

A STRATEGIC ANALYSIS OF THE TECHNOLOGY IMPLEMENTATION PROCESS OF AN AIR NAVIGATION SERVICE PROVIDER

by

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PROJECT SUBMITTED IN PARTIAL FULFILLMENT
OF THE REQUIREMENTS FOR THE DEGREE OF

MASTER OF BUSINESS ADMINISTRATION

In the
Faculty
of
Business Administration

Management of Technology Program

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SIMON FRASER UNIVERSITY



Spring 2006

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ABSTRACT

NAV CANADA's mission is to facilitate the safe movement of aircraft, efficiently and cost-effectively, through the provision of air navigation services on a long-term, sustainable basis. The adoption of new technology is essential to fulfilling this mission. This project makes the case that coordination with users is essential to ensuring user acceptance of new technology and minimizing the number of unsatisfactory condition reports and change proposals generated by users. To that end, this paper examines the nature and level of user involvement in the system design process for a sample of NAV CANADA's air navigation technologies. In addition to investigating user involvement, "off-the-shelf" and internally developed technologies are analysed and compared in the context of reducing the aforementioned risks and schedule slippage. The project concludes with recommendations on ways to reduce the number of unanticipated issues during implementation while satisfying NAV CANADA's corporate objectives.

DEDICATION

I wish to dedicate this project to my wife, Darveena, whose unrelenting support and encouragement helped me get the most out of this program and this project.

ACKNOWLEDGEMENTS

I wish to thank my supervisory committee, Dr. Elicia Maine and Dr. Jill Shepherd, for their valuable feedback and direction in completing this project. I'd also like to express my appreciation to the rest of the faculty and staff of Simon Fraser University's Management of Technology MBA Program for creating an extremely fruitful educational environment.

I also wish to express my gratitude to my Executive Sponsor, Kim Troutman, for his valuable input, mentorship and guidance throughout this project. Finally, I'd like to thank all of the key NAV CANADA employees who participated in and supported my research for this project. The experience and knowledge of all of these people has made this project more insightful and my learning experience more enriched.

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1 INTRODUCTION

1.1 Company Background

NAV CANADA is the owner and operator of Canada's civil Air Navigation Service (ANS). Its customers are airlines and other owners and operators of aircraft. Its services include air traffic control, flight information, weather briefings, airport advisory services, aeronautical information services and electronic aids to navigation (Nav Canada, 2005). The company is a non-profit, private, non-share capital corporation which purchased the ANS from the Canadian Federal Government on November 1, 1996 for \$1.5 billion (Nav Canada, 2005).

The company is governed by a Board of Directors comprised of ten members: four from air carriers, one from general and business aviation, three from the Federal Government, two from bargaining agents, as well as four independent directors appointed by the board (Nav Canada, 2005). The President and CEO is also a director. In addition, there is an Advisory Committee made up of groups and individuals who have an interest in aviation and air navigation that advise the board on a wide range of issues. The company is headquartered in Ottawa, Ontario and employs approximately 5,400 employees from coast to coast (Nav Canada, 2005).

NAV CANADA's mission is to provide safe air navigation services. The company is not motivated by profits. Revenues predominantly come from service charges paid by customers. In accordance with the Civil Air Navigation Services Act ("ANS Act"), the company sets service charges with the goal of recovering the cost of providing its services (Nav Canada, 2005). NAV CANADA's acquisition and ongoing capital requirements are financed with debt issued in the public markets (Nav Canada, 2005). In essence, NAV CANADA is owned and operated by those groups and individuals that it serves.

With regard to safety and efficiency, NAV CANADA is held in very high regard in the world of air navigation services. The company has one of the best safety records in the world and maintains a strong culture of safety. Since becoming a corporation, NAV CANADA has cut annual operating costs by \$100 million while handling eleven million aircraft movements annually (Nav Canada, 2005). Aircraft movements include take-offs, landings and over-flights in Canadian controlled airspace. The company has passed \$700 million in cumulative savings on to customers (Nav Canada, 2005). Safety and efficiency are the most important aspects of NAV CANADA's service.

Technology plays an essential role in the provision of air navigation services. NAV CANADA currently employs an aggressive strategy to modernize and enhance delivery of air traffic services. Over one billion dollars has been invested since 1996 on new systems and technologies. The modernization and enhancement of the ANS is intended to serve customers' needs well into the future.

1.2 Corporate Vision, Mission and Objectives

The company's vision is to be the world's most respected ANS in the eyes of the flying public, its customers and its employees (Nav Canada, 2005). NAV CANADA's Business Plan (2005-2008) states the company's mission and corporate objectives as follows:

Mission

NAV CANADA facilitates the safe movement of aircraft, efficiently and cost-effectively, through the provision of air navigation services on a long-term, sustainable basis.

Primary Corporate Objectives

As a good corporate employer the Company will achieve this by:

- maintaining a safety record in the top decile of major Air Navigation Service Providers (ANSPs) worldwide;

- maintaining ANS customer service charges, on average, in the bottom quartile (lowest charges) of major ANSPs worldwide;
- implementing and maintaining a modern, cost-efficient ANS technology platform in the top quartile of major ANSPs worldwide; and
- ensuring that the growth in costs of providing air navigation services does not exceed the growth in charging units, thereby resulting in a decline in customer service charges over the long term.

(Nav Canada, 2005, p.5)

1.3 Implementing New Technology

NAV CANADA aims to coordinate the adoption of new technology with all of its stakeholders. The pace at which new technologies are implemented must take into account the effect on the human component of the system. In particular, the day to day work of the company's operational staff cannot be compromised. The company ensures that operational safety is maintained while implementing new technology (Nav Canada, 2005). Unsatisfactory Condition Reports (UCRs) and Change Proposals (CPs) are indicators of difficulties arising from the adoption of new technology. To reduce the disruption caused by the adoption and implementation of new technology, coordination and cooperation between the company's different functional groups is essential.

Implementation efforts are also coordinated with customers. NAV CANADA has to be ready to match its ANS technology with advances in aircraft technology. This allows for the planning of parallel investments with customers. Additionally, the development of system requirements must be consistent with the customers' goals. This ensures acceptance of the new technology among customers and NAV CANADA operational staff (Nav Canada, 2005).

The modernization and enhancement of Canada's ANS infrastructure is an extremely large and challenging task. The total ANS is comprised of more than 100 different Communications, Navigation, Surveillance / Air Traffic Management (CNS/ATM) system types

(Nav Canada, 2005). There are in excess of 10,000 individual systems in deployment across Canada (Nav Canada, 2005). Maintaining this infrastructure is a complex task with some unique challenges.

There is significant cost and complexity associated with maintaining a system that must be kept safe, reliable and in perpetual operation. Adding to the cost and complexity is the fact that some parts of the infrastructure are located in remote and isolated regions of Canada. The climate and environment in these regions represents a significant challenge in the enhancement and maintenance of the ANS. Additionally, each of NAV CANADA's different operational sites has very specific technology requirements depending on the purpose of the site, its geographic location and the nature of the air traffic in its airspace.

For each new system or substantial system upgrade, the company must also schedule and plan just-in-time training for an already busy operational workforce. Maintenance and enhancement are further complicated because the ANS is comprised of many interdependent systems that must be interoperable. In order to deal with all of these factors, NAV CANADA employs an incremental approach to technology adoption whenever possible. This minimizes the risks associated with introducing too much change in a real-time, safety-critical system.

1.4 Rationale for Analysis

When new air navigation technology is implemented, substantial resources must be committed in the short term to deal with Unsatisfactory Condition Reports (UCRs) and Change Proposals (CPs) that are reported by operational staff. Dealing with these system changes can potentially increase technical complexity, inflate costs and delay the scheduling of new functionality. The effect on the technology implementation process is that (a) there are fewer resources available to develop innovative system capabilities, and (b), the scheduled implementation of new capabilities that have already been developed is delayed. This paper

highlights factors that contribute to the number of UCRs and CPs being reported when new technologies are adopted and implemented.

This paper includes a review of relevant trade and academic literature on the sources of innovation, user involvement in system design and safety-critical system design best practices. This paper also includes industry, macro-environment and organizational analyses. This is followed by an assessment of currently implemented systems at NAV CANADA. The systems are analyzed in terms of the number of UCRs and CPs generated in a year, the nature and level of user involvement in the design process, and how the system was developed. For instance, the system may be a commercial off-the-shelf (or “COTS”) system, a custom contractor-supplied system, or an in-house developed system. Primary research for this paper was gathered by conducting interviews with middle and senior managers. In addition, data concerning the number of UCRs and CPs generated in a single year for a sample of NAV CANADA’s systems was also collected. From the analysis, alternatives are generated on how best to meet NAV CANADA’s strategic goals while satisfying users.

2 LITERATURE REVIEW

This chapter provides an overview of the academic and trade literature that is relevant to the analysis of NAV CANADA's technology implementation process. The literature provides a foundation on which to evaluate and assess the company's current system implementations. Different modes of user involvement in the development process are discussed. Prototyping is proposed as an effective way to elicit feedback from users. Research that supports the idea of the user as a significant source of innovative capabilities is presented. Later in this chapter, literature is reviewed that examines the dimensions that influence a firm's decision to outsource its technological capabilities or develop them in-house. It cannot be emphasized enough that NAV CANADA's ANS technologies are quite unique in that they are real-time, safety-critical systems. Therefore, this chapter concludes with two case studies on the development of safety-critical systems, similar to those implemented by NAV CANADA. These cases offer valuable insights into achieving user satisfaction and reducing system anomalies in operational systems.

2.1 User Involvement

User involvement in development of a new technical system or in the development of functional improvements is an important factor in ensuring user acceptance of the system. Users of a technical system are generally more receptive to a new system if they have contributed to its design (Leonard, 1998). Moreover, they have specialized knowledge of the environment in which the new technology will be utilized so their involvement helps achieve an optimal design. If an organization aims to optimize user satisfaction with a new technology, Dorothy Leonard, in Wellsprings of Knowledge, argues that users should be involved in the design process (Leonard,

1998). Leonard presents four modes of user involvement – no user involvement, consultancy mode, codevelopment and apprenticeship mode (Leonard, 1998).

No user involvement is useful only if developers are as knowledgeable about the users' work environment as the users are. In consultancy mode, the user is only periodically involved in development. Codevelopment and apprenticeship mode require that the user is substantially more involved in the development process.

In a codevelopment context, users are part of the development team and strongly influence the design of the system. Companies use codevelopment when the users' work processes are significantly affected or changed by a new system. Leonard states that it facilitates shared problem solving and is very effective in fostering learning within the organization (Leonard, 1998). Thus, codevelopment is conducive to achieving "buy-in" from users. Leonard warns that a potential drawback of this mode of user involvement is that influential users may be fixated on what is currently working well and may lack forward vision (Leonard, 1998). In this case, there is a risk that an inefficient process may simply become automated. However, she contends that if users exercise enough forward vision the project can succeed beyond expectations (Leonard, 1998).

Leonard's final mode of user involvement is the apprenticeship mode. In this scenario, users basically apprentice themselves to the developers early in the project's life. Subsequently, the users design and implement the system themselves. Very few projects subscribe to this method of user involvement as the user requires substantial time and resources to become a technical expert in addition to being a user of the system.

Leonard refers to "mutual adaptation" as the process by which the technology is adapted to the user environment and the user environment adapts to the technology so as to exploit the full potential of the technology (Leonard, 1998). This process may require some degree of

organizational change in addition to technical change. Leonard states that: “It [mutual adaptation] requires that managers in charge of implementing new technical systems recognize and assume responsibility for both technical and organizational change” (Leonard, 1998, p. 104). Leonard asserts that managers who pay attention to both user involvement and mutual adaptation can achieve long term benefits from process innovations (Leonard, 1998).

2.2 Prototyping

One proven method of involving users in the technology development process is prototyping. Leonard presents prototyping as an effective method of filling information gaps between users and designers of technical systems. She puts forth that it is a powerful exercise in achieving outbound communication to the user and elicitation of information from the user (Leonard, 1998). If an organization wants user knowledge to freely flow back to the designers of the technology, she states that the information feedback loop should be short and frequent (Leonard, 1998). In other words, rapid prototyping cycles are needed if an organization wants to learn quickly from the prototype. Additionally, Leonard stresses that a learning environment within the organization should be emphasized if the prototyping is to be truly effective (Leonard, 1998).

2.3 Sources of Innovation

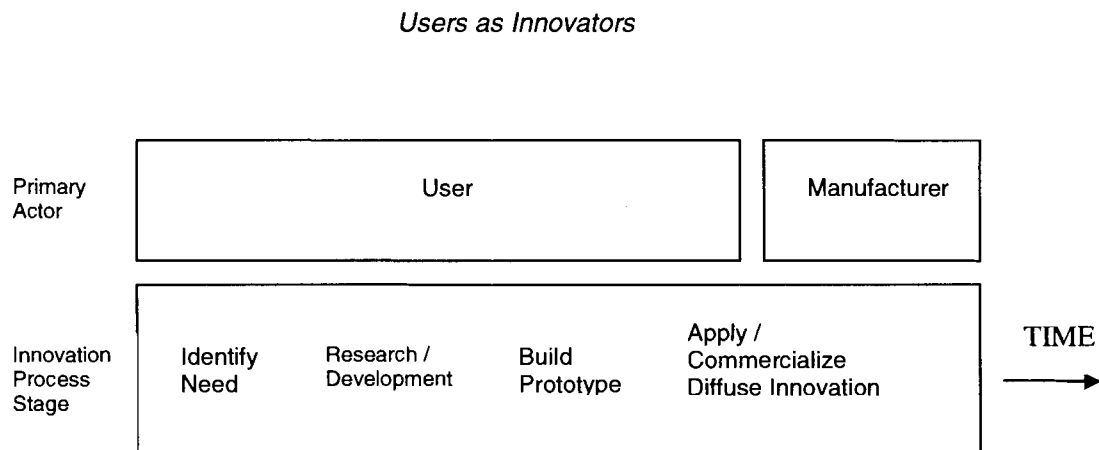
For any technology company, innovations and information contributing to innovations come from many sources. In this section, literature that proclaims that the user is an important source of innovations is explored. The examination emphasizes that users are capable of making considerable improvements to products, processes and services – making their involvement in the production process indispensable. This section also looks at research that investigates the sources of innovation specifically within the Canadian transportation industry.

2.3.1 Von Hippel

In Eric von Hippel's The Sources of Innovation, a series of research studies show that innovation can come from various sources. He categorizes firms and individuals based on the functional relationship through which they derive benefit from a given product, process or service innovation. The functional sources of innovation are users, manufacturers or suppliers (von Hippel, 1988). The source of innovations varies among these three functional groups. Users are quite often the source of innovation.

In accordance with von Hippel's research, Figure 2.1 illustrates that most of the innovation process is centred on the user. Counterintuitively, the manufacturer only becomes involved in the process in the late stages of commercialization and diffusion of the innovation (von Hippel, 1988). According to von Hippel, in many cases the manufacturer only provides the manufacturing and marketing capabilities of the process, whereas, the user initiates, develops and tests the innovation (von Hippel, 1988).

Figure 2.1 Steps Observed in the User Development of an Innovation



Adapted from von Hippel, 1988, p. 25, by permission

Von Hippel hypothesizes that the variation in the source of innovation originates from “the potential innovators’ relative pre-innovation expectations of innovation-related benefits” (von Hippel, 1988, p. 35). He further states that innovators (individuals or firms) “will be found among those whose analyses lead them to expect a rent they consider attractive” (von Hippel, 1988, p. 44). His assertion is that the individual or firm that is in the best position to capture benefits from the innovation will be the likely innovator (von Hippel, 1988).

Von Hippel contends that one factor that contributes to the amount and likelihood of user innovation is the ease with which the user can modify a product, process or service (von Hippel, 1988). He maintains that if the user can easily (i.e. inexpensively) modify the product then this, in effect, encourages user-initiated innovation activity (von Hippel, 1988). Conversely, if changing a product is difficult (i.e. expensive) then the user is deterred from trying to do so.

Von Hippel's research finds that users are the most likely source of innovation in specialized applications where manufacturers and suppliers do not foresee great economic benefit (von Hippel, 1988). In other words, for products that are easily customizable, users look for ways to improve the product for their specialized purpose. At the same time, if manufacturers and suppliers do not foresee much economic benefit from improving a product then they have little incentive to innovate.

2.3.2 Statistics Canada

A Statistics Canada working paper entitled "Innovation in Selected Transportation Industries: Results from the Survey of Innovation 2003" (Lonmo, 2005) was recently released which looked at innovation in selected Canadian transportation industries. Important transportation industries surveyed include air transportation, airport operations and port and harbour operations among others. This working paper highlights that innovation in the transportation industry is spurred on by both internal and external sources of information.

The industries surveyed indicated that internal sources of information play an important role in the development of innovations. In the industries surveyed, management staff were the most frequently indicated sources of information that contributed to innovations (Lonmo, 2005). However, external sources of information also played a significant role in spurring innovation. In the air transportation and airport operations industries, the suppliers of software, hardware, materials or equipment were the most frequently indicated sources of external information contributing to innovation (Lonmo, 2005). Clients and customers followed as the second most frequently indicated external source of information (Lonmo, 2005). The study demonstrates that internal and external sources of information play a crucial role in the development of innovation.

The research also finds that the supply chain member that actually develops the innovation varies markedly by industry (Lonmo, 2005). However, most of the air transportation

companies surveyed indicated that product innovations were developed mainly within their organization – either within their business unit or within their firm (Lonmo, 2005). Despite that, the two facilities operations industries, airport operations and port and harbour operations, indicated that product innovations were usually developed in collaboration with other firms or organizations (Lonmo, 2005). The reasons given for collaboration were to share costs and spread risks (Lonmo, 2005). Therefore, in the transportation industry, the firm itself or a close affiliate is usually responsible for product innovations.

2.4 Importing Knowledge

No company can afford to internally develop every single technology that they require in order to function. Managers make outsourcing decisions everyday. When it comes to NAV CANADA's ANS technologies, many factors play into the decision to either purchase a COTS system, contract out a customized system or develop the technology in-house. The same factors play into the decision on the best way to enhance an existing system. Even the most technically capable companies have to procure technology externally. This section reviews Leonard's work regarding the decision to externally source technology.

According to Leonard, a capability gap exists if "strategically important technical expertise is unavailable or not adequate internally" (Leonard, 1998, p.138). She argues that the existence of a capability gap depends on two considerations. Firstly, on how relevant the necessary technology is to the core technological capabilities of the firm, and secondly, on the firm's existing degree of familiarity with the requisite technical knowledge (Leonard, 1998).

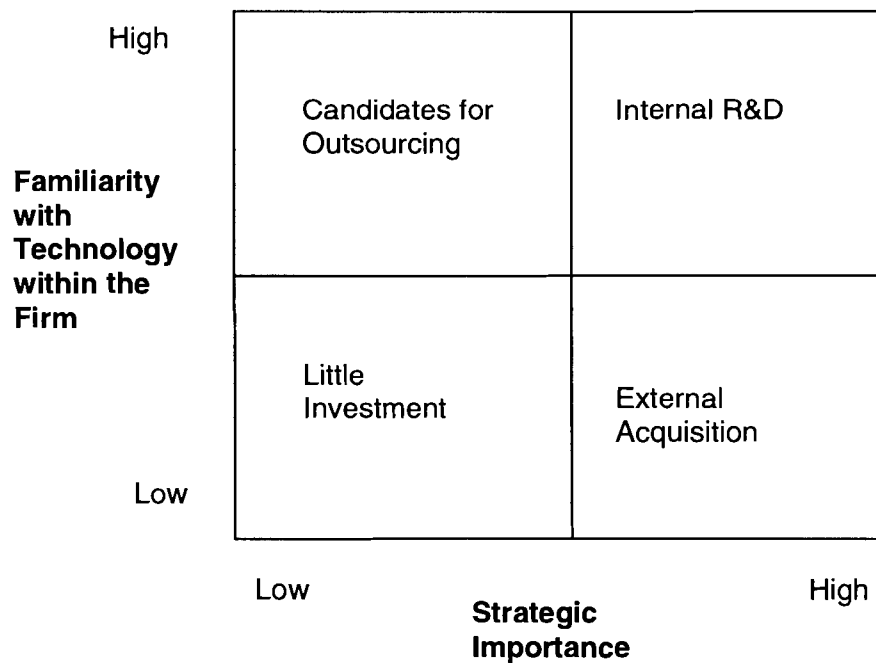
For a company to determine if a capability gap exists, Leonard contends that it should try to establish a link between their business strategy and their technological capabilities (Leonard, 1998). The company's strategic intent must be clear in order to identify the technological capabilities that are necessary to achieve it. Moreover, managers should ask themselves: Is our

technological capability sufficient to fulfilling our corporate strategy? In other words, does the company house the necessary technical skills, knowledge and resources to fulfil its corporate strategy?

Internal development of technical systems is an option available to those firms that have the necessary technological capability. According to Leonard, the necessary technological capability consists of physical systems, skills, knowledge, managerial systems and supporting norms within the company (Leonard, 1998). She goes on to state that internal development depends on whether the company's required technical skills and knowledge are current and complete (Leonard, 1998).

If a capability gap does exist and internal development is not an option then a company can look to acquire technical systems from an external source. In Figure 2.2, Leonard examines four potential technology sourcing situations by "juxtaposing the two dimensions of strategic importance and degree of familiarity with the technology" (Leonard, 1998, p. 143).

Figure 2.2 Need for External Sourcing of Technology



Adapted from Leonard, 1998, p. 144, by permission

Technologies falling into the lower left quadrant require little or no investment since it is neither strategically important nor does the firm have much experience with it. Technologies in the upper left quadrant may be sourced to specialty firms because although the firm is familiar with the technology, it is of very little strategic importance. Technologies in the upper right quadrant are components of current core capabilities of the firm and should be developed in-house. External acquisition is needed when a capability gap exists (lower right quadrant) – I.e. the strategic importance for the technology is high however the firm has very little internal knowledge about it.

2.5 Safety-Critical Systems Development

The development of safety-critical, real-time systems presents the implementer with a unique set of challenges. Reliable and predictable behaviour is a mandatory requirement. This

section presents two case studies of safety-critical system implementations. The first one demonstrates how close collaboration with the user of the system all of the way through the development process can maximize user satisfaction when the system is released operationally. This in turn can reduce enhancement costs. The second case study puts forth that discovering unclear and ambiguous requirements during the testing phase of development can reduce the amount of anomalous behaviour reported during full-scale operations, which in turn reduces development costs associated with rectifying the anomalous behaviour.

2.5.1 Centre/TRACON Automation System

In the paper “A Systems Approach to Design: Developing a Usable Automation Tool for Air Traffic Control” (Halverson, Harwood, Davis & Brinton, 1992), the design and development of an air traffic control automation tool is studied. The system under study is the Centre/TRACON Automation System (CTAS) developed at NASA Ames Research Centre in the early 1990’s. The paper describes how iterative feedback from the system’s users was successfully applied to develop a set of automation tools for terminal area air traffic control.

The authors posit that for a new air traffic control technology to be effective and useful, the global system objectives must be embraced as well as the local needs of the users (i.e. pilots, air traffic controllers and airways facilities personnel) (Halverson et al., 1992). An example of a global system objective is the need to improve the safety and efficiency of aircraft movement. An example of a local user need is to reduce the controller’s workload. For CTAS, both global system goals and local user goals were designed into the system (Halverson et al., 1992).

An iterative design process was employed that involved being responsive to the user’s frequent feedback. The process began with an initial assessment of users’ needs and desires. Designers gathered information from field observations as well as written and verbal responses from controllers (Halverson et al., 1992).

The system's design was changed iteratively based on user testing of a prototype. This involved testing the prototype in a simulated environment with retired controllers. Periodically, active controllers were brought in to participate in the evaluations. Designers carefully ensured that user-initiated changes did not compromise the global system objectives of the tool. Feedback from these users and the designers' observations were directed back into the redesign and refinement process. This process allowed the designers to see how the system was changing the users' procedures and vice-versa how user-initiated changes were affecting the system's performance capabilities. Ultimately, the user interface became the realization of both system and user goals.

In this case study, the "user-centred" design process resulted in a user interface that satisfied the air traffic controller users (Halverson et al., 1992). The resulting design also satisfied the system goals of productivity and efficiency (Halverson et al., 1992). The paper concludes that frequent user participation in the design process resulted in greater user acceptance of the automation tool (Halverson et al., 1992).

2.5.2 Mars Exploration Rovers

The paper "Requirements Discovery during the Testing of Safety Critical Software" (Lutz & Mikulski, 2003) discusses the role of requirements discovery during the testing phase of safety-critical software. The research was carried out at the Jet Propulsion Laboratory, California Institute of Technology, under a contract with NASA. The data for the analysis came from problem reports completed by project test teams during integration and system testing of the Mars Exploration Rovers. One of the findings of the study is that requirements discovery during testing provides a rich source of information that can be used to reduce unpredictable behaviour in operational systems (Lutz & Mikulski, 2003).

The authors stress that problem reports generated during testing are an underused source of information about potential requirements related anomalies that may occur after a software system is deployed (Lutz & Mikulski, 2003). The analysis of problem reports uncovered four mechanisms for the discovery of new requirements:

1. “Incomplete requirements resolved by changes to the software” (Lutz & Mikulski, 2003, p. 578).
2. “Unexpected requirements interactions resolved by changes to operational procedures” (Lutz & Mikulski, 2003, p. 578).
3. “Requirements confusion by the testers resolved by documentation changes” (Lutz & Mikulski, 2003, p. 578).
4. “Requirements confusion by the testers resolved by a determination that no change was needed” (Lutz & Mikulski, 2003, p. 578).

According to the authors, “One of the lessons learned was that requirements discovery during testing is frequently due to communication difficulties and subtle interface issues.” (Lutz & Mikulski, 2003) If an organization is to prevent slippage of requirements related problems into operations, Lutz and Mikulski argue that they should better understand the various requirements discovery mechanisms (Lutz & Mikulski, 2003). They further state that misunderstandings and confusion about requirements, left unaddressed, may foreshadow misunderstandings out in the field of operations.

2.6 Summary

The users of NAV CANADA’s ANS systems are the company’s operational staff that includes air traffic controllers, flight service specialists, and other operational support specialists.

This chapter put forth that in order to maximize user satisfaction the user must be involved in the system development and implementation process in some way. This chapter explored some varying ways to do this such as consultancy, codevelopment, apprenticeship and mutual adaptation.

Also, prototyping is introduced as an effective way to obtain user feedback in order to refine a technology product. The CTAS development case study supports the use of a fast and frequent user feedback loop in order to satisfy air traffic control users and reduce the amount of post-implementation work required on an ANS system.

For a system that has been developed for a specialized purpose, like NAV CANADA's ANS systems, many innovations will originate from the users of the system. These systems are very specialized and its users are a great source of functional improvements. However, the system design team must be aware that one downside to extensive user involvement is that users may end up leading the design process down the wrong path if they begin to dictate a certain design without exercising enough forward vision. The amount of user involvement required for the successful implementation of an ANS system needs to be determined by the development team up front.

This chapter also explored the factors that need to be considered when outsourcing technology or developing it internally. The factors are the company's familiarity with the technology and the strategic importance of the technology. This decision is very relevant to NAV CANADA and it is one that the company makes on every ANS system that it implements.

This chapter concludes with a case study on importance of the testing phase in safety critical systems development. The Mars Exploration Rover software development process is analysed and critiqued. The analysis yields some lessons learned that shed light on ways to minimize unpredictable system behaviour when the system is in full operations.

3 INDUSTRY ANALYSIS

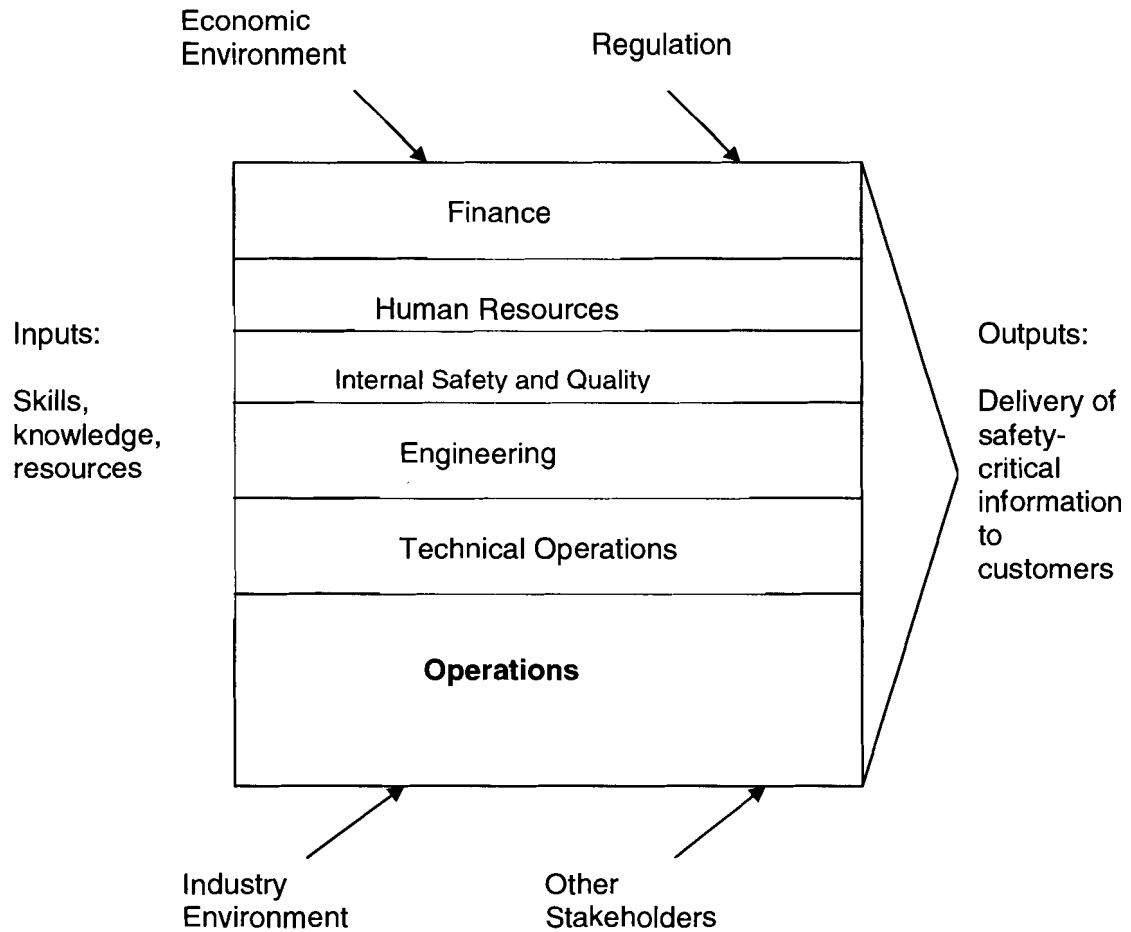
This chapter describes the business of air navigation service provision and analyzes important industry issues as a background to the analysis of NAV CANADA's technology implementation process. The industry analysis begins with the examination of an ANSP's value chain. The value chain analysis exposes the core business processes and related business network of a typical ANSP. The analysis examines the way in which an ANSP creates value for its customer while dealing with regulatory bodies, stakeholders, and the industry environment. This is followed by an analysis of NAV CANADA's macro-environment.

3.1 Global Air Navigation Service Provider Industry

The major customers of any ANSP are airlines and other aircraft operators such as charter companies and private pilots. The customers range from small private aircraft owners to the world's largest airlines. Every ANSP is tasked with providing safe, reliable and accessible services to facilitate their customers' aviation interests. The primary goal is to provide customers with the highest level of service at the lowest possible cost while maintaining safety.

The core capability of an ANSP is its ability to deliver safe air navigation services at a reasonable cost. Delivery of these services is highly dependent on the organization's knowledge, skills and technology resources. Meanwhile, external factors such as economic conditions, regulatory bodies, industry agencies and other key stakeholders must be reconciled in order to provide adequate levels of services to customers. The value chain of a typical ANSP is illustrated in Figure 3.1.

Figure 3.1 Air Navigation Service Provider Value Chain



Based on Molinari & Papavramides, 2002

3.1.1 Air Navigation Services

Air navigation services consist of air traffic management, communications, navigation, surveillance, aeronautical informational services, meteorological services and search and rescue services (Molinari & Papavramides, 2002). ANSPs are a key element of the air transportation value system. They facilitate the orderly flow of air traffic, prevent collisions in the air and on the ground, provide navigational charts and meteorological services, facilitate search and rescue operations and provide communication services to pilots in the sky.

Value for the end-customer comes in the form of safety-critical air traffic information from the operational staff of the ANSP.

The basic needs of the public and of the airspace users are focused in: a) safety, b) security, c) punctuality (i.e. no delays), d) cost efficiency (i.e. delivery of specified services with the lowest possible cost) and e) protection of the environment. (Molinari & Papavramides, 2002, p. 924)

Delivery of services depends on new services, procedures and technology being implemented that keep pace with customers' needs. Customers are looking for increased ANS service efficiencies that would in turn increase their own efficiency. To do this ANSPs are required to recruit, train and retain highly skilled operational staff, establish operational and administrative processes, and finally, evaluate and maintain the ANS infrastructure. It follows that shortcomings in service can be caused by not employing enough operational staff, having out-of-date technology or having an inadequately designed airspace (Button, 2005).

The service delivery activities of an ANSP are carried out by the Operations group. This group includes air traffic controllers and flight service specialists. Air traffic controllers carry out the essential tasks of air traffic management, communications, navigation and surveillance. Flight service specialists provide services such as weather briefings, pre-flight information, airport advisories and issuances of safety notices. This group is the front line staff that communicates directly with the end-customer. Closely supporting the Operations group is the Technical Operations group. This group consists of technologists that maintain and repair technical systems on-site.

The supporting activities of an ANSP are typically carried out by the Engineering group, Human Resources group and Finance group. Of course, group titles and specific responsibilities vary across ANSPs. There is also usually an Internal Safety and Quality group that monitors the

ANSP's performance. Although the staffing level may be small for this group, its function is very valuable to the ANSP.

The Engineering group is responsible for acquiring or developing the technology required to deliver the service. The air transportation industry requires a costly, complex and extensive technological infrastructure. Integrating and implementing new technology that increases safety and cost-efficiency adds value for the customer. Since the ANS industry is so technology-intensive, the Engineering group plays a crucial role within the ANSP as the evaluator and maintainer of the ANS technology infrastructure.

3.1.2 Regulation and Privatization

Generally speaking, there is only one ANSP operating within each country around the world (although there are a few exceptions to this). This essentially creates a monopoly for air navigation services within that country. State regulation of the industry addresses this lack of competition and monopoly status of ANSPs. Regulators exist in order to ensure the standardization and monitoring of the ANSP's performance (Molinari & Papavramides, 2002). State regulation was institutionalized and articulated at the Convention of International Civil Aviation in Chicago in 1944 (Button, 2005). It made national governments responsible for providing air navigation services.

While airline companies have undergone an extensive privatization and liberalization process in the past few decades, ANSPs have experienced much less privatization and liberalization overall. The changes that have occurred in the air navigation sector have been varied from country to country. The ownership model ranges from strict state ownership to varying forms of regulated private companies. As we already know, Canada supports a fully privatized non-profit corporation, the UK employs a partly privatized ANS, while the US and France have fully state-owned ANSPs. These varying forms of ownership are an attempt to

achieve the optimal level of service for customers while maintaining national security and public safety (Button, 2005). The common thread between all countries is that their respective ANSPs are regulated in some way by government.

Table 3.1 below is based on a study conducted by Kenneth Button (School of Public Policy, George Mason University Fairfax, Virginia). The study analyses the impact of commercialization and deregulation of the ANS industry around the world. The data is collected from the ANSPs of eleven countries from 1997 to 2004. It compares and contrasts the basic features of ANSPs. The ownership models and regulation schemes are almost as diverse as the countries themselves. Also, note that the only country in which the ANSP is not financed by user fees is the US (Federal Aviation Administration), which is financed by taxation (Button, 2005).

Table 3.1 Basic Features of Some Major ANSPs

| Country | Ownership | Rate Regulation | Safety Regulation |
|----------------|------------------------------------|--------------------------------|-----------------------------|
| Australia | Government corporation | Commission oversight | Separate Agency |
| Canada | Non-profit private corporation | Legislated principles/appeals | Separate Agency |
| France | State department | Approved by transport ministry | Internal but separate |
| Germany | Government corporation | Approved by transport ministry | Internal |
| Ireland | Government corporation | Regulatory commission | Internal but separate |
| Netherlands | Government agency | Approved by transport ministry | Transport ministry/separate |
| New Zealand | Government corporation | Self-regulating | Separate Agency |
| South Africa | Non-profit joint-stock corporation | Transport ministry committee | Separate Agency |
| Switzerland | Non-profit joint-stock corporation | Approved by transport ministry | Separate Agency |
| United Kingdom | Public/private partnership | Price capping | Separate Agency |
| United States | State department | Financing from taxation | Internal but separate |

Data source: Button, 2005

NAV CANADA is the first and only fully privatized ANSP in the world. It is the first private sector company in the world to use a non-share capital structure to commercialize a government service (Nav Canada Corporate Website, n.d.). It has moved further away from the government ownership model than any other ANSP. The United Kingdom's National Air Traffic Services is closest to NAV CANADA in terms of private ownership. But even it is only partly privately owned.

Larger ANSPs that are privatized, like the UK's and Canada's, have seen fewer safety incidents than the other more publicly sponsored ANSPs (Button, 2005). Privatization also has an affect on the costs incurred in providing service. While the privatized firms have generally decreased costs per instrument flight rules movement (a measure of the cost to provide service to a customer), the state-owned FAA increased its cost per instrument flight rules movement during the period from 1997 to 2004 (Button, 2005). Moreover, privatized ANSPs have access to more diverse capital sources and do, in fact, experience efficiency improvements (Button, 2005). Value from privatization of an ANSP comes in the form of cost savings as well as efficiency and safety improvements that are ultimately passed to customers. Large customers, like airlines, benefit the most.

NAV CANADA, although it is the only privatized ANSP in the world, still has its performance monitored by the Canadian Federal Government. Additionally, its customer service charges are set according to legislated principles. The result of this is that the company must maintain its exemplary safety and performance record while upgrading the ANS cost-effectively. Consequently, the technology implementation process must provide advanced technology solutions that add value to air navigation services while maintaining control over development and implementation costs.

3.1.3 Industry Environment

The growth or decline of air traffic levels has a great impact on an ANSP's business. Air traffic levels directly affect the bottom line of ANSPs that charge user fees to recover costs (e.g. NAV CANADA) – less air traffic means less revenue for these ANSPs. Table 3.2 displays international passenger and freight air traffic growth forecasted through to 2009. The percentages represent average annual growth rate.

Table 3.2 Forecasted International Air Traffic Growth for 2005-2009

| Route Area | Passenger Air Traffic (%) | Freight Air Traffic (%) |
|--------------------------------|----------------------------------|--------------------------------|
| North Atlantic | 5.3 | 4.6 |
| Trans Pacific | 5.8 | 6.0 |
| Within Europe | 5.1 | 4.1 |
| Within Asia Pacific | 6.8 | 8.5 |
| Europe to Asia Pacific | 5.9 | 5.7 |
| Europe to Africa | 5.7 | 4.5 |
| Middle East to Europe | 6.6 | 5.1 |
| Middle East to Asia Pacific | 6.7 | 8.8 |
| North America to Latin America | 4.6 | 3.7 |
| Within Latin America | 4.2 | 5.0 |
| All international routes | 5.6 | 6.3 |

Data source: International Air Transportation Association, 2006

This forecasted growth in air traffic is significant for NAV CANADA. Since NAV CANADA charges customer service fees, the growth in air traffic equates to growth in revenue for the company. Increased traffic along North Atlantic and Trans Pacific routes are particularly relevant to NAV CANADA. These routes that fly through Canadian controlled airspace include some of the busiest airways in the world, thus, presenting NAV CANADA with an opportunity to capture significant gains in revenue.

Additionally, the forecasted traffic growth is a positive sign for both ANSPs as well as the airline industry. Currently, the global aviation industry is emerging from the worst downturn in aviation history. However, the growth can be easily disrupted by certain macro-environmental forces that are discussed in the next section. Both ANSPs and their customers are trying to achieve the same goal. That is to provide higher levels of service at lower costs. Any significant decrease in air traffic negatively affects both industries.

Most ANSPs work with a broad range of international and national aviation industry associations. The three major international associations that NAV CANADA works with are the International Civil Aviation Organization (ICAO), the Civil Air Navigation Services Organization (CANSO) and the International Air Transport Association (IATA). All three of these international associations work toward establishing and maintaining the global aviation infrastructure which includes the global ANS infrastructure. Collaboration with these industry associations gives NAV CANADA a means to interface its business with the worldwide ANS industry.

ICAO is a global organization that sets the standards and procedures for the entire aviation industry, including the ANS industry. One important function of this organization is to delegate international airspace to individual ANSPs. It is an agency of the United Nations that ensures the safe and orderly growth of international civil aviation throughout the world (Nav Canada Corporate Website, n.d.).

CANSO represents ANSPs worldwide that are not operating under direct government control. This organization develops benchmarks to compare safety performance among these ANSPs. It is based in the Netherlands and was founded in 1998 (Nav Canada Corporate Website, n.d.).

IATA is the trade association of the world's international airline industry. Its members collectively represent 95% of all international air traffic (Nav Canada Corporate Website, n.d.). Its mission is to "represent, lead and serve the airline industry (International Air Transportation Association, 2006).

In addition to industry agencies, ANSPs must work closely with other ANSPs, especially those that border one another's airspace. They, in fact, share customers. Thus, ANS systems must be able to communicate with one another. Safe and efficient movement of aircraft depends on neighbouring ANSPs working together and having interoperable systems. For that reason, the adoption of new ANS technology must be done with some degree of coordination between bordering ANSPs.

For companies like NAV CANADA, the technology implementation process has to consider the needs of customers (i.e. airlines), international and national aviation industry associations as well as other ANSPs. The implementation process is thus very complex and must be coordinated with a network of organizations.

3.1.4 Other Stakeholders

An ANSP operates in an environment with a few large but influential stakeholder groups. In addition to customers and government regulators, the flying public's view of a safe and reliable ANS is of primary importance. Peoples' perception of a safe flying experience affects whether they fly or use some other form of transportation (or communication). After all, the cost of service does eventually trickle down to them.

The experience, skills and knowledge of employees is central to the success of any ANSP. Approximately sixty to seventy percent of operating costs are labour costs (Button, 2005). The operational workforces, who are the users of ANS systems, require extensive

training. There is a high rate of attrition among trainees. Those who make it through the rigorous training process are paid above average salaries. As well, they are unionized making bargaining agents a key stakeholder. Maintaining sufficient operational staffing levels is a challenge for all ANSPs.

For privatized ANSPs, such as NAV CANADA, the financial community is a key stakeholder since capital requirements are financed through means other than taxation. Difficulty in raising capital can influence operational staffing levels as well as technology infrastructure maintenance and enhancement. Companies like NAV CANADA strive to maintain high credit ratings with lenders and rating agencies so that their access to low cost capital is consistently reaffirmed.

3.1.5 Summary

An ANSP creates value for its customer by delivering safe air navigation services at a reasonable cost. The key inputs for this service delivery are the ANSP's skills, knowledge and technical resources. The service delivery is influenced by a host of external factors which include government regulation, the industry environment and some key stakeholder groups. Although these external factors are beyond the control of the ANSP, they do determine the size, shape and nature of the ANSP. This, in turn, determines the technology needs of the ANSP as well as its ability to deliver the necessary technologies to its operational workforce.

3.2 Macro-Environment Analysis of NAV CANADA

There are many important external forces that influence the business of ANSPs. However, the primary macro-environmental forces that influence an ANSP's need and ability to implement new technology are the global and national economy, the national government and the existing and emerging technology options. The economy has a direct impact on air traffic levels and thus on NAV CANADA's revenue stream. Less revenue constrains the company's ability to

upgrade the technology infrastructure. The Government of Canada's regulation of NAV CANADA's performance and service rates forces the company's operations to be as cost-efficient as possible. Greater operational efficiency is achieved, in part, through a current and up-to-date technology infrastructure. Lastly, the technological environment offers options to NAV CANADA as it implements, maintains and enhances its technology infrastructure. This section concludes with two emerging external forces that influence new technology development at NAV CANADA – changing demographics and a new competitive domain.

3.2.1 Economy

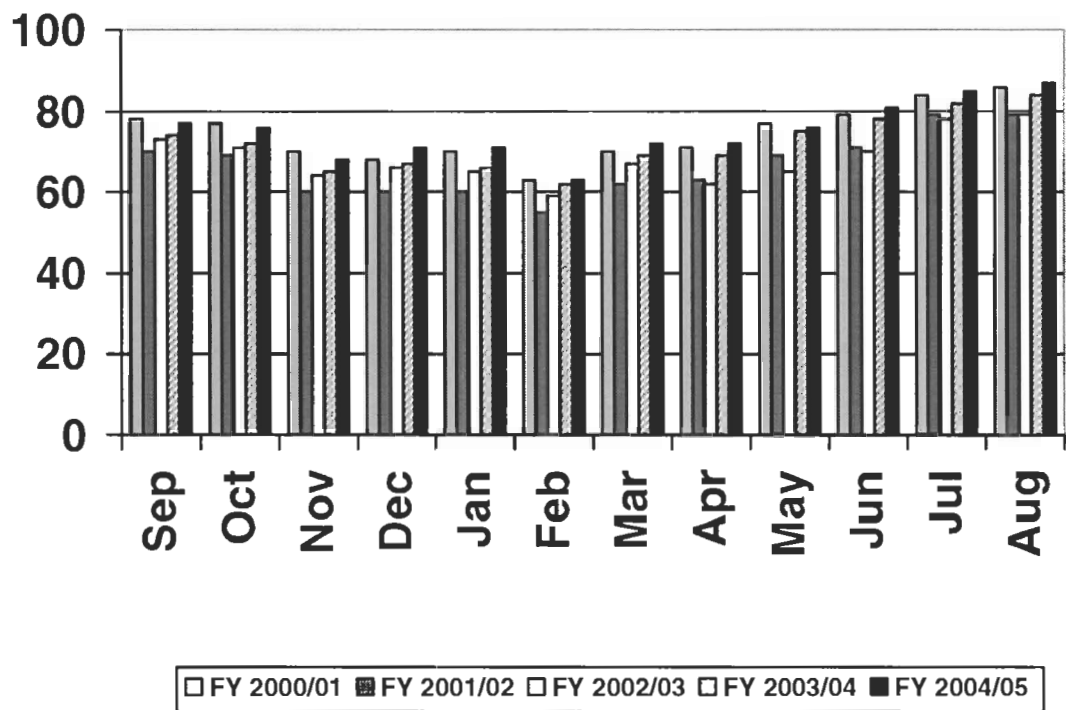
The global aviation industry suffered an unprecedented downturn in the aftermath of the terrorist attacks on September 11, 2001 (9/11). This was followed by a series of subsequent events that kept the aviation industry in a depressed state. As a result, global traffic volumes fell to unprecedented lows. There was a 10% decline in traffic over Canadian airspace in the year ending August 31, 2002 because of the 9/11 terrorist attacks and the ensuing war in Afghanistan (Nav Canada, 2003). The combined operating loss for NAV CANADA's top ten customers (all major airlines) was US\$8.9 billion in 2001 (Nav Canada, 2003). Globally, airlines lost US\$18 billion in 2001 (Nav Canada, 2003).

The aviation industry downturn continued into 2002 and 2003. From September 2002 to January 2003, there were some signs of recovery but the war in Iraq, SARS outbreak, and massive power blackout in central Canada in the summer of 2003 caused traffic levels to fall back to the unprecedented low levels. The combined operating loss for the 12 months ending June 2003 for NAV CANADA's top ten customers was US\$7.8 billion (Nav Canada, 2004).

Air traffic figures have only recently returned to pre-9/11 volumes (Nav Canada, 2005). Overall, air traffic for fiscal year 2005 was 5% higher than the previous year (Nav Canada, 2005). Figure 3.2 below shows air traffic levels pertaining to NAV CANADA for the period of 2001 to

2005 in terms of “weighted charging units”. Weighted charging units reflect the number of flights, aircraft size and distance flown (Nav Canada, 2005). NAV CANADA uses weighted charging units (in millions along the y-axis in the figure below) as a way to measure air traffic volumes in Canadian controlled airspace.

Figure 3.2 Weighted Charging Units, Fiscal Year 2000/01 – 2004/05



Adapted from Nav Canada, 2005

The price of crude oil directly influences the profitability of ANSPs’ largest customers – domestic and international airlines. Crude oil prices have been increasing recently and, according to Bloomberg.com, are currently sitting at US\$62.62 per barrel as of February 9, 2006 (Bloomberg.com, 2006). These prices are very high and are driving up the operating costs of all those in the aviation business, especially airlines.

Interest rates also influence the profitability of all major airlines as well as the financing structure of ANSPs like NAV CANADA. The prime interest rate in Canada as of January 2006 is 5.25% (Government of Canada – Canadian Economy Online, 2006). This is 1% higher than in January 2005 and further growth is anticipated.

Air traffic levels can be volatile. Unforeseen events in the airline industry like low-cost carrier competition, airline restructurings and insolvencies have a direct effect on air traffic levels (Nav Canada, 2000). Looking forward, new potential terrorist activities and disease epidemics and pandemics are sure to have a negative effect on air traffic levels.

3.2.2 Government

The privatization of Canada's air navigation service was a significant event in terms of the Canadian government's view of what an ANSP should be responsible for. In May 1995, NAV CANADA was incorporated as a non-profit, non-share capital, private corporation (Nav Canada, 2000). On November 1, 1996, following a payment of \$1.5 billion to the Canadian government, NAV CANADA assumed ownership and control of the country's ANS (Nav Canada, 2000).

Before NAV CANADA was incorporated, Transport Canada operated our country's air navigation service. Under the ANS Act, NAV CANADA serves as the ANSP while Transport Canada is the safety and performance regulator (Nav Canada, 2000). As well, customer service rates are set and administered by NAV CANADA in accordance with the ANS Act (Nav Canada, 2000). The two main reasons for the privatization were (a) to separate the ANSP from the safety regulatory body (previously both tasks were performed by Transport Canada), and (b), to operate the ANS at lower operating costs. The Canadian Government has a very important role in ensuring safe air navigation service at a reasonable cost to customers. With privatization, NAV CANADA's performance is monitored by the Transport Canada, therefore, the ANS

infrastructure must be kept up-to-date and capable of handling air traffic well into the future. The effectiveness of the company's technology implementation process is central to maintaining and enhancing the ANS infrastructure.

3.2.3 Technology

Since the mid 1990's, COTS software and hardware that is commercially available has been the focus of air traffic technology solutions. These systems can be integrated into the current ANS infrastructures of developed countries. To a certain extent, acquiring COTS technology gives the buyer the impression that they are buying proven and tested technology. One drawback to acquiring a COTS system is that it may not perfectly fit the buyer's current processes and procedures.

In addition to COTS systems, ANSPs have the option to purchase customized technology supplied by an external supplier. Many ANS COTS systems were originally developed from customized requirements for a particular customer. These customized systems are later "standardized" into COTS systems for the larger ANS market.

The last option an ANSP has to obtain ANS technology assets is to develop systems internally. This option really depends on the strategic importance of the system and the ANSP's internal development capabilities. NAV CANADA is one ANSP that has successfully marketed some of its in-house developed ANS systems globally.

During the lifecycle support stage of a technology, the ease with which a COTS or contractor supplied system can be enhanced and modified depends on the licensing terms negotiated with the supplier. Basically, the system changes can be contracted to the supplier, a third party or performed in-house.

The ANS industry is very technology-intensive and ANS technology has become more important but sourcing it and implementing it more complex. Thus, crucial to the success of any ANSP is the competence to manager all of this and make the right sourcing and implementation decisions.

3.2.4 Demographics

In North America, demographics are shifting and these shifts may have an impact on the ANSP industry. In industrialized nations, a wave of baby boomer retirements is forecast. This may leave ANSPs with a shortage of operational staff that may, in turn, affect the quality of air navigation service provided to customers. Similarly, a shortage of engineering and management staff can affect an ANSP's ability to develop, implement and maintain its ANS infrastructure.

3.2.5 Competition

Generally speaking, an ANSP operates without competition within a particular country. However, the geographic location of Canadian domestic and Canadian controlled international airspace offers a unique opportunity for NAV CANADA to capture over-flight ANS business (Nav Canada, 2000). Some flights connecting the US to Europe and to Asia may potentially fly through Canadian controlled airspace. This creates a competitive environment for NAV CANADA if it offers comprehensive service and low service charges (Nav Canada, 2000).

On the global stage, NAV CANADA competes with other ANSPs as well as air traffic system contractors in the sale of COTS ANS technologies. Many of the world's ANSPs have to upgrade their infrastructures. This creates a market for NAV CANADA to generate extra revenue from its internally developed technologies. In NAV CANADA's case, the extra revenue covers operational costs that would otherwise be covered by customer service fees. This marketing exercise, in effect, can help reduce or at least stabilize the customer service fees that NAV CANADA charges.

3.2.6 Summary

This section looked at NAV CANADA's macro-environment. In particular, it examined issues that influence NAV CANADA's need and ability to implement new technology. The most important issues are the current economic conditions, the political environment and the technological environment. Nevertheless, changing demographics and competition are emerging forces that affect the company's ability to develop and implement cutting edge ANS technology.

NAV CANADA is not your normal type of organization, or ANSP for that matter. It operates in a network of many stakeholders, it is not-for-profit but it is privatised, and it has a huge challenge in maintaining an exemplary safety record in a changing environment while exercising cost control. In addition, it operates essentially as a monopoly but there is a competitive aspect to its business, and last but not least, technology is critical to achieving its mission. At the same time, the technology sourcing decision is renowned for not being easy to make and actually implementing the technology is a very difficult task as the systems being implemented are large, complex and safety-critical. In the next chapter the analysis looks at how NAV CANADA copes with these challenges.

4 INTERNAL ANALYSIS OF NAV CANADA

The purpose of this chapter is to analyze NAV CANADA's internal environment in order to gain an understanding of the company's competencies and resources. The chapter begins with a description and analysis of the organization. This is followed by a review of the business model and company principles. Next, the factors that NAV CANADA considers when adopting and implementing new technology are outlined. This chapter also analyzes the company's systems development capabilities. Finally, the chapter concludes with an analysis of some issues faced by a sample of NAV CANADA's current implementations.

This internal analysis is presented in two parts. The first part analyses the organization at a high level covering an overview of the functional organization of the NAV CANADA, its business model, its business principles and its technology adoption methodology. The second part delves much deeper in to the fine detail of the organization including the company's technology development skills, competencies, resources and weaknesses. This second part also includes an assessment of a sample of NAV CANADA's current system implementations. These two levels of analysis are necessary to determine whether the organization's general structure, principles, model and culture are appropriate and also whether day-to-day technology-related activities complement the high level strategic intent of the company.

4.1 Organizational Analysis

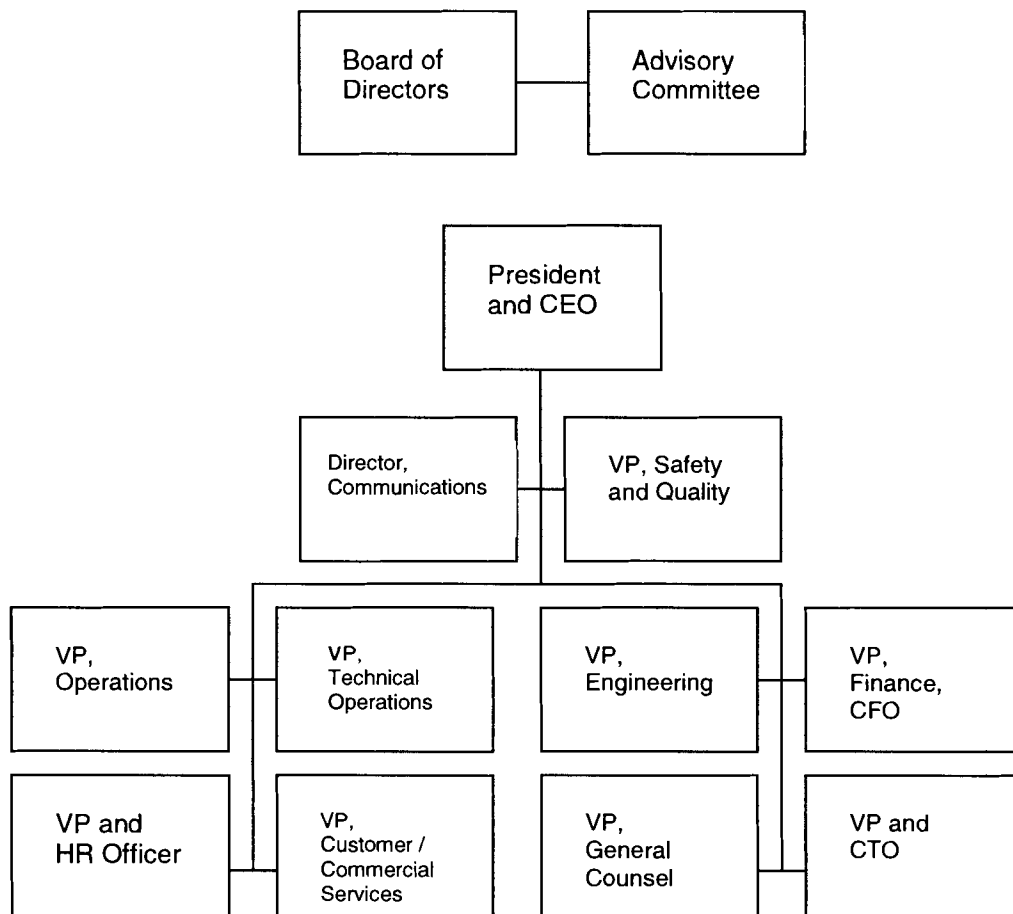
The makeup of NAV CANADA's corporate governance is described in section 1.1. ANS customers are well represented in NAV CANADA's corporate governance. Thus, delivering safe, efficient and reasonably priced services to customers is part of the company's culture. The company's employees and the Federal Government are also well represented. This governance

structure ensures that all key stakeholder groups have input into how air navigation services are provided, making for a unique yet very effective ANSP.

During the late 1990's NAV CANADA underwent a significant transformation. The company went from a regionally administered, decentralized organization to a centralized administrative structure while maintaining a regional operational focus. Headquarters, a Technical Systems Centre, a Simulation Centre and a National Operations Centre are based in Ottawa, Ontario. A National Training Institute and Conference Centre are located in Cornwall, Ontario. The company's regional facilities consist of: seven Area Control Centres, 42 control towers, 66 Flight Service Stations, six Flight Information Centres, 41 maintenance centres and over 1,000 un-staffed navigational aid sites (Nav Canada, 2005).

Generally speaking, NAV CANADA employs a functional organization structure. The organizational structure of the company is illustrated in Figure 4.1. However, like most corporate organizations it has evolved to fit its ever changing environment and does not employ a purely functional structure. For instance, the Engineering group makes use of project groups while the Operations group still maintains a certain degree of divisional focus. The divisional focus relates to the regional sites previously listed.

Figure 4.1 NAV CANADA Organizational Structure



Adapted from Nav Canada, 2005

The task of modernizing NAV CANADA's air navigation technology is a collaborative effort among many within the company, but especially among the Engineering and Operations groups. Both of these functional groups work closely to that end. It is Engineering's responsibility to provide Operations with the necessary technological capabilities to allow them to offer the best possible service to NAV CANADA's customers. Appendix 1 outlines

Engineering's organization structure while Appendix 2 outlines Operations' organization structure.

The Engineering department is responsible for evaluating NAV CANADA's operational requirements for new technology and equipment and developing or acquiring systems that meet required specifications. Engineering is organized based on the type of air navigation technology that is being supported. For example, there is a group in charge of all of the systems related to air traffic management (ATM). Another group is in charge of communications, navigation and surveillance equipment (CNS). Furthermore, project groups are employed either within the ATM or CNS groups, or as separate entities depending on the nature of the project. An example of this is the engineering team involved in implementing the Canadian Automated Air Traffic System (CAATS). Due to its large size and scope and the fact that it touches on many areas of the ANS, the CAATS team exists as an autonomous project team that does not fall under ATM or CNS. The CAATS Corporate Manager reports directly to the Vice President of Engineering.

The Engineering group is involved in a wide variety of development projects geared to advancing the technological capabilities of the company. In addition to acting as a technology deployment office, the Engineering group also executes lifecycle support activities on all of NAV CANADA's ANS technologies. This group has even successfully marketed some of its in-house developed technology solutions to other ANSPs around the world.

The Operations group is in part, organized divisionally based on the company's many regional operational sites. However as mentioned, most of the administration and engineering specialization has been centralized at the company's Technical Systems Centre in Ottawa. This group comprises the majority of NAV CANADA's workforce. It consists of air traffic controllers, flight service specialists, air traffic operations support specialists, pilots, electronic technologists, and a variety of operational specialists, instructors and managers. Their top

priority is to use their skills, knowledge, technological capabilities and training to provide the safest possible air navigation service to end-customers consisting of airlines and other aircraft operators. The people employed by the Operations group are the users of the ANS systems that are either acquired or developed by the Engineering group.

Technology requirements are channelled from the Operations group to the Engineering group through the Operational Systems Requirements (OSR) team which is part of the Operations group. OSR team members work as part of the different Engineering project teams during the development and deployment of new technology. They develop the operational requirements of new systems. They are also responsible for testing and certifying new systems, supporting in-service systems and identifying safety improvements and efficiency enhancements. This group has the critical role of ensuring that all operational facilities are capable of providing safe and efficient service to customers.

In conclusion, the organization is organized to reflect the multiple stakeholders and customers to the extent that its culture is very appropriately geared towards safety. However, balancing the introduction of new technology (that may lower costs in the long term) whilst maintaining or increasing safety and performance is not an easy task in what is already a relatively complex organization. Having a clear structure for accountability is integrated with a project structure that allows for the cross-functional work needed to introduce technology effectively. Because this balance is so critical to the technology implementation process, this brief organizational analysis leads to more detailed analysis provided in sections 4.4 and 4.5.

4.2 Business Model and Business Principles

NAV CANADA fulfils its service obligation to its customers through prudent financial management. In compliance with the ANS Act, customer service charges are set to cover the cost of operations. Air traffic, as it relates to revenue generation, and operation costs are forecast and

become the basis for customer service charges. Any revenue generated in excess of costs is passed back to customers in the form of lower customer services charges in the future. Barring any adverse events that might affect air traffic levels substantially, the company does not intend to increase service charges in fiscal year 2006.

NAV CANADA is committed to being fair and reasonable when setting service charges. The methodology used to set service charges is reviewed with customers (Nav Canada, 2005). One of the company's corporate objectives is "that growth in costs should be less than growth in traffic over the long term" (Nav Canada, 2005, p. 48). Service charges have been kept below inflation since 1999 when charges were fully implemented. This is a great achievement given the adverse industry conditions that arose to cause major decreases in air traffic figures in the aftermath of 9/11. The company has been able to "weather the storm" with cost savings through restructuring, mitigation plans and extra revenue generated through the licensing of its ANS technologies (Nav Canada, 2005).

NAV CANADA's business model facilitates a true commitment to delivering exceptional service at the lowest possible cost. The aim of the organizational structure and the business model are to provide the public with an essential service that is as safe and as cost-efficient as possible. This commitment is the focus of each of the company's functional groups.

To that end, NAV CANADA operates its business based on a few key business principles. The first one relates to safety and the reduction of risk in their systems to as low as possible (Nav Canada, 2005). It emphasizes that safety should be on each employee's mind in all of the work that they do.

The company is also very focused on their customer (Nav Canada, 2005). Providing safe and efficient services at a reasonable cost is essential to meeting the requirements of customers. Customer service goes hand-in-hand with transparency and consultation with customers on issues

like those relating to service charges (Nav Canada, 2005). In addition, the company firmly believes that sharing information with other ANSPs and implementing common systems is the way to meet the needs of mutual customers (Nav Canada, 2005).

Like the organizational structure (analyzed in section 4.1), the business model and principles are very much geared quite rightly to the goal of maximum safety and efficiency while being financially prudent. This is not an easy goal as it is almost a paradox because more money can always be spent on improving safety. Once again, this brief analysis suggested a more in-depth analysis to be done on the systems development and implementation process which appears in sections 4.4 and 4.5.

4.3 Technology Adoption Methodology

“Nav Canada believes that a modernized ANS is a safe and efficient ANS.” (Nav Canada, 2005, p. 18) The company is dedicated to modernizing the ANS in order to sustain long term operational safety. Maintaining and enhancing the technical infrastructure is a large, complex and costly task.

ANS systems communicate across operational units that belong to NAV CANADA as well as other ANSPs. These systems also communicate with systems aboard aircrafts. For this reason, corporate investments in technology are coordinated with all stakeholders. This ensures that the new technology is safely introduced (Nav Canada, 2005). As well, it ensures that customers can plan appropriate investments in their own technology (Nav Canada, 2005). And finally, it tries to ensure that acceptance of the new technology among customers and NAV CANADA staff is maximized (Nav Canada, 2005). In summation, the adoption of new technology is done in coordination with the user of the system as well as the end-customer.

In order to minimize costs, technical risks and schedule slippage, NAV CANADA employs an incremental approach to most of its technology adoption. The goal of this approach is to disrupt current operations as little as possible while deriving early benefits from new technology (Nav Canada, 2005). Therefore, implementation of new technology in operational units is paced appropriately so that safety risks associated with human performance can be managed – sometimes a new technology may require a significant learning curve. The incremental approach also gives consideration to the fact that operational units must allocate time and resources to train their controllers on the new technology.

When adopting new ANS systems, NAV CANADA uses the three sources of technology outlined in section 3.2.3. The company tries to use COTS technology whenever possible to avoid the risks associated with systems development (Nav Canada, 2005). However, as already mentioned in section 3.2.3, there could be a gap between what the COTS technology offers and NAV CANADA's requirements. Alternatively, an external contractor may be hired to develop a customized system to meet the company's specific needs. Finally, internal development may be undertaken. The Engineering group has experience acquiring (or developing), maintaining and enhancing systems originating from all three of the sources noted above.

4.4 Systems Development Capabilities

4.4.1 Skills and Competencies

The Engineering group's ability to evaluate, implement and maintain Canada's ANS infrastructure represents one of NAV CANADA's threshold competencies. This activity is essential in supporting the company's main objective of providing safe air navigation services. The Engineering group maintains and supports 122 distinct systems that comprise the ANS technology infrastructure. Many of these systems were developed and are maintained internally.

Collectively, this group has a tremendous amount of knowledge, skills and experience in evaluating and meeting NAV CANADA's ANS technology needs.

NAV CANADA delivers safety-critical services while operating in a very dynamic environment. Thus, the company must be nimble enough to deliver maximum value to customers in the face of challenging and changing circumstances. In order to do this, the Engineering group has to be able to supply the Operations group with effective technology solutions within time constraints that allow operational staff to deliver the best possible service to end-customers. To that end, the Engineering group is fully capable of delivering in-house developed systems to the Operations group in a timely fashion.

All aspects of technology development such as systems engineering, software development, testing, configuration management, hardware support, change control, installation and lifecycle support can be performed internally. Additionally, all lifecycle support is managed by managers from the Engineering group regardless of whether the system was developed in-house or purchased externally. This allows the organization to stay responsive to the needs of the user in the field.

Currently, the only technology related activity that NAV CANADA does not perform internally is hardware manufacturing. In the past, the company used to develop its own hardware, in some instances, but has given that up in favour of purchasing COTS hardware. The reasons for this are that the price of externally supplied hardware in recent years has decreased and it allows the company to implement common hardware platforms throughout the ANS infrastructure, making maintenance and enhancement easier.

One of the company's business principles is customer service focus. This applies to the end-customer as well as internal customers. One of the Engineering group's customers is

operational staff (i.e. the users of the ANS systems). Since this customer is internal, the ability to obtain fast and frequent user feedback on systems related issues is readily available.

4.4.2 Resources

The Engineering group employs approximately 450 engineering staffers. The engineering staffers include systems engineers, system architects, software developers, test and certification specialists, electronic technologists, and hardware specialists. Most of these employees work at the company's Technical Systems Centre. OSR team members are also located at this location since they work closely with members of the Engineering group. This facility provides resources for ANS systems development and operational support. At the Technical Systems Centre, systems can be developed, integrated, tested and supported to ensure that technology is safely and judiciously introduced into the field.

Generally speaking, every system development team at NAV CANADA is comprised of Engineering staff as well as OSR staff (recall that OSR is part of the Operations group). Since most OSR staffers were originally in operational positions, they offer a wealth of operational knowledge and experience that benefits every non-operational team member. As discussed in section 4.1, OSR basically links the needs of the user in the field to the work of the engineers at the Technical System Centre. There is great synergy within project teams due to this team approach.

4.4.3 Weaknesses

There are two weaknesses to note in the area of systems development. Both weaknesses are related. Firstly, project management practices are not as strong as they could be, and secondly, system testing is sometimes not stringent enough.

There is a variation across different engineering projects in the project management practices that are used. There is no consistent methodology that is employed across all technology projects. One way in which the company is addressing this weakness is by offering project management courses to its project and line managers.

Once a system has been implemented it should not exhibit unpredictable behaviour. This event may not happen often but it has happened with a NAV CANADA operational system. For an ANSP, this is of particular concern because the system is related to safety. Consequently, unpredictable behaviour causes the users of the system to lose confidence in the system. And of course, time, financial and human resources are consumed by investigating and fixing such problems.

According to a senior manager, the organization has to make more use of automation in testing. Automated software regression testing is one method to ensure that changes made to software do not inadvertently cause adverse side effects. As a software developer on the CAATS team, the author of this paper has witnessed this problem first hand. In response, his team has taken measures to address this issue by developing a regression suite of simulation scripts that is automatically run periodically to catch functionality that is broken by new software changes.

4.5 Assessment of Current System Implementations

As part of the internal analysis of the current situation, a study was conducted of the strengths and weaknesses of the current technology implementation approach. In particular, the focus of this assessment is on the nature and level of user involvement in the design and implementation of ANS systems. This has implications on the quantity of UCRs and CPs that are generated by users. This study also looks at how system changes are implemented – whether they are externally supplied or in-house developed. This influences the cost of completing the work

required for the UCRs and CPs. To gauge the current implementation process, a sample of NAV CANADA's ANS systems was studied.

4.5.1 Methodology

A sample of five systems was chosen for the study. The sample is representative of the wide range of ANS technologies that the Engineering group currently maintains. It consists of a variation of COTS, contractor-supplied and in-house developed systems. In addition, the maturity level, size and scope of the systems are very diverse. The systems chosen for the study are: the Airport Surface Detection Equipment (ASDE), the Voice Switching and Control System (VSCS), the Canadian Automated Air Traffic System (CAATS), the Gander Automated Air Traffic System (GAATS) and the Scheduling and Sequencing System (SASS). Table 4.1 briefly describes each of the systems studied.

Table 4.1 Description of ANS Systems

| System | Description¹ | Relative Size (Small / Medium / Large) | Relative Scope (Narrow / Medium / Broad) | Approximate Age² |
|---------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------|-----------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------|
| ASDE | Surface movement radar system used to control and monitor aircraft vehicle movements on the manoeuvring area of an airport. | Small | Narrow | Less than 5 years |
| VSCS | Digital switch providing clear communication capabilities for air traffic control. It gives the end-user flexibility in the assignment and use of communication resources at their positions. | Medium | Medium | Between 5 and 10 years |
| CAATS | New integrated Canadian national air traffic management system using advanced technology in software, communications, and computing equipment. The nationwide automation infrastructure will be installed at all seven Area Control Centres (ACCs) across the country. When completed, CAATS will manage over 5.8 million square miles of airspace. | Large | Broad | Currently in the process of being installed nation wide. Two of seven ACCs have already had the system installed. |
| GAATS | Controls air traffic over the North Atlantic through flight strip printing, storing flight plans, using a weather model to calculate fix times and performing conflict prediction between aircraft. | Medium | Medium | Over 30 years but re-hosted 3 times |
| SASS | Assists controllers at traffic management units in allocating available landing slots. It also ensures arrival separations are minimized at designated major airports. Flow metering also improves efficiency by dealing with inbound traffic surges or changing weather conditions which adversely affect the available capacity. | Small to Medium | Narrow | Less than 5 years |

¹ These descriptions merely summarize the very complex and varying functionality of these ANS systems.

² System installation and implementation is a gradual process that can take years to be fully completed across the country. As well, the larger the system is, the greater the time to fully install and implement it.

Most of the data about the systems was gathered through interviews with key NAV CANADA employees in charge of the systems. For ASDE, VSCS and CAATS, the corporate line manager for each system was interviewed. For GAATS, the project leader was interviewed. Her position was not as high as that of the line managers but she had vast knowledge of the technical side of GAATS as well as its history and background. The highest ranking employee interviewed was the Director of OSR. She was interviewed in order to obtain the user's perspective on the implementation process. She also contributed valuable insight into the development of SASS and CAATS.

Each interview lasted, on average, approximately one hour. The only exception was the interview with the Director of OSR which lasted approximately two hours. Appendix 3 lists the questions that were asked. The aim of these questions was to provide a framework for the interview sessions. The questions are based on and motivated by the literature review presented in Chapter 2.

In addition to interviews, primary data was also collected regarding the quantity of UCRs and CPs reported for each system in the year 2005. This data came from internal reporting tools. Table 4.2 summarizes the pertinent information gathered from all of the internal sources described above.

There is quite a wide range in the number of UCRs and CPs raised for each of the systems in Table 4.2. These numbers depend on several factors, including the system's size, scope, and maturity, which are discussed in section 4.5.2.1. It is also interesting to note that SASS is the only system completely developed internally with heavy user involvement from the very beginning of its development. This high level of early user involvement and the flexibility offered by in-house development has resulted in a relatively low number of implementation issues.

Perhaps the most significant finding from the research was the divergence in goals of Engineering and OSR team members. This issue was raised by almost all of the interviewees. This divergence in goals has negative implications on the scheduling of new, innovative system capabilities that can improve the overall safety and performance of the ANS.

Table 4.2 Current System Implementation Assessment

| System | System Origin | Source of Software Changes | Nature of User Involvement | Level of Early User Involvement in Design (H/M/L) | Use of Prototyping ³ (Y/N) | Number of UCRs and CPs for 2005 |
|--------|-----------------------------------------|----------------------------|-------------------------------------------------------------------------|---------------------------------------------------|---------------------------------------|---------------------------------|
| ASDE | COTS | contractor | OSR part of procurement team | Low | N | 48 |
| VSCS | COTS | contractor | OSR part of procurement team | Low | N | 22 |
| CAATS | custom, contractor-supplied | in-house | OSR part of development team only after the system was brought in-house | High | Y | 340 |
| GAATS | contractor-supplied (re-hosted 3 times) | in-house | OSR part of development team | Medium ⁴ | Y | 143 |
| SASS | in-house developed | in-house | OSR part of development team | High | Y | 28 |

³ Prototyping here refers to any method of eliciting user feedback during the development process (e.g. formal evaluations or spiral development cycles).

⁴ GAATS has been in operation for over 30 years and is consistently evolving out in the field. It was difficult to ascertain the exact amount of early user involvement in the design.

4.5.2 Findings from NAV CANADA System Study

The sourcing decision is generally based on whether there are commercially available systems that would nicely fit NAV CANADA's requirements. The better the fit, the less anticipated post-implementation work required for fielding the system. For example, the voice communication needs in the operational environment seem fairly standard among ANSPs so VSCS was purchased commercially. On the other hand, SASS is a system that was cheaper to design internally rather than to adapt an existing COTS system. In fact, the COTS system that was in the running against SASS was CTAS, whose development process was chronicled earlier in this paper's literature review (section 2.5.1). Note that the post-implementation work for both SASS and VSCS was relatively low (in each case there were less than 30 UCRs and CPs in 2005). In the case of SASS and VSCS the sourcing decision strategy seems to be effective in reducing the work required to operationally field the systems.

At the other end, CAATS and GAATS required substantial work in 2005 (Table 4.2). CAATS is a major new initiative and is in the process of being fielded across the country. Thus it is expected to have a higher level of implementation issues at this early stage of major implementation. In contrast, the high level of UCRs and CPs reported for GAATS in 2005 is somewhat surprising, given that GAATS has been in operation for over 30 years (although it has been re-hosted three times). Reasons for the high number of implementation issues attributed to these two systems, as well as other significant issues that came out of the interviews, are discussed in the following sections.

4.5.2.1 Unsatisfactory Condition Reports and Change Proposals

Generally speaking, UCRs are system defects that need to be corrected. On the other hand, CPs are new requirements or changes to existing requirements. In some cases, they may constitute scope creep. One manager suggested that in order to avoid scope creep, the

engineering teams require clear and unambiguous requirements early in the development cycle. Having said this, OSR and sometimes operational staff in the field discover beneficial requirements after the original requirements have been written. It is ultimately up to the Change Control Board (CCB) for each system to prioritize these new requirements.

From the user's (OSR's) perspective, small user interface issues matter a great deal. Seemingly insignificant issues like a cursor being in the wrong place when a new window is opened can cause inefficiencies in the controller's tasks. In a safety-critical and time-sensitive environment, these issues carry weight and should be investigated and corrected. In these circumstances, the developer usually does not have specific requirements to refer to. He or she makes these implementation decisions independently based on his or her own judgment. Many of these implementation decisions can result in UCRs or CPs.

Before a new system is to be implemented in the field, users from the field are brought in to test and evaluate the new system. The users identify small issues that need to be addressed as well as new or missing system requirements. These formal user evaluations allow development teams to gauge the operational readiness of the system and refine the system so that a minimum number of UCRs and CPs are raised once the system is in full operation.

The numbers of UCRs and CPs presented in the Table 4.2 must be examined with caution as they are dependent on many variables. The numbers depend on the maturity of the system – whether the system has been in operation for any length of time so that the bugs have been worked out and the users have adjusted to it – as well as the size and scope of the system. Table 4.1 provides further information on these variables. The number of UCRs and CPs also depends on how closely the system interfaces with the user's tasks and procedures. For instance, a system that is transparent to the user generally results in less post-implementation work.

Given the moderating impact of maturity, size and scope, it is surprising that GAATS generated so many UCRs and CPs in 2005. One explanation for this is that GAATS relies on requirements discovery from operational staff. Another reason is that since GAATS is deployed in Canadian controlled international airspace, it must conform to international agreements that do occasionally change. It is essentially evolving out in the field, so although it is relatively mature, it still generates a lot of post-implementation work.

4.5.2.2 System Changes

The decision to purchase a COTS system is based on how closely its features meet NAV CANADA's requirements. When NAV CANADA's requirements are judged to be fairly standard in relation to those of other ANSPs, then a COTS offering is an option. However, managers indicated that making changes to COTS software can be very costly in terms of time and money if the changes are outsourced. The costs are reduced significantly when the source code is purchased and the changes are done in-house. This activity, in addition to saving cost, gives the engineering team greater control over the changes being made.

If a change is deemed to be safety-critical then it is done regardless of the cost. However, engineering managers indicated that the cost is very high when trying to meet all of the users' requests. They attribute this to receiving numerous non-safety-related requests. Many of these changes can be categorized as "nice to have". The result is, in some cases, schedule slippage and budget overruns. In these cases a decision is made by the CCB for the project. The CCB determines the priority of UCRs and CPs and decides whether the change is absolutely necessary.

4.5.2.3 Relationship with the Users

As mentioned earlier in this chapter, the link between the users in the field and the Engineering group is the OSR team. OSR represent the users. The relationship between OSR and Engineering staffers is very important to consider because OSR generates the requirements

that need to be implemented. In addition, as already mentioned in section 4.4.2, development project teams are comprised of both OSR and Engineering staffers.

One issue that was prevalent in the interviews conducted was that although OSR was part of each development team, its goal was slightly different with respect to the implementation schedule of a system. Its goal is to improve the functionality of a given system as much as possible with less weight given to scheduling. These improvements include safety and efficiency improvements as well as minor tweaks that may, in the end, improve the system but are not critical to the system's deployment. OSR's goal is less schedule-driven than that of the rest of the development team.

In many instances, the Engineering team members are quite rightly schedule-driven because the delivery of new technology must take into account the timing of operational training needs. To them, fielding a stable and reliable system is the main priority and non-critical system tweaks and enhancements are best left to the lifecycle support stage. This view is shared by senior management. It is also consistent with NAV CANADA's incremental approach to technology adoption in that it facilitates deriving early benefits from a system and providing a path to future benefits (Nav Canada, 2005). The result of this difference in goals is that a number of change requests, in the opinion of some engineering managers, are not required for the system to be successfully fielded. This issue has in the past delayed the full implementation of a system that would otherwise generate efficiency and productivity improvements.

Although OSR's goal is not totally consistent with that of Engineering, its role is extremely vital to the successful implementation of all of NAV CANADA's ANS systems. Synergy between both groups plays an important role in optimizing the modernization process of the ANS infrastructure. The ultimate goal of both groups is to satisfy the end-customer and make air navigation as safe as possible.

4.5.2.4 CAATS

The CAATS system is a very important system for NAV CANADA going forward. Although it generated the largest number of UCRs and CPs in 2005, it is also the largest, most complex and newest systems studied in this internal analysis (Tables 4.1 and 4.2). It was originally sourced externally and built according to NAV CANADA's customized requirements and is now in the process of being implemented nationwide in all seven of the company's Area Control Centres. It represents a huge step in improving operational efficiency. At the same time, it has a large impact on its users' procedures and must be implemented with as little disruption to their work as possible, making its implementation very complex and challenging.

CAATS is the most advanced air traffic system in the world and aids the air traffic controller immensely. Fielding this system is one of NAV CANADA's top priorities. This process is very schedule-driven and determining which change requests should actually be implemented is a challenge. The CAATS CCB, which includes an OSR team member, determines the criticality of each UCR and CP. There is recognition across the company that even a "basic" version of CAATS is a vast improvement over the current technology that is at the end of its lifecycle.

4.6 Summary

In this internal analysis of NAV CANADA, the first level of analysis was performed at a fairly high level. The conclusion of the first level of the analysis is that the organizational structure, business model, business principles and the company's general technology adoption methodology are all in line with the strategic intent of the company. Furthermore, it led to the need to look deeper at the micro level into NAV CANADA's systems implementation approach.

The assessment of NAV CANADA's current system implementations was very revealing with regard to the performance of the company's technology implementation process. The

systems chosen for the study were very diverse in terms of age, functionality, size, and development source. This diversity helped uncover a broad range of strengths as well as weaknesses in the implementation process. In the end, each system implementation undertaken by NAV CANADA is a valuable opportunity to learn about what has worked well and what hasn't worked well with regard to minimizing the number of UCRs and CPs generated by the users of the system. Mistakes in one system implementation can be identified and avoided in subsequent implementations. Vice-versa, the skills, knowledge and processes employed on successful implementations can be carried forward on ensuing implementations. From the preceding analysis of some of their systems, NAV CANADA is clearly a learning organization.

In summation, this micro level of analysis has identified both strengths and weaknesses of the current technology implementation process. These are summarized in the next chapter and strategic alternatives are generated that NAV CANADA should consider in its development and implementation approach.

5 STRATEGIC ALTERNATIVES

This chapter begins by summarizing the strengths and weaknesses of NAV CANADA's technology implementation process. It generates and discusses strategic alternatives for the implementation process and evaluates them based on the company's corporate objectives. Finally, it concludes with a choice of one strategic alternative that NAV CANADA can follow to reduce the post-implementation work required for its systems while satisfying its corporate goals.

5.1 Strengths and Weaknesses of the Technology Implementation Process

Table 5.1 summarizes the strengths and weaknesses of NAV CANADA's technology implementation process. It was constructed based on the internal analysis of Chapter 4. So far in this analysis, the adoption of technology was scrutinized based on safety, cost-effectiveness and the level of user satisfaction of the implementation. The strengths and weaknesses in this table are the foundation for the generation of strategic alternatives aimed at meeting users' needs while reducing the number of system anomalies during full-scale operations.

Each criterion is related to a corporate objective of the company. Safety is the top priority of the company. After all, the aim of modernizing the ANS infrastructure is to increase the long term safety of the overall system. In addition, cost-effectiveness is critical to delivering the service at a reasonable price to the customer – service charges are set in accordance with the ANS Act so cost control is a central objective. Finally, user satisfaction is an important standard because it has implications on both the safe delivery of service and the cost associated with fielding a system. These assessment criteria are used to evaluate strategic alternatives and are in line with NAV CANADA's unwavering focus on the customer of ANS services.

Table 5.1 Strengths and Weakness of Technology Implementation Process

| Technology Implementation Assessment Criteria | Strengths of Implementation Process | Weaknesses of Implementation Process | Relevant Corporate Goals |
|------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------|
| Safety | <ul style="list-style-type: none">• Incremental approach to technology adoption• ANS expertise within Operations | <ul style="list-style-type: none">• Testing• Project Management | <ul style="list-style-type: none">• Exemplary Safety Record• Modern ANS Technology |
| Cost-Effectiveness | <ul style="list-style-type: none">• Use of COTS• Internal development capabilities | <ul style="list-style-type: none">• High number of UCRs and CPs• Outsourcing customized changes | <ul style="list-style-type: none">• Low Customer Charges• Control Growth in Costs• Modern ANS Technology |
| User Satisfaction | <ul style="list-style-type: none">• Internal development capabilities• Customer focus | <ul style="list-style-type: none">• Divergent goals of Engineering and OSR• ANS knowledge within software team | <ul style="list-style-type: none">• Exemplary Safety Record• Control Growth in Costs• Modern ANS Technology |

5.2 Identifying Alternatives

Fielding an ANS system requires coordination by different teams from separate functional groups. If the goals of these teams are inconsistent, then the result is a technology deployment project pulled in different directions. At NAV CANADA, the representatives of the users, or OSR team members, endeavour to ensure that the system is as complete as possible with less weight given to the effect that has on the implementation schedule. Consequently, new requirements may be added that only amount to small improvements and are not required for successful system implementation. On the other hand, the Engineering team has to try and meet the requirements of OSR while fielding the system according to a schedule. Ultimately, the entire deployment team must keep in mind and satisfy NAV CANADA's corporate objectives.

In view of NAV CANADA's corporate goals, the implementation of new technology must meet three critical objectives. First, the technology must be implemented judiciously while maintaining high performance levels. Second, the technology must be introduced cost-effectively. And third, the implementation must satisfy the operational users in order to be commissioned as an operational system. From the preceding analysis, three strategic options have been developed to be considered for NAV CANADA's technology implementation process. They are the "Safety Maximization Strategy", the "Cost Minimization Strategy" and the "Complete User Satisfaction Strategy".

5.2.1 Cost Minimization Strategy

The first option is to attempt to reduce the cost of implementation as much as possible while fielding a safe system. This involves scanning the market for COTS systems that would require little customization. The emphasis is on procuring a system that meets NAV CANADA's needs while minimizing the customization required. The aim of trying to adopt COTS technology is to minimize technical risks, high development costs and schedule delays while deriving benefits from advanced technology. With this strategy, fielding the system with as little schedule slippage as possible is essential to minimizing the cost of implementation.

There may be drawbacks to this strategy. It requires that the user makes a considerable effort to adapt to the new system. Costs may substantially increase if a lot of user training and overtime is required. Costs may increase if customization is to be performed by the supplier. There may not even be a COTS system available in the market that suits NAV CANADA's needs. This option carries with it safety risks as well. It is questionable whether this option is viable at all.

5.2.2 Maximize User Satisfaction Strategy

The focus of this strategy is to try and maximize user satisfaction. This option recognizes that the user is a source of innovation in the provision of air navigation service. The emphasis here is to perform work on as many system issues and change requests as possible, critical or not, before there is an attempt to field the system operationally. With this strategy, procurement would rarely ever be an option. Customized development supplied internally or externally would be required. Frequent user feedback is required during development.

This option would undoubtedly result in schedule delays and a high cost in development. As well, any safety and efficiency improvements that would be gained initially from a “basic” implementation of the system are nullified. Another drawback is that users may begin to dictate the design of systems. Therefore, inefficient user processes may simply become automated due to a lack of forward vision in the system changes that are requested.

5.2.3 Safety Maximization Strategy

This option is very closely linked to the strategic intent of the company. It focuses on implementing the safest possible system. Whether the system is COTS, contractor-supplied or in-house developed, the incremental approach to adoption is applied to minimize risks. For systems that interface closely with users, internal development is required to maintain strict control over system changes.

The new system must be stable and reliable before being installed in the field. Therefore, rigorous system testing is advocated by this strategy. The safety benefits of the new technology are realized as the full implementation moves forward. Along the way, all critical UCRs and CPs related to safety are completed. Issues that are deemed not safety-critical or add little in the way of productivity improvements are worked after the full system is deployed. In the end, this

maximizes safety since new functionality that adds efficiency improvements is not delayed. In the long term, it maximizes the productivity of operations.

This strategy mandates mutual adaptation without compromising safety. The user adapts to the new system while the system is adapted to the user's environment in order to fully exploit the benefits of the technology. The only drawback is that costs may be high in the short term due to user training and overtime.

5.2.4 Analysis of Alternatives

Choosing between these alternatives is not straightforward. In fact, although the options laid out are mutually exclusive, they also contain interrelated variables. Safety-maximization involves satisfying the users in the field to a great extent. After all, the users are the ones who have the ultimate say in whether the system is safe or not and whether or not it meets their operational needs. The question is how much of what the user's representative, OSR, wants is actually required to ensure safe deployment and operation? Which change requests are just "nice to have" and can wait until the enhancement phase of the deployment? The CCB attempts to answer these questions. But even raising "nice to have" issues and investigating their criticality constitutes a cost to the company, not too mention actually doing the development work. Thus the cost of implementation is considered, along with safety and user satisfaction, in the selection of a strategic alternative for NAV CANADA.

5.3 Strategic Choice

Choosing a strategic alternative for NAV CANADA's technology implementation process is dependent on three basic assessment criteria – safety, cost-effectiveness and user satisfaction. Safety is the top priority of the company. Safety in technology implementation is best met through incremental adoption and deriving early benefits from the full implementation of an innovative new system. Cost-effectiveness is best met through efficiency and productivity

improvements to current operations. User satisfaction is important because it has implications on both the safe delivery of service and the cost associated with fielding a new system. The user should have complete confidence in the system in order to maximize its operational performance.

After examination, weights were assigned to these criteria according to NAV CANADA's strategic intent. Each strategic alternative is scored on a scale of 1 to 10 for each criterion – 10 being the most acceptable and 1 being the least. Table 5.2 below summarizes the results.

Table 5.2 Evaluation of Alternatives

| Criterion | Weight Total = 1 | Strategic Alternative | | |
|--------------------------------|-----------------------------|------------------------------|-------------------------------------------|--------------------------------|
| | | Cost Minimization | Complete User Satisfaction | Safety Maximization |
| Safety | 0.5 | 1 | 6 | 9 |
| Cost- Effectiveness | 0.2 | 8 | 2 | 7 |
| User Satisfaction | 0.3 | 1 | 10 | 5 |
| Score | | 2.4 | 6.4 | 7.4 |

From the evaluation, NAV CANADA's best option is the "Safety Maximization Strategy" outlined in section 5.2.3. This strategy fits NAV CANADA's strategic intent very well. While the company already subscribes to a safety maximization philosophy in its technology adoption process, there were some issues that were uncovered in the internal analysis that need to be addressed. Addressing these weaknesses mitigates some of the high costs associated with dealing with excessive numbers of UCRs and CPs raised during the deployment of new systems.

6 RECOMMENDATIONS AND CONCLUSION

6.1 Recommendations

From the assessment of strategic options in Chapter 5, NAV CANADA should adopt a Safety Maximization strategy in its technology implementation approach. This strategy involves fielding a system without any critical defects and without delaying new capabilities that will improve safety and performance in the field. In order to be fully committed to this strategy, this chapter highlights some areas of the technology implementation process that NAV CANADA can strengthen. The areas that can be improved are testing, ANS-specific knowledge within software teams and the divergent goals within deployment teams.

6.1.1 Testing

There have been instances where an operational system has suffered from unpredictable behaviour. These instances happen seldom but steps can be taken to further minimize their occurrence. To do this, NAV CANADA engineering teams should advance competencies in testing, and in particular, automated regression testing. Automated regression testing is crucial in finding adverse system side effects resulting from software changes. Repeatable test scenarios are prime candidates to be automated. These detailed scenarios can be coded into test scripts that are run periodically as part of a regression test suite for a particular system. Running an automated regression test suite periodically can help identify these side effects as well as other latent system defects. All of NAV CANADA's safety-critical systems are candidates for rigorous, automated regression testing.

In addition to advancing automated testing competencies, development teams need to ensure proper unit and integration testing of their software modules. Certification test teams should not be relied upon to perform unit or integration tests. That is not their role. All software developers should allow ample time to perform the necessary unit and integration tests before propagating software into a release.

6.1.2 Air Navigation Service Knowledge within Development Teams

Small user interface issues matter to OSR and operational users. Many of these small issues are escalated to UCRs or CPs and must be investigated, developed, tested and integrated into software. Collectively, these kinds of small issues represent a substantial cost. One way to alleviate this is to advance the air traffic control knowledge of Engineering development team members including for example, systems engineers, software developers and test specialists. This aids them in making those small implementation decisions that are not part of any requirements documentation. Having OSR members on each of NAV CANADA's engineering project teams is a great source of operational experience and knowledge available to the entire team. But the operational knowledge of non-OSR team members can be augmented further in a few different ways.

As a software developer, the author of this paper learned much about the behaviour of operational staff by spending one week at the Moncton Area Control Centre. He learned first hand about the aspects of the CAATS system that air traffic controllers found helped them in their tasks. They also indicated to him user interface behaviour that could be improved. These were very minor issues but having development teams become aware of them is beneficial for future developments. For example, one controller indicated that it would be helpful if certain important flight information was more conspicuous on the screen in certain circumstances. This sort of exposure to the company's operational environment can give a developer an appreciation for

what controllers are looking for in the way of system improvements. It also gives the developer an appreciation for the utmost importance of avoiding a catastrophic system failure. The developer can take this tacit knowledge and employ it in his or her day to day development role.

Exposure to the operational environment can be achieved without having to send engineers into the field. From time to time, controllers come to the Technical Systems Centre in Ottawa to participate in user system evaluations in a simulated environment. Simply observing the controllers and how they use the system can yield valuable insights for development staff.

6.1.3 Divergent Goals

The Engineering group works closely with the Operations group to ensure that technology is implemented safely. On the whole, the goals of Engineering and Operations are very much in line. However, one issue uncovered in the internal analysis is that, in some instances, the goal of OSR is not aligned with that of Engineering. The result is that this incongruence slows down the implementation process and can forego opportunities to derive early benefit from a full system implementation.

Since OSR and Engineering collaborate so closely, they need to have the same clear mission. They are, in fact, part of the same development and implementation team. Both OSR and Engineering must be clear about the requirements of their output. During the technology deployment phase, there is a great need for OSR to prove that the changes that they request have safety implications. In addition, there must be an agreed upon measure of performance, that being safety and efficiency related. Clear goals provide all members of the implementation team with the direction and information needed to manage their work.

The task of implementing a large and complex ANS system is very challenging in itself on a technical level. The task is made even more challenging if the implementation process is

being pulled in different directions by different team members. Add to this the challenges of maintaining high performance and safety levels while controlling costs during implementation. And, ultimately, all of this is scrutinized by the Federal Government and airline customers. Managing all of this is extremely difficult. The role of senior management is crucial in helping the lower levels of the organization come to terms with the difficult challenges of ANS technology implementation.

The senior manager of each functional group sets its organization's goals. Senior management should actively clarify the goals of the implementation team as a whole. OSR and Engineering's implementation goals should be made more consistent in order to ensure that the technology implementation process is not pulled in different directions.

6.2 Conclusion

The aim of this project was to analyze and assess NAV CANADA's technology implementation process within the context of the company's primary corporate objectives – I.e. maintain one of the best safety records in the world, maintain low service charges, modernize the ANS infrastructure and control the growth of costs. To that end, this project recommends ways that NAV CANADA can attempt to maximize overall safety and minimize development costs by reducing the number of unanticipated issues during and after a system is implemented. The analysis has been based on a review of relevant literature, an examination of the ANSP industry environment, and an examination of the internal NAV CANADA environment.

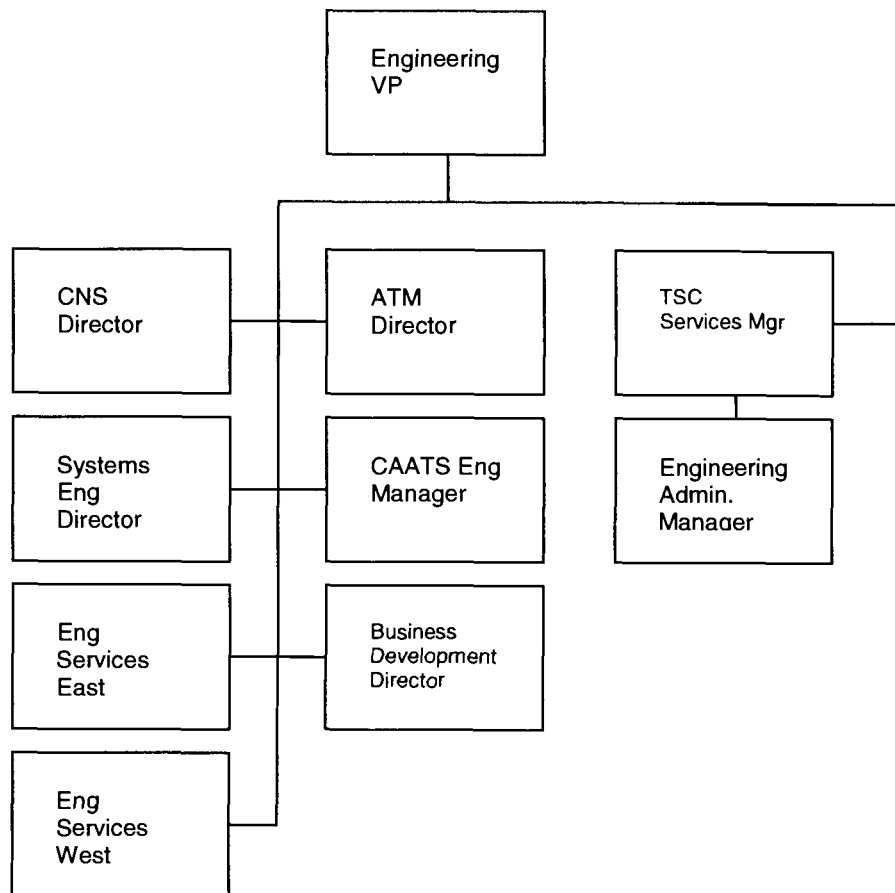
A review of research literature provided a foundation on which to assess the company's current performance with respect to implementing new technology. User involvement emerged as a way to maximize user acceptance of a new system. In addition, a firm's technical expertise and the strategic importance of a particular technology to the firm were highlighted as important dimensions in technology sourcing decisions.

An external analysis uncovered that ANSPs provide service in a very dynamic environment. For companies like NAV CANADA, forces beyond their control must be dealt with and mitigated in order to provide the safest possible air navigation service to their customers. External forces like government regulators, the air navigation industry, and key stakeholder groups invariably determine how an ANSP operates. In addition, global economic indicators, the financial health of customers and the technological environment influence NAV CANADA's need and ability to develop and implement new technology.

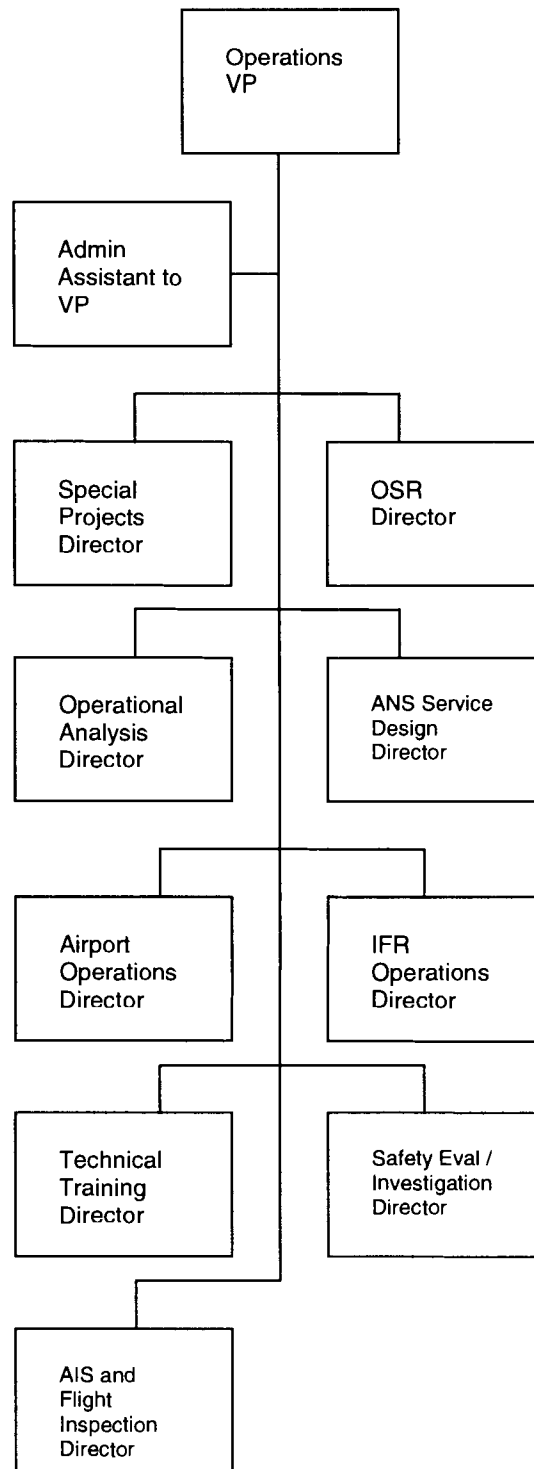
The internal analysis has shown that broadly nothing should be changed. However, at a more micro level, the assessment of NAV CANADA's current technology implementation process exposed some important issues that should be dealt with, such as, the alignment of Engineering and OSR's goals, the system testing methodology and ANS-specific knowledge within development teams. These issues that were uncovered are an inevitable part of balancing safety maximization and cost-efficiency. On the whole, the company's technology adoption approach is in line with its corporate goals. Nevertheless, addressing the issues raised will allow NAV CANADA to fully exploit its technology for safety maximization while increasing the cost-efficiency of its implementation process. The Safety Maximization strategy recommended in this project squarely focuses on inducing the safest and most efficient ANS performance with the goal of maximizing value for NAV CANADA's customers.

APPENDICES

Appendix 1 – Engineering Group Organization Chart



Appendix 2 – Operations Group Organization Chart



Appendix 3 – Interview Questions

Purpose:

The purpose of these interview questions was to gain an understanding of some of the issues surrounding the implementation of NAV CANADA's air navigation technologies.

Questions:

How long has the system been in operation?

How many fulltime employees worked on developing the project in 2005? How many of those employees worked on UCRs/CPs?

Did working on UCRs/CPs affect the scheduling of new functionality?

Is the system COTS, in-house developed or contractor-supplied? Did this present challenges in terms of satisfying the user? Or did it make it easier?

What motivated the decision? Were the benefits ever realized?

What was the nature and level of user involvement in the design? How is information about requirements elicited from users?

Is the development of the system an iterative process using a prototype? Or is the product evolving out in the field?

At what stage did the user involvement in the project begin?

Can you characterize your team's relationship with the users of your system?

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