOV10-JUL11: 3rd MI = 0, 204th MI = 52, 48, 50, 58, 52, 55, 52, 70, 50

**MC Data**

FEB11-JUL11: 3rd MI = 72, 80, 90, 80, 90, 204th MI = 50, 54, 54, 53, 70, 56

| Q400 Operator | # of aircraft | # Days per year scheduled for maintenance |
|---|---|---|
| FBI | 1 | |

| | |
|---|---|
| # Days per year scheduled for mainteance (unavailable) | 15 |
| # Days per year for unscheduled maintenance (unavailable) | 1 |

Operational Readiness = # of days available /( # of days available + # of days unavailable)

FBI Q400 Operational Readines 95.6%

| | DHC-7 | Q400 |
|---|---|---|
| Out of a 365 day year, each aircraft is available a total of this many | 260 | 349 |

| | |
|---|---|
| The Q400 has an advantage of: | 89 days |
| The Q400 is available: | 134.4% more of the time |
| Therefore, 8 x Q400's equals: | 10.7 DHC-7's in terms of readiness |

**Civilian Q400 Operators**

Fleet Dispatch Reliability 98.5%

B-1

## Appendix C - Payload Capability

| | | |
|---|---|---|
| **DHC-7** | | |
| Max Take-off Weight (MTOW): | 44,000 lbs | *Bombardier |
| Max Landing Weight (MLW): | 42,000 lbs | *Bombardier |
| Max Zero Fuel Weight (MZFW): | 39,000 lbs | *Bombardier |
| Operating Weight Empty (OWE): | 27,570 lbs | *Bombardier |
| Max Useable Fuel: | 10,155 lbs | *Bombardier |
| Crew/Stations: 3 (pilots counted for in OWE) | 750 lbs | *estimate based on average 200lb person + workstation rack, monitor, etc |
| Max Payload: | 6,275 lbs | *calculation |
| Currently configured ARL payload: | 6,275 lbs | *Bombardier and discussion with Lee Ilse (20 JUL 11) and previous discussions with PM ACS (Dash7 is maxed out) |
| | | |
| **Q400** | | **HIGH GROSS** |
| Max Take-off Weight (MTOW): | 65,200 lbs | *Bombardier |
| Max Landing Weight (MLW): | 62,000 lbs | *Bombardier |
| Max Zero Fuel Weight (MZFW): | 58,000 lbs | *Bombardier |
| Operating Weight Empty (OWE - includes 10,000lb in | 39,284 lbs | *Bombardier |
| Max Useable Fuel (without auxiliary internal tanks): | 11,724 lbs | *Bombardier |
| Max Useable Fuel (including auxiliary tanks) | 21,724 lbs | *calculation |
| Crew/Stations: 3 (pilots counted for in OWE) | 750 lbs | *estimate based on average 200lb person + workstation rack, monitor, etc |
| Max Payload (MZFW - OWE): | 18,716 lbs | *calculation |
| Max Payload with Max Fuel (including auxiliary intern | 4,192 lbs | *calculation |
| Proposed ARL Payload Configuration: | 6,000 lbs | *Bombardier and discussion with TCM-IS |
| Max fuel allowed with proposed ARL configuration: | 15,724 lbs | *calculation |

C-1

## Appendix D - ARL Standard Mission Profile

| | | | |
|---|---|---|---|
| 150 miles | 130 | nm | Transit from base to target area |
| 6 hours | | | Loiter (as long as fuel permits) |
| 150 miles | 130 | nm | Transit from target area to base |

**DHC-7 Miission Profile / Cost (with 45 minute reserve)**

| | | | | |
|---|---|---|---|---|
| Endurance Mission Speed: | 140 | knots | | |
| VC/Hour: | $3,338 | | | |
| Transit to: | 0.93 | hours | 56 | Minutes transit from base to target area |
| Loiter/Mission Time: | 6.0 | hours | | |
| Transit from: | 0.93 | hours | 56 | Minutes transit from base to target area |
| Total Time: | 7.83 | hours | | |
| Mission nm: | 836.2 | nm | | |
| Total nm: | 1096.2 | nm | | |
| Total Cost: | $26,140 | | $4,377 | Cost per recon mission hour |
| Cost per nm covered: | $31.26 | | | |

**Q400 Miission Profile / Cost - Most Likely Use Scenario (with 45 minute reserve)**

| | | | | |
|---|---|---|---|---|
| Endurance Mission Speed: | 222 | knots | | |
| Transit to: | 0.59 | hours | 35 | Minutes transit from base to target area |
| Loiter/Mission Time: | 8.83 | Loiter (as long as fuel permits) | | |
| Transit from: | 0.59 | hours | 35 | Minutes transit from base to target area |
| VC/Hour: | $2,072 | | | |
| Total Time: | 10 | hours | *based on 6Klb payload with 10K lb internal aux tanks | |
| Mission nm: | 1960 | nm | | |
| Total nm: | 2220 | nm | *10 hours @ 22 KIAS | |
| Total Cost: | $20,723 | | $2,347 | Cost per recon mission hour |
| Cost per nm covered: | $10.57 | | | |

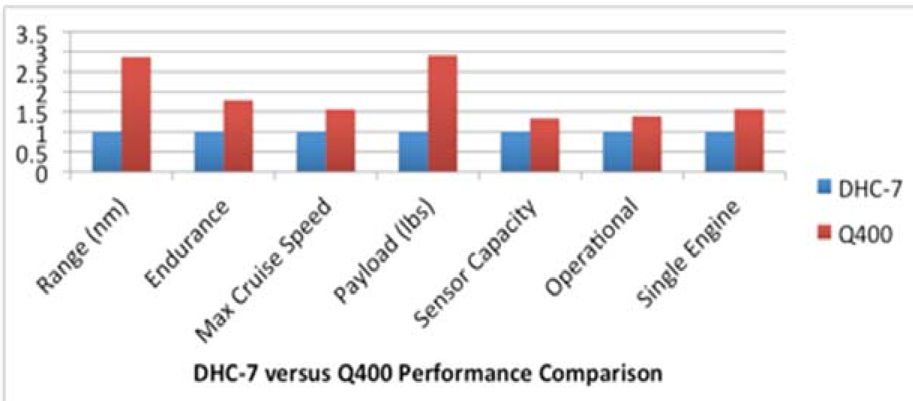
**Q400 Miission Profile / Cost - Maximum Endurance (with 45 minute reserve)**

| | | | | |
|---|---|---|---|---|
| Endurance Mission Speed: | 222 | knots | | |
| Transit to: | 0.59 | hours | 35 | Minutes transit from base to target area |
| Loiter/Mission Time: | 13.03 | Loiter (as long as fuel permits) | | |
| Transit from: | 0.59 | hours | 35 | Minutes transit from base to target area |
| VC/Hour: | $2,072 | | | |
| Total Time: | 14.2 | hours | *based on 6Klb payload with 10K lb internal aux tanks | |
| Mission nm: | 2892 | nm | | |
| Total nm: | 3152.4 | nm | *14.2 hours @ 222 KIAS | |
| Total Cost: | $29,427 | | $2,259 | Cost per recon mission hour |
| Cost per nm covered: | $10.17 | | | |

D-1

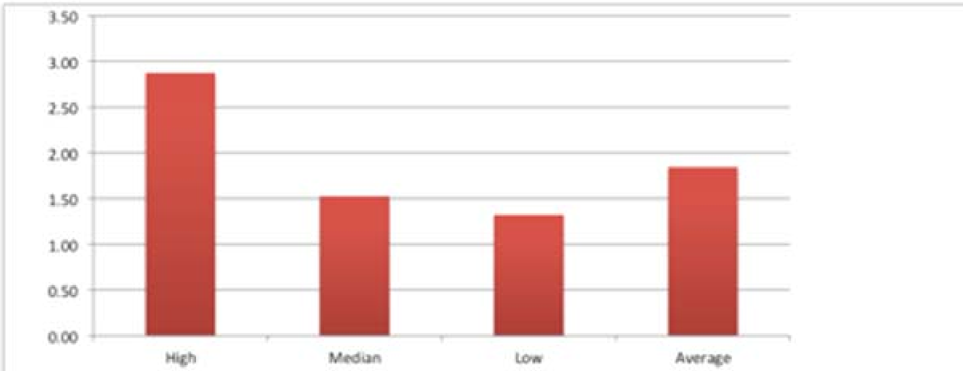
**Appendix E - Overall Comparison of DH-7 VS Q400**

| | Ratio | | Actual Performance | |
|---|---|---|---|---|
| CAPABILITY | DHC-7 | Q400 | DHC-7 | Q400 |
| Operational Availability | 1 | 1.32 | 0.745 | 0.985 |
| Range (nm) | 1 | 2.88 | 1096 | 3152 |
| Endurance (hours) | 1 | 1.79 | 7.83 | 14 |
| Max Cruise Speed (knots) | 1 | 1.56 | 231 | 360 |
| Payload (lbs) | 1 | 2.91 | 6424 | 18716 |
| Sensor Capacity | 1 | 1.33 | 3 | 4 |
| Operational Ceiling | 1 | 1.39 | 18000 | 25000 |
| Single Engine Ceiling (feet) | 1 | 1.57 | 13,000 | 20,347 |




E-1

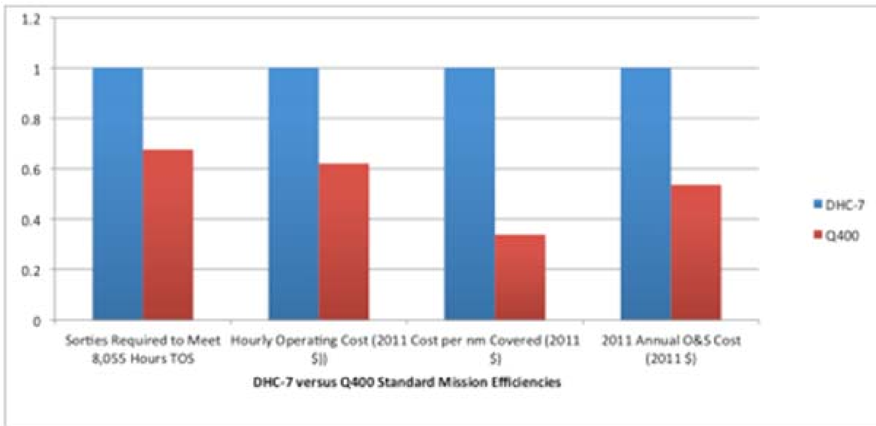
| | Q400 |
|---|---|
| High | 2.88 |
| Median | 1.525 |
| Low | 1.32 |
| Average | 1.84 |



Q400 Performance Comparison Results

E-2

| | Ratio | | Actual Performance | |
|---|---|---|---|---|
| **EFFICIENCY** | **DHC-7** | **Q400** | **DHC-7** | **Q400** |
| Sorties Required to Meet 8,055 Ho | 1 | 0.68 | 1349 | 912 |
| Hourly Operating Cost (2011 $)) | 1 | 0.62 | $3,338.48 | $2,072.30 |
| Cost per nm Covered (2011 $) | 1 | 0.34 | $31.26 | $10.57 |
| 2011 Annual O&S Cost (2011 $) | 1 | 0.54 | $35,254,328 | $18,907,447 |
| | | | | |
| Annual Hours Required to Meet IN: | 1 | 0.86 | 10560 | 9124 |




E-3

## Appendix F - Current INSCOM Demand For TOS

Assumptions:
Current INSCOM planned hours - transit time = current demand for Time on Station (TOS)
Current demand = future demand

| Line | | | |
|---|---|---|---|
| 1 | 3rd MI BN Planned Hours: | 3900 | hours |
| 2 | 204th MI BN Planned Hours: | 2640 | hours |
| 3 | Total DHC-7 Planned Hours: | 6540 | hours |
| | **DHC-7** | | |
| 4 | Max Endurance Time: | 7.83 | hours |
| 5 | # of Sorties Required (Line 3 / Line 4): | 835 | sorties |
| 6 | Total Transit Time per Sortie (based on standard mission) | 1.857 | hours |
| 7 | Equals Total DHC-7 Transit Time (Line 5 x Line 6) | 1551 | hours |
| **8** | **Current Demand for TOS (Line 3 - Line 7)** | **4989** | **hours** |
| | **Q400 (Same # of Sorties Based on Same 6 hour TOS)** | | |
| 9 | Total Transit Time per Sortie (based on standard mission) | 1.17 | hours |
| 10 | # of Sorties Required (Line 3 / Line 4): | 835 | sorties |
| 11 | Total Q400 Transit Time (Line 9 x Line 10): | 978 | hours |
| 12 | Total # of Required Hours to Meet Current Demand for TOS (Line 8 + Line 11): | 5967 | hours |
| | **Q400 (With Reduced # of Sorties Based on Optimum Mission Endurance Time of 10 hours)** | | |
| 13 | Optimum Mission Endurance Time: | 10 | hours |
| 14 | Total Transit Time per Sortie (based on standard mission) | 1.17 | hours |
| 15 | Actual TOS (Line 13 - Line 14): | 8.83 | hours |
| 16 | # of Sorties Required (Line 8 / Line 15): | 565 | sorties |
| 17 | Plus New Q400 Transit Time Required (Line 14 x Line 16): | 662 | hours |
| 18 | Total # of Required Hours to Meet Current Demand for TOS (Line 8 + Line 17): | 5651 | hours |
| | **Q400 (With Reduced # of Sorties Based on Max Endurance Time of 14 hours)** | | |
| 18 | Maximum Endurance Time: | 14.2 | hours |
| 19 | Total Transit Time per Sortie (based on standard mission) | 1.17 | hours |
| 20 | Max Endurance Time (Line 18 - Line 19): | 13.03 | hours |
| 21 | # of Sorties Required (Line 8 / Line 20): | 383 | sorties |
| 22 | Plus New Q400 Transit Time Required (Line 19 x Line 21): | 448 | hours |
| 23 | Total # of Required Hours to Meet Current Demand for TOS (Line 8 + Line 22): | 5437 | hours |

F-1

**CALCULATIONS BASED ON 110 HOURS PER MONTH PER AIRCRAFT ASSUMPTION BY PM**
**FIXED WING**

| Line | | | |
|---|---|---|---|
| 1 | Hours per month | 110 | hours |
| 2 | Months per year | 12 | months |
| 3 | Total # of ARL's | 8 | aircraft |
| 4 | Total DHC-7 Planned Hours: | 10560 | hours |
| | **DHC-7** | | |
| 5 | Max Endurance Time: | 7.83 | hours |
| 6 | # of Sorties Required (Line 4 / Line 5): | 1349 | sorties |
| 7 | Total Transit Time per Sortie (based on standard mission) | 1.857 | hours |
| 8 | Equals Total DHC-7 Transit Time (Line 6 x Line 7) | 2505 | hours |
| **9** | **Current Demand for TOS (Line 4 - Line 8)** | **8055** | **hours** |
| | **Q400 (With Reduced # of Sorties Based on Optimum Mission Endurance Time of 10 hours)** | | |
| 10 | Optimum Mission Endurance Time: | 10 | hours |
| 11 | Total Transit Time per Sortie (based on standard mission) | 1.17 | hours |
| 12 | Actual TOS (Line 10 - Line 11): | 8.83 | hours |
| 13 | # of Sorties Required (Line 9 / Line 12): | 912 | sorties |
| 14 | Plus New Q400 Transit Time Required (Line 11 x Line 13): | 1069 | hours |
| 15 | Total # of Required Hours to Meet Current Demand for TOS (Line 9 + Line 14): | 9124 | hours |

F-2

**CALCULATIONS BASED ON 125 HOURS PER MONTH PER AIRCRAFT THAT THE ARMY HAS CONTRACTED FOR**

| Line | | | |
|---|---|---|---|
| 1 | Hours per month | 125 | hours |
| 2 | Months per year | 12 | hours |
| 3 | Total # of ARL's | 8 | aircraft |
| 4 | Total DHC-7 Planned Hours: | 12000 | hours |
| | **DHC-7** | | |
| 5 | Max Endurance Time: | 7.83 | hours |
| 6 | # of Sorties Required (Line 4 / Line 5): | 1533 | sorties |
| 7 | Total Transit Time per Sortie (based on standard mission) | 1.857 | hours |
| 8 | Equals Total DHC-7 Transit Time (Line 6 x Line 7) | 2846 | hours |
| **9** | **Current Demand for TOS (Line 4 - Line 8)** | **9154** | **hours** |
| | **Q400 (With Reduced # of Sorties Based on Optimum Mission Endurance Time of 10 hours)** | | |
| 10 | Optimum Mission Endurance Time: | 10 | hours |
| 11 | Total Transit Time per Sortie (based on standard mission) | 1.17 | hours |
| 12 | Actual TOS (Line 10 - Line 11): | 8.83 | hours |
| 13 | # of Sorties Required (Line 9 / Line 12): | 1037 | sorties |
| 14 | Plus New Q400 Transit Time Required (Line 11 x Line 13): | 1214 | hours |
| 15 | Total # of Required Hours to Meet Current Demand for TOS (Line 9 + Line 14): | 10368 | hours |

F-3

## Appendix G - 20-Year Life Cycle Cost Calculation (110 Hours per Aircraft per Month)

**DHC-7**

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Assumptions: | Inflation = | 2.5% | Per hour Operating Cost = | | | $3,338 (2011 $) | |
| | O&S Increase = | 5.00% | Flight Hours Per Year to meet TOS Demand= | | | 10,560 hours | |
| | FY | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 |
| | Year | 0 | 1 | 2 | 3 | 4 | 5 |
| | Acquisition Cost | $0 | $0 | $0 | $0 | $0 | $0 |
| | O&S Cost | $35,254,328 | $35,254,328 | $35,254,328 | $35,254,328 | $35,254,328 | $35,254,328 |
| | O&S Cost Adjusted (2011 $) | $35,254,328 | $37,017,044 | $38,867,896 | $40,811,291 | $42,851,856 | $44,994,448 |
| | Inflation and O&S Adjusted Cost | $35,254,328 | $37,898,402 | $40,740,782 | $43,796,341 | $47,081,067 | $50,612,147 |
| | Total LCC Cost for ARL DHC-7 Fleet (2011 $) = | | $1,259,258,208 | | Then $ | $1,676,432,561 | |
| | LCC Cost per aircraft (2011 $) = | | $157,407,276 | | Then $ | $209,554,070 | |

**Q400**

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Assumptions: | Inflation = | 2.5% | Per hour Operating Cost = | | | $2,072 (2011 $) | |
| | O&S Increase = | 0.00% | Flight Hours Per Year to meet TOS Demand= | | | 9,124 hours | |
| | Per Aircraft Cost = | $50,000,000 | | | | | |
| | FY | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 |
| | Year | 0 | 1 | 2 | 3 | 4 | 5 |
| | Acquisition Cost | $400,000,000 | $0 | $0 | $0 | $0 | $0 |
| | O&S Cost | $18,907,447 | $18,907,447 | $18,907,447 | $18,907,447 | $18,907,447 | $18,907,447 |
| | O&S Cost Adjusted (2011 $) | $18,907,447 | $18,907,447 | $18,907,447 | $18,907,447 | $18,907,447 | $18,907,447 |
| | Inflation and O&S Adjusted Cost | $18,907,447 | $19,380,133 | $19,864,636 | $20,361,252 | $20,870,284 | $21,392,041 |
| | Total LCC Cost for ARL Q400 Fleet (2011 $) = | | $797,056,386 | | Then $ | $913,966,313 | |
| | LCC Cost per aircraft (Then $) = | | $99,632,048 | | Then $ | $114,245,789 | |
| | Breakeven Point (2011 $) = | | 13 Years | | Then $ | 12 Years | |
| | Cost Avoidance (2011 $)= | | $462,201,821 | | Then $ | $762,466,248 | |

G-1

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 2017 | 2018 | 2019 | 2020 | 2021 | 2022 | 2023 | 2024 |
| 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 |
| $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 |
| $35,254,328 | $35,254,328 | $35,254,328 | $35,254,328 | $35,254,328 | $35,254,328 | $35,254,328 | $35,254,328 |
| $47,244,171 | $49,606,379 | $52,086,698 | $54,691,033 | $57,425,585 | $60,296,864 | $63,311,707 | $66,477,293 |
| $54,408,058 | $58,488,662 | $62,875,312 | $67,590,960 | $72,660,282 | $78,109,803 | $83,968,038 | $90,265,641 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 2017 | 2018 | 2019 | 2020 | 2021 | 2022 | 2023 | 2024 |
| 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 |
| $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 |
| $18,907,447 | $18,907,447 | $18,907,447 | $18,907,447 | $18,907,447 | $18,907,447 | $18,907,447 | $18,907,447 |
| $18,907,447 | $18,907,447 | $18,907,447 | $18,907,447 | $18,907,447 | $18,907,447 | $18,907,447 | $18,907,447 |
| $21,926,842 | $22,475,013 | $23,036,888 | $23,612,810 | $24,203,131 | $24,808,209 | $25,428,414 | $26,064,124 |

| | | | | | | |
|---|---|---|---|---|---|---|
| 2025 | 2026 | 2027 | 2028 | 2029 | 2030 | 2031 |
| 14 | 15 | 16 | 17 | 18 | 19 | 20 |
| $0 | $0 | $0 | $0 | $0 | $0 | $0 |
| $35,254,328 | $35,254,328 | $35,254,328 | $35,254,328 | $35,254,328 | $35,254,328 | $35,254,328 |
| $69,801,157 | $73,291,215 | $76,955,776 | $80,803,565 | $84,843,743 | $89,085,930 | $93,540,227 |
| $97,035,564 | $104,313,232 | $112,136,724 | $120,546,978 | $129,588,002 | $139,307,102 | $149,755,135 |

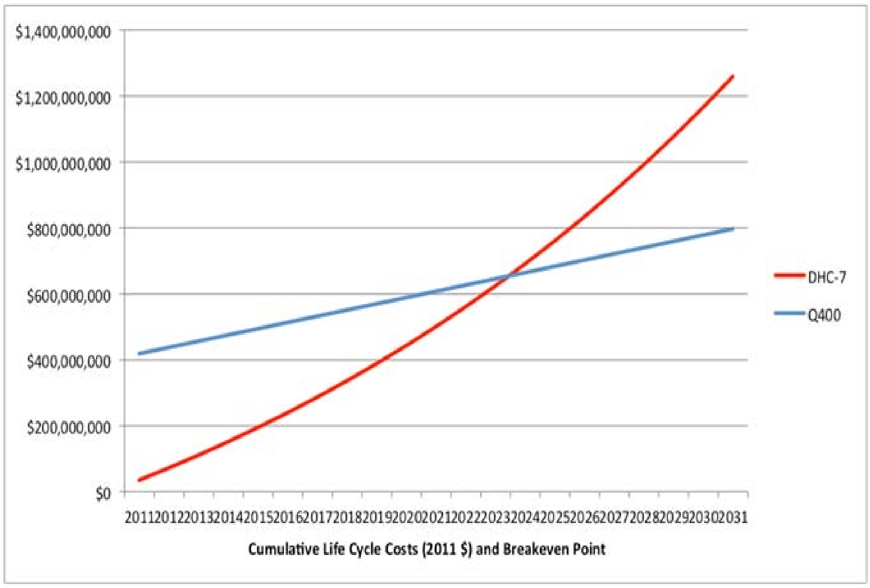
| | | | | | | |
|---|---|---|---|---|---|---|
| 2025 | 2026 | 2027 | 2028 | 2029 | 2030 | 2031 |
| 14 | 15 | 16 | 17 | 18 | 19 | 20 |
| $0 | $0 | $0 | $0 | $0 | $0 | $0 |
| $18,907,447 | $18,907,447 | $18,907,447 | $18,907,447 | $18,907,447 | $18,907,447 | $18,907,447 |
| $18,907,447 | $18,907,447 | $18,907,447 | $18,907,447 | $18,907,447 | $18,907,447 | $18,907,447 |
| $26,715,728 | $27,383,621 | $28,068,211 | $28,769,917 | $29,489,164 | $30,226,394 | $30,982,053 |

| COST DELTAS | INV COST | O&S SAVINGS | | | | |
|---|---|---|---|---|---|---|
| FY | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 |
| Difference | -$383,653,119 | $18,109,597 | $19,960,449 | $21,903,844 | $23,944,409 | $26,087,001 |
| PRESENT VALUE | $268,682,461 | | | | | |
| IRR | 6.9% | | | | | |

| Break Even Points | | 2011 Dollars | | Then Dollars | |
|---|---|---|---|---|---|
| Year | FY | DHC-7 | Q400 | DHC-7 | Q400 |
| 0 | 2011 | $35,254,328 | $418,907,447 | $35,254,328 | $418,907,447 |
| 1 | 2012 | $72,271,372 | $437,814,894 | $73,152,730 | $438,287,580 |
| 2 | 2013 | $111,139,268 | $456,722,341 | $113,893,512 | $458,152,217 |
| 3 | 2014 | $151,950,559 | $475,629,788 | $157,689,853 | $478,513,469 |
| 4 | 2015 | $194,802,415 | $494,537,235 | $204,770,920 | $499,383,753 |
| 5 | 2016 | $239,796,863 | $513,444,682 | $255,383,067 | $520,775,793 |
| 6 | 2017 | $287,041,034 | $532,352,129 | $309,791,125 | $542,702,635 |
| 7 | 2018 | $336,647,413 | $551,259,576 | $368,279,787 | $565,177,648 |
| 8 | 2019 | $388,734,112 | $570,167,023 | $431,155,098 | $588,214,536 |
| 9 | 2020 | $443,425,145 | $589,074,470 | $498,746,058 | $611,827,347 |
| 10 | 2021 | $500,850,730 | $607,981,917 | $571,406,340 | $636,030,477 |
| 11 | 2022 | $561,147,594 | $626,889,364 | $649,516,144 | $660,838,686 |
| 12 | 2023 | $624,459,301 | $645,796,811 | $733,484,182 | $686,267,100 |
| 13 | 2024 | $690,936,594 | $664,704,258 | $823,749,823 | $712,331,225 |
| 14 | 2025 | $760,737,752 | $683,611,705 | $920,785,388 | $739,046,952 |
| 15 | 2026 | $834,028,967 | $702,519,151 | $1,025,098,620 | $766,430,573 |
| 16 | 2027 | $910,984,743 | $721,426,598 | $1,137,235,344 | $794,498,784 |
| 17 | 2028 | $991,788,308 | $740,334,045 | $1,257,782,322 | $823,268,701 |
| 18 | 2029 | $1,076,632,051 | $759,241,492 | $1,387,370,324 | $852,757,865 |
| 19 | 2030 | $1,165,717,981 | $778,148,939 | $1,526,677,426 | $882,984,259 |
| 20 | 2031 | $1,259,258,208 | $797,056,386 | $1,676,432,561 | $913,966,313 |

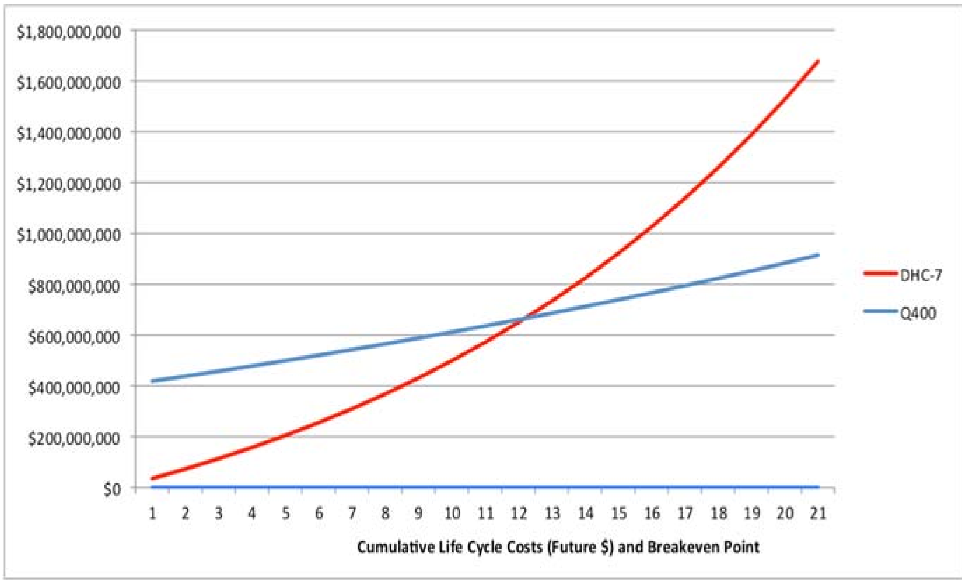
G-4

| 2017 | 2018 | 2019 | 2020 | 2021 | 2022 | 2023 | 2024 |
|---|---|---|---|---|---|---|---|
| $28,336,724 | $30,698,932 | $33,179,251 | $35,783,586 | $38,518,138 | $41,389,417 | $44,404,260 | $47,569,846 |




G-5

| 2025 | 2026 | 2027 | 2028 | 2029 | 2030 | 2031 |
|---|---|---|---|---|---|---|
| $50,893,710 | $54,383,768 | $58,048,329 | $61,896,118 | $65,936,296 | $70,178,483 | $74,632,780 |




G-6

## Appendix H - 20-Year Life Cycle Cost Calculation (125 Hours per Aircraft per Month)

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| **DHC-7** | | | | | | | |
| Assumptions: | Inflation = | 2.5% | Per hour Operating Cost = | | | $3,338 (2011 $) | |
| | O&S Increase = | 5.00% | Flight Hours Per Year to meet TOS Demand= | | | 12,000 hours | |
| | FY | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 |
| | Year | 0 | 1 | 2 | 3 | 4 | 5 |
| | Acquisition Cost | $0 | $0 | $0 | $0 | $0 | $0 |
| | O&S Cost | $40,061,736 | $40,061,736 | $40,061,736 | $40,061,736 | $40,061,736 | $40,061,736 |
| | O&S Cost Adjusted (2011 $) | $40,061,736 | $42,064,823 | $44,168,064 | $46,376,467 | $48,695,290 | $51,130,055 |
| | Inflation and O&S Adjusted Cost | $40,061,736 | $43,066,366 | $46,296,344 | $49,768,569 | $53,501,212 | $57,513,803 |
| | Total LCC Cost for ARL DHC-7 Fleet (2011 $) = | | | $1,430,975,236 | | Then $ | $1,905,037,001 |
| | LCC Cost per aircraft (2011 $) = | | | $178,871,905 | | Then $ | $238,129,625 |
| **Q400** | | | | | | | |
| Assumptions: | Inflation = | 2.5% | Per hour Operating Cost = | | | $2,072 (2011 $) | |
| | O&S Increase = | 0.00% | Flight Hours Per Year to meet TOS Demand= | | | 10,368 hours | |
| | Per Aircraft Cost = | $50,000,000 | | | | | |
| | FY | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 |
| | Year | 0 | 1 | 2 | 3 | 4 | 5 |
| | Acquisition Cost | $400,000,000 | $0 | $0 | $0 | $0 | $0 |
| | O&S Cost | $21,485,735 | $21,485,735 | $21,485,735 | $21,485,735 | $21,485,735 | $21,485,735 |
| | O&S Cost Adjusted (2011 $) | $21,485,735 | $21,485,735 | $21,485,735 | $21,485,735 | $21,485,735 | $21,485,735 |
| | Inflation and O&S Adjusted Cost | $21,485,735 | $22,022,879 | $22,573,451 | $23,137,787 | $23,716,231 | $24,309,137 |
| | Total LCC Cost for ARL Q400 Fleet (2011 $) = | | | $851,200,439 | | Then $ | $984,052,628 |
| | LCC Cost per aircraft (Then $) = | | | $106,400,055 | | Then $ | $123,006,578 |
| | Breakeven Point (2011 $) = | | | 12 Years | | Then $ | 11 Years |
| | Cost Avoidance (2011 $)= | | | $579,774,797 | | Then $ | $920,984,373 |

H-1

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 2017 | 2018 | 2019 | 2020 | 2021 | 2022 | 2023 | 2024 |
| 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 |
| $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 |
| $40,061,736 | $40,061,736 | $40,061,736 | $40,061,736 | $40,061,736 | $40,061,736 | $40,061,736 | $40,061,736 |
| $53,686,558 | $56,370,886 | $59,189,430 | $62,148,901 | $65,256,347 | $68,519,164 | $71,945,122 | $75,542,378 |
| $61,827,338 | $66,464,389 | $71,449,218 | $76,807,909 | $82,568,502 | $88,761,140 | $95,418,226 | $102,574,592 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 2017 | 2018 | 2019 | 2020 | 2021 | 2022 | 2023 | 2024 |
| 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 |
| $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 |
| $21,485,735 | $21,485,735 | $21,485,735 | $21,485,735 | $21,485,735 | $21,485,735 | $21,485,735 | $21,485,735 |
| $21,485,735 | $21,485,735 | $21,485,735 | $21,485,735 | $21,485,735 | $21,485,735 | $21,485,735 | $21,485,735 |
| $24,916,866 | $25,539,787 | $26,178,282 | $26,832,739 | $27,503,558 | $28,191,146 | $28,895,925 | $29,618,323 |

| | | | | | | |
|---|---|---|---|---|---|---|
| 2025 | 2026 | 2027 | 2028 | 2029 | 2030 | 2031 |
| 14 | 15 | 16 | 17 | 18 | 19 | 20 |
| $0 | $0 | $0 | $0 | $0 | $0 | $0 |
| $40,061,736 | $40,061,736 | $40,061,736 | $40,061,736 | $40,061,736 | $40,061,736 | $40,061,736 |
| $79,319,497 | $83,285,472 | $87,449,745 | $91,822,233 | $96,413,344 | $101,234,012 | $106,295,712 |
| $110,267,687 | $118,537,763 | $127,428,096 | $136,985,203 | $147,259,093 | $158,303,525 | $170,176,289 |

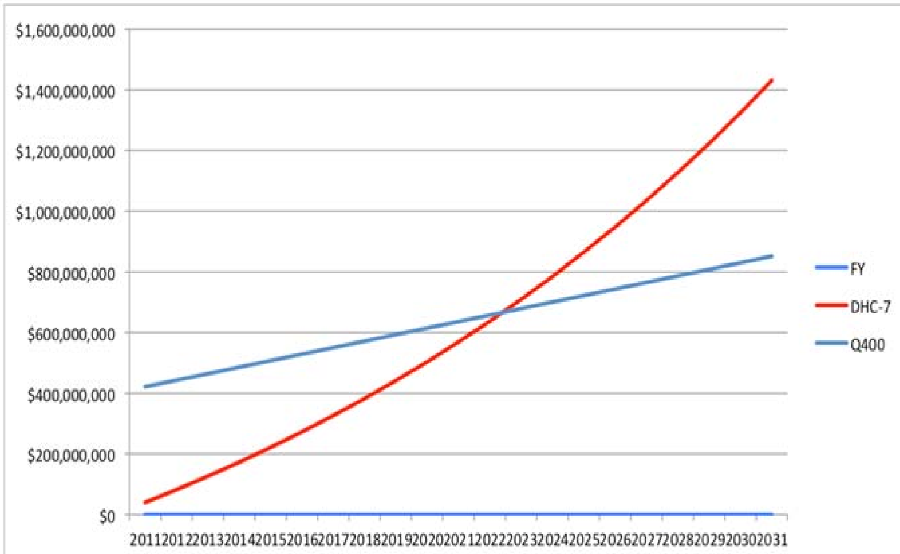
| | | | | | | |
|---|---|---|---|---|---|---|
| 2025 | 2026 | 2027 | 2028 | 2029 | 2030 | 2031 |
| 14 | 15 | 16 | 17 | 18 | 19 | 20 |
| $0 | $0 | $0 | $0 | $0 | $0 | $0 |
| $21,485,735 | $21,485,735 | $21,485,735 | $21,485,735 | $21,485,735 | $21,485,735 | $21,485,735 |
| $21,485,735 | $21,485,735 | $21,485,735 | $21,485,735 | $21,485,735 | $21,485,735 | $21,485,735 |
| $30,358,781 | $31,117,751 | $31,895,695 | $32,693,087 | $33,510,414 | $34,348,175 | $35,206,879 |

H-3

| COST DELTAS | | INV COST | O&S SAVINGS | | | | |
|---|---|---|---|---|---|---|---|
| | FY | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 |
| | Difference | -$381,423,999 | $20,579,088 | $22,682,329 | $24,890,732 | $27,209,555 | $29,644,320 |
| | PRESENT VALUE | $359,866,433 | | | | | |
| | IRR | 8.3% | | | | | |

| Break Even Points | | 2011 Dollars | | Then Dollars | |
|---|---|---|---|---|---|
| Year | FY | DHC-7 | Q400 | DHC-7 | Q400 |
| 0 | 2011 | $40,061,736 | $421,485,735 | $40,061,736 | $421,485,735 |
| 1 | 2012 | $82,126,559 | $442,971,470 | $83,128,102 | $443,508,614 |
| 2 | 2013 | $126,294,623 | $464,457,206 | $129,424,446 | $466,082,064 |
| 3 | 2014 | $172,671,090 | $485,942,941 | $179,193,015 | $489,219,851 |
| 4 | 2015 | $221,366,380 | $507,428,676 | $232,694,227 | $512,936,083 |
| 5 | 2016 | $272,496,435 | $528,914,411 | $290,208,031 | $537,245,220 |
| 6 | 2017 | $326,182,993 | $550,400,146 | $352,035,369 | $562,162,086 |
| 7 | 2018 | $382,553,879 | $571,885,882 | $418,499,757 | $587,701,873 |
| 8 | 2019 | $441,743,309 | $593,371,617 | $489,948,975 | $613,880,155 |
| 9 | 2020 | $503,892,210 | $614,857,352 | $566,756,884 | $640,712,894 |
| 10 | 2021 | $569,148,557 | $636,343,087 | $649,325,387 | $668,216,451 |
| 11 | 2022 | $637,667,721 | $657,828,822 | $738,086,527 | $696,407,598 |
| 12 | 2023 | $709,612,843 | $679,314,557 | $833,504,752 | $725,303,523 |
| 13 | 2024 | $785,155,221 | $700,800,293 | $936,079,345 | $754,921,846 |
| 14 | 2025 | $864,474,718 | $722,286,028 | $1,046,347,032 | $785,280,628 |
| 15 | 2026 | $947,760,190 | $743,771,763 | $1,164,884,795 | $816,398,379 |
| 16 | 2027 | $1,035,209,935 | $765,257,498 | $1,292,312,891 | $848,294,073 |
| 17 | 2028 | $1,127,032,168 | $786,743,233 | $1,429,298,093 | $880,987,160 |
| 18 | 2029 | $1,223,445,512 | $808,228,969 | $1,576,557,186 | $914,497,574 |
| 19 | 2030 | $1,324,679,524 | $829,714,704 | $1,734,860,711 | $948,845,749 |
| 20 | 2031 | $1,430,975,236 | $851,200,439 | $1,905,037,001 | $984,052,628 |

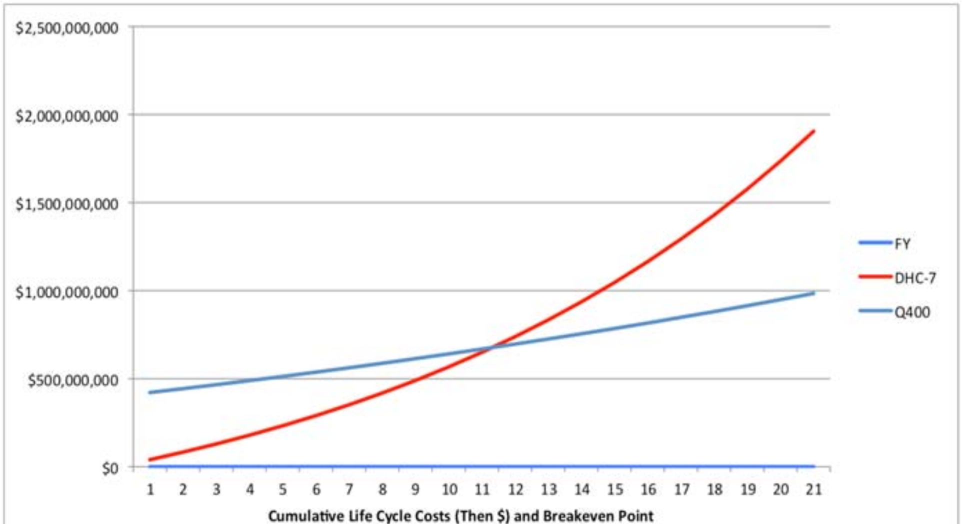
| 2017 | 2018 | 2019 | 2020 | 2021 | 2022 | 2023 | 2024 |
|---|---|---|---|---|---|---|---|
| $32,200,823 | $34,885,150 | $37,703,695 | $40,663,166 | $43,770,611 | $47,033,429 | $50,459,387 | $54,056,643 |



Cumulative Life Cycle Costs (2011 $) and Breakeven Point

H-5

| | | | | | | |
|---|---|---|---|---|---|---|
| 2025 | 2026 | 2027 | 2028 | 2029 | 2030 | 2031 |
| $57,833,762 | $61,799,737 | $65,964,010 | $70,336,498 | $74,927,609 | $79,748,276 | $84,809,977 |



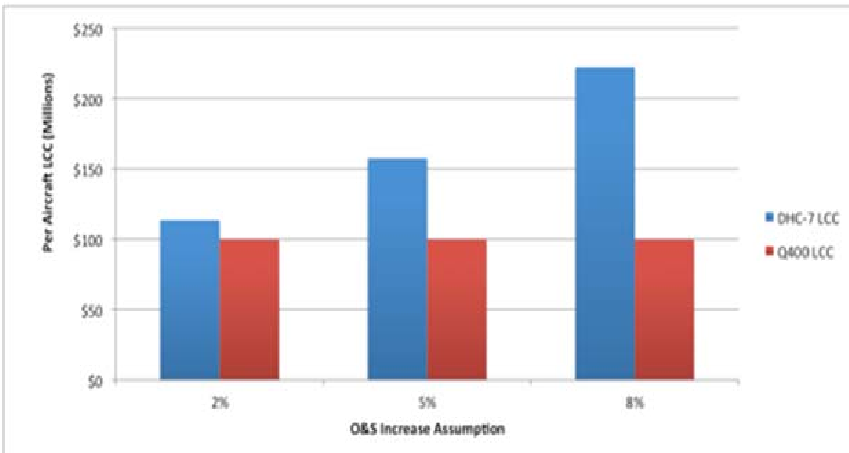
Cumulative Life Cycle Costs (Then $) and Breakeven Point

H-6

## Appendix I - Sensitivity Analysis

**Per Aircraft LCC Costs at 10,560 Hour Assumption (Q400 can deliver same TOS with 9,124 annual flying hours)**

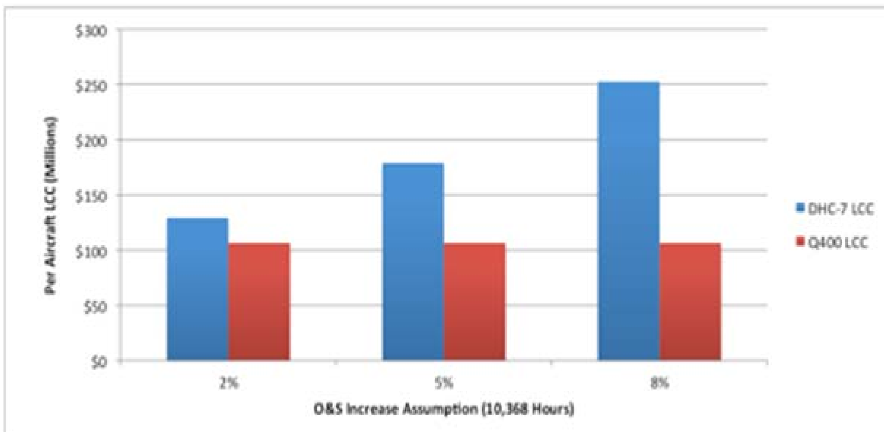
| | 2% | 5% | 8% |
|---|---|---|---|
| DHC-7 LCC | $113,621,689 | $157,407,276 | $222,203,274 |
| Q400 LCC | $99,632,516 | $99,632,516 | $99,632,516 |




I-1

**Per Aircraft LCC Costs at 12,000 Hour Assumption (Q400 can deliver same TOS with 10,368 annual flying hours)**

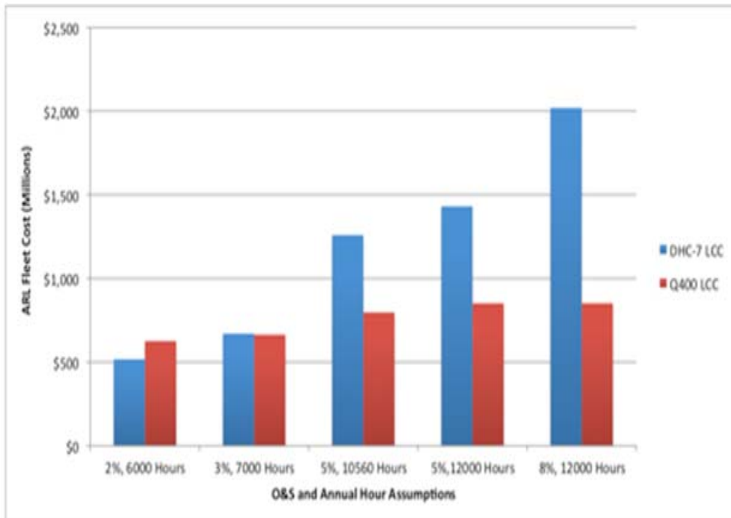
| | 2% | 5% | 8% |
|---|---|---|---|
| DHC-7 LCC | $129,115,556 | $178,871,905 | $252,503,721 |
| Q400 LCC | $106,399,597 | $106,399,597 | $106,399,597 |




I-2

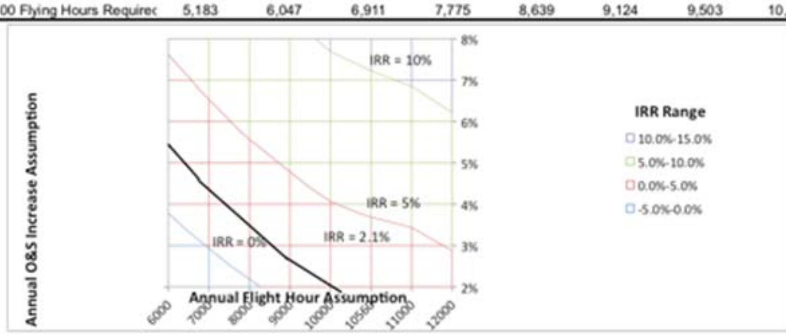
**Overall ARL Fleet LCC Cost Range**

| | 2%, 6000 Hours | 3%, 7000 Hours | 5%, 10560 Hours | 5%,12000 Hours | 8%, 12000 Hours |
|---|---|---|---|---|---|
| DHC-7 LCC | $516,462,223 | $670,150,717 | $1,259,258,208 | $1,430,975,236 | $2,020,029,767 |
| Q400 LCC | $625,554,870 | $663,154,601 | $797,060,125 | $851,196,776 | $851,196,776 |




I-3

| | | Flying Hours | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | 6000 | 7000 | 8000 | 9000 | 10000 | 10560 | 11000 | 12000 |
| O&S Increase | 2% | -2.7% | -1.4% | -0.3% | 0.8% | 1.8% | 2.3% | 2.7% | 3.6% |
| | 3% | -1.1% | 0.1% | 1.3% | 2.4% | 3.4% | 3.9% | 4.3% | 5.2% |
| | 4% | 0.3% | 1.6% | 2.8% | 3.9% | 4.9% | 5.5% | 5.9% | 6.8% |
| | 5% | 1.7% | 3.0% | 4.2% | 5.3% | 6.4% | 6.9% | 7.4% | 8.3% |
| | 6% | 3.0% | 4.3% | 5.6% | 6.7% | 7.8% | 8.4% | 8.8% | 9.7% |
| | 7% | 4.2% | 5.6% | 6.9% | 8.0% | 9.1% | 9.7% | 10.2% | 11.1% |
| | 8% | 5.5% | 6.9% | 8.1% | 9.3% | 10.4% | 11.0% | 11.5% | 12.5% |
| Actual TOS Delivered: | | 4,577 | 5,340 | 6,103 | 6,866 | 7,628 | 8,055 | 8,391 | 9,154 |
| Q400 Flying Hours Requirec | | 5,183 | 6,047 | 6,911 | 7,775 | 8,639 | 9,124 | 9,503 | 10,368 |




I-4

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# 2003 - 2011 SPONSORED RESEARCH TOPICS

## Acquisition Management

- Acquiring Combat Capability via Public-Private Partnerships (PPPs)
- BCA: Contractor vs. Organic Growth
- Defense Industry Consolidation
- EU-US Defense Industrial Relationships
- Knowledge Value Added (KVA) + Real Options (RO) Applied to Shipyard Planning Processes
- Managing the Services Supply Chain
- MOSA Contracting Implications
- Portfolio Optimization via KVA + RO
- Private Military Sector
- Software Requirements for OA
- Spiral Development
- Strategy for Defense Acquisition Research
- The Software, Hardware Asset Reuse Enterprise (SHARE) repository

## Contract Management

- Commodity Sourcing Strategies
- Contracting Government Procurement Functions
- Contractors in 21$^{st}$-century Combat Zone
- Joint Contingency Contracting
- Model for Optimizing Contingency Contracting, Planning and Execution
- Navy Contract Writing Guide
- Past Performance in Source Selection
- Strategic Contingency Contracting
- Transforming DoD Contract Closeout
- USAF Energy Savings Performance Contracts
- USAF IT Commodity Council
- USMC Contingency Contracting

## Financial Management

- Acquisitions via Leasing: MPS case
- Budget Scoring
- Budgeting for Capabilities-based Planning
- Capital Budgeting for the DoD
- Energy Saving Contracts/DoD Mobile Assets
- Financing DoD Budget via PPPs
- Lessons from Private Sector Capital Budgeting for DoD Acquisition Budgeting Reform
- PPPs and Government Financing
- ROI of Information Warfare Systems
- Special Termination Liability in MDAPs
- Strategic Sourcing
- Transaction Cost Economics (TCE) to Improve Cost Estimates

## Human Resources

- Indefinite Reenlistment
- Individual Augmentation
- Learning Management Systems
- Moral Conduct Waivers and First-term Attrition
- Retention
- The Navy's Selective Reenlistment Bonus (SRB) Management System
- Tuition Assistance

## Logistics Management

- Analysis of LAV Depot Maintenance
- Army LOG MOD
- ASDS Product Support Analysis
- Cold-chain Logistics
- Contractors Supporting Military Operations
- Diffusion/Variability on Vendor Performance Evaluation
- Evolutionary Acquisition
- Lean Six Sigma to Reduce Costs and Improve Readiness
- Naval Aviation Maintenance and Process Improvement (2)

- Optimizing CIWS Lifecycle Support (LCS)
- Outsourcing the Pearl Harbor MK-48 Intermediate Maintenance Activity
- Pallet Management System
- PBL (4)
- Privatization-NOSL/NAWCI
- RFID (6)
- Risk Analysis for Performance-based Logistics
- R-TOC AEGIS Microwave Power Tubes
- Sense-and-Respond Logistics Network
- Strategic Sourcing

## Program Management

- Building Collaborative Capacity
- Business Process Reengineering (BPR) for LCS Mission Module Acquisition
- Collaborative IT Tools Leveraging Competence
- Contractor vs. Organic Support
- Knowledge, Responsibilities and Decision Rights in MDAPs
- KVA Applied to AEGIS and SSDS
- Managing the Service Supply Chain
- Measuring Uncertainty in Earned Value
- Organizational Modeling and Simulation
- Public-Private Partnership
- Terminating Your Own Program
- Utilizing Collaborative and Three-dimensional Imaging Technology

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