6.4 Recommendations

Our team recommends that Canada take a leadership role in this project, more specifically that we focus our expertise in the field of space robotics, remote sensing and autonomous vehicle design for a greater role than our resources would otherwise allow. Given Canada's expertise in these areas we could provide the payload packages while other nations can be responsible for the spacecraft that will carry them to Europa.

6.5 Conclusions

Our group believes that a mission to Europa is a worthwhile goal for Canada to pursue. Given our nation's expertise in certain areas, we are in a position to contribute greatly to this enterprise. We propose that Canada takes the lead and try to involve other international partners to this cause. The benefits of undertaking the Europa missions are numerous and we believe that our nation would be greatly enriched through this experience. There are many things that Canada can contribute to the field of space exploration and there are much more to be learned. Through our participation in an Europa mission, Canadians can help answer one of humanity's earliest questions: Are we alone?

A Long-Term Space Strategy for Canada

Final Report of the 2002 National Space Awareness Workshop

Organized by the Canadian Alumni of the International Space University

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Canadian Alumni of the International Space University

Les anciens élèves canadiens de l'université internationale de l'espace

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Due to the potential presence of liquid oceans, exploration of Europa exhibits a higher probability of finding evidence of life than the current Mars projects. Hence, our team believes that if the present goal of space exploration is to look for existing life, missions to places such as Europa make more sense and should be pursued. With the National Aeronautics and Space Administration (NASA) and the European Space Agency (ESA) having Mars exploration covered for the moment, Canada can focus its attention to other areas of interest with the exploration of Europa being the most interesting in our opinion. In addition to being a part of the greatest discovery of human history if life is indeed found, the goal of looking for life beyond Earth could also focus our nation much like the space race focused the efforts of the United States. Terrestrial applications of the technologies developed for the Europa mission could have profound changes in the way our country operates.

The exploration of Europa, Jupiter's moon, is justified by the findings of the Galileo probe, which suggests the presence of liquid water oceans under its surface ice crust. In order to explore the possibility of life in these oceans, we propose an exploration mission comprised of two phases. The first phase will seek to confirm the presence of these water oceans; the second will consist of developing and using two autonomous robotic tools allowing us to explore these oceans if they exist. The first tool would drill through the surface of ice and the second, a submarine robot, would search for life in these oceans.

6.2 Background: Mission Definition

The Europa exploration project is two fold. The preliminary mission would be to survey this moon and determine its characteristics. Specifically, the presence of a liquid ocean must be confirmed and an analysis of the landing conditions and the thickness of the ice crust should be studied in order to justify the feasibility of the mission. The latter would be completed by a satellite orbiting around Europa as well as a vehicle which would perform tests on the surface. Provided the first part of the mission is successful and yields favourable results, the second phase of the mission will land a robotic probe equipped with an automated drilling mechanism and an autonomous underwater submarine type vehicle. This vehicle will survey the underwater area surrounding the drill site and search for the evidence of organic molecules and other indications of present or past life.

6.3 Benefits

Numerous benefits emanate from this mission. In particular, this project would broaden and strengthen Canada's leadership in specific space technology niches such as mining vehicles and robotic instruments. In addition, the research and development required for these missions such as the drilling instruments and underwater vehicles would enable Canada to implement spin-off applications of this new technology such as deep-water exploration. Furthermore, continuing Canada's active involvement in the space industry will build and strengthen international collaborations. Finally, a mission of this magnitude could provide Canada with a focus for its space efforts much in the same way as the race to the Moon defined NASA's focus in the 1960's. Humans have always been curious about whether life existed elsewhere and our proposed mission could help satisfy that curiosity.

6.0 Space Exploration

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6.1 Introduction

In August of 1996, the Galileo probe imaged the surface of Europa, one of Jupiter's moons. Those images strongly suggest the presence of a liquid ocean or oceans beneath the Moon's surface. If those oceans are indeed made up of water, then the likelihood of finding extraterrestrial life in our Solar System greatly increases. Our team proposes that Canada leads an international effort for a two-part mission to Europa to look for evidence of present or past life. The first part will seek to confirm the presence of these water oceans using remote sensing from an orbiting spacecraft; the second will consist of developing and using autonomous robotic tools to allow us to explore these oceans if they exist.

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5.7 Conclusions

Although there have been significant Canadian successes in space, a murky atmosphere of doubt and apprehension clouds the general public's appreciation of the space exploitation industry. Everyday Canadians know little or nothing of the past or present benefits space science and technology have provided them. Consequently, investment and public support are not as high as possible.

While promoting the past benefits of space exploitation encourages Canadians to invest in and support space programs, further commercialisation is also critical to winning support and approval, while benefiting them in key areas. Focusing on rendering space ventures profitable will strengthen the economy, without depleting natural resources, creating jobs and encouraging higher education and the retention of bright minds. Commercialisation also implies global benefits, including increased international cooperation and understanding.

There are application areas in which commercialisation efforts have been successful in the past, and where continued efforts would yield further results. New ideas with the potential for profit abound and may be the key to the future of space commercialisation. However, in order for any endeavour to succeed, market studies must be conducted to prove that space applications are appropriate. User costs must also be minimized from the outset to maximize market demand.

The CSA's program includes certain key policies that have worked well in the past, and must be continued. Namely, the CSA has a visionary strategy of international and domestic cooperation in virtually every project undertaken. However, the Canadian approach to developing space technology should include extensive involvement of non-space private organizations, in order to develop technology more relevant to its Earth-bound citizens, as well as to accelerate the technology transfer process. The CSA should also adopt a more business-like approach to space, focusing on developing applications likely to result in commercial gain for its partners. Furthermore, popularizing space exploitation and its benefits should be integral to the CSA's strategy, in order to encourage popular support and investment.

The global space industry remains government-driven, resulting in a slow and arduous technology transfer process from space to ground. Canada is no exception. While government support is essential to developing any industry, imperfect program structuring can and has resulted in an undesirable dependence on dwindling government funds. Commercialization of space exploitation is crucial to push the limits of space science and technology to their fullest potential.

5.5 Program Structure

There are aspects of the current CSA program structure that are critical to successful commercialization, and must be maintained and expanded. Prime among these aspects are domestic and international partnerships in all space-related endeavours. It is particularly important to continue the strong interaction between government, corporate and academia, for the purposes of financial risk sharing and technology transfer.

The CSA is committed to developing and applying space knowledge for the benefit of Canadians and humanity. It is impractical to fulfill that commitment by developing space applications and then trying to create a demand for them. Space experts are not terrestrial experts, and involving non-space people and corporations is critical to understanding what is needed and wanted on Earth. Armed with this knowledge, space experts can then develop space programs to bring these products and services to Earth. In addition to improving the usefulness of products and services, this approach promises a more efficient technology transfer between space and ground. The financial risks are also diminished by the development of wider partnerships.

The CSA's approach should also be refined in that government investments should not be directed toward science or technology development with no foreseeable, or only very distantly foreseeable commercial gain. Rather, funding should be directed toward creating new undertakings or improving existing programs with a substantiated potential to produce profit. This philosophy is critical to minimizing corporate dependence on meagre government funding.

The current widespread ignorance of Canadian efforts in space is a testament to insufficient attention to space education and awareness by the CSA. Millions of children are enthusiastic about space and dream of becoming astronauts, but their enthusiasm is insufficiently nurtured and only a fraction retain their enthusiasm as they become mature voters and investors. Space education should be considered an integral component of every space mission. From the planning stage onward, the project should strive to connect the mission with everyday Canadians, and especially youth. This may require a more transparent process, in terms of public interaction and publicized cost benefit analyses. Popularizing space and creating awareness of its impacts on everyday life is critical to dissolving the apprehension currently slowing investment and widespread support.

5.6 Recommendations

In order to promote the commercialization of space in Canada, the CSA should consider the following recommendations:

1. Involve space and non-space partners for risk and information sharing, and to systematically develop niche products and services for broad terrestrial markets.
2. Focus on developing new technologies that enable low cost space applications.

Preface

Aux deux ans, l'Association canadienne des anciens étudiants de l'Université Internationale de l'Espace (CAISU) organise un atelier national sur l'espace. La journée du CAISU National Space Awareness Workshop est tenue en même temps que le "Canadian Aeronautics and Space Institute (CASI) Astronautics conference". Cette année ne faisait pas exception.

L'atelier de cette année soulignait l'aspect multidisciplinaire du domaine spatial en mettant l'emphase sur le développement futur des activités spatiales canadiennes. La structure de la journée était basée sur le concept du programme d'été de l'Université Internationale de l'Espace: des conférences multidisciplinaires, une conférence avec invité d'honneur, ainsi qu'un projet où les participants devaient émettre des idées, travailler en équipe, prendre des décisions et présenter de façon succincte leurs résultats.

Le déroulement de la journée fut des plus dynamique. Après une matinée de conférences très stimulantes portant sur les divers aspects de l'espace, l'astronaute Dr. Robert B. Thirsk a présenté le périple d'un astronaute, à partir de la sélection jusqu'à la mission. Par la suite, les participants étaient séparés en six groupes pour définir leur vision d'un secteur d'activités spatiales. Cette imposante tâche a été réalisée de façon exemplaire, en seulement six heures de travail (14h à 20h).

Au nom du comité organisateur, c'est avec une grande fierté que je vous présente le fruit du travail des participants du CAISU NSAW 2002.

Bonne lecture !

Every two years, The Canadian Alumni of the International Space University (CAISU) organizes a Canada-wide activity. The one day CAISU National Space Awareness Workshop is typically held in conjunction with the Canadian Aeronautics and Space Institute (CASI) Astronautics conference. This year was no exception.

This year's workshop theme highlighted the interdisciplinary nature of space, with special emphasise on the future participation of Canada in space activities. Our intense day together was organised into a compressed International Space University session: interdisciplinary lectures, distinguished lecture, design project brainstorming, teamwork, decision-making and presentation.

The day was very exciting. After a morning of excellent and enthusiastic lectures, Dr. Robert B. Thirsk, astronaut, addressed the journey of an astronaut, from the selection to the mission. Afterwards, attendees were split into six workgroups to define their vision of different space sector activities. This daunting task has been successfully fulfilled despite a huge time constraint (six hours of work, from 14:00 to 20:00).

On behalf of the organisation committee, I am pleased to present you the work of the attendees of the 2002 CAISU NSAW.

Enjoy your reading !

Richard Giroux
Chair, CAISU NSAW 2002

Résumé Exécutif

Le Canada a toujours contribué de façon significative à l'activité spatiale internationale, autant par sa main-d'oeuvre qualifiée que par les découvertes scientifiques et les accomplissements technologiques de calibre mondial. De tels projets nécessitent des investissements et une planification stratégique de façon à conserver l'intérêts des gouvernements et du public. Ainsi, le développement d'une stratégie à long terme pour le rôle du Canada dans l'activité spatiale est impératif pour conserver notre position de leader et assurer un avenir pour les prochaines générations. Les priorités pour le programme spatial canadien dans six secteurs, telles qu'identifiées par les jeunes canadiens, sont les suivantes:

Éducation et promotion de l'espace

Il a été observé que les efforts et mesures mis en place pour la promotion et l'éducation des Canadiens en sciences spatiales se sont avérés peu efficaces. Il est évident que nos concitoyens ne peuvent que grandement bénéficier d'une information juste afin de les aider à prendre des décisions éclairées. Une fois que les Canadiens réaliseront l'influence des sciences spatiales sur la vie de tous les jours, nous prévoyons un renouveau d'intérêt pour ce domaine, résultant dans un accroissement d'investissements tant au niveau social que financier.

En ce sens, nous faisons les recommandations suivantes : premièrement, nous proposons que les organisations gouvernementales concernées, ainsi que les institutions d'enseignement, bâtissent les fondations d'une «conscience spatiale» chez les jeunes Canadiens ; en second lieu, cet éveil doit être maintenu et encouragé auprès du grand public en conservant les initiatives canadiennes en aérospatiale en avant-plan. Le développement des outils nécessaires à la réalisation de ces objectifs requiert un investissement significatif en ressources humaines

Sciences spatiales

LE SAVOIR POUR LE SAVOIR est le slogan pour ce groupe de travail. Ce savoir sert d'appui pour diversifier, agrandir et renforcer le rôle du Canada dans les activités spatiales. Un effort de R&D puissant et motivé dans les domaines de la propulsion, des débris spatiaux, de la physique théorique, de la météorologie et de la bio-technologie sont à la proue de ce document présenté par le groupe de cet atelier. Le groupe confirme aussi le thème de sa vision: **Rendre l'effort R&D visible à la masse.** Cette vision nécessire une approche pondérée afin de:

- Synchroniser les besoins de la masse et de l'industrie avec l'effort spatial,
- Développer, au sein de la communauté canadienne, l'image d'un Canada étant un acteur principal du domaine spatial en utilisant les médias de masse comme les journaux et la télévision,
- Procéder au transfert adéquat et efficace des résultats de R&D dans l'industrie,
- Développer des mécanismes améliorant la recherche, l'innovation et la créativité dans le milieu du travail.

Interagissant tous ensemble, ces éléments aident et supportent l'apport financier privé et gouvernemental de l'Agence Spatiale Canadienne, son rôle, ses activités et sa vision.

Of course, the history of space exploitation is not exclusively negative--far from it. Canadians have unique needs, and space technology has served to effectively meet some of those needs through the successful telecommunications infrastructure, ice remote sensing, and other means. These projects, while often under-appreciated by the public due to their invisibility, are nonetheless profitable and may even be considered irreplaceable.

5.3 Benefits

The majority of laypeople, and perhaps even passionate space pioneers, do not realize the benefits that can result from commercializing space. An important step toward increasing public acceptance of space exploitation, thereby increasing private investment and support, is clarifying the terrestrial benefits that result.

Commercialization, creating and expanding existing profitable ventures, of the domestic space industry will benefit Canada by broadening a knowledge-based industry with enormous potential for profit not dependant on exploiting natural resources. There is potential to create high technology jobs, which not only help to strengthen the economy, but encourage higher education and retention of highly qualified personnel (HQP). Furthermore, ventures that become profitable are invariably developed to provide improved products and services at reduced cost. There are areas of great importance to Canadians, such as agriculture, geology and environmental monitoring that have the potential to be made profitable with sufficient investment leading to the aforementioned practical benefits. Furthermore, there is a great deal of potential for profit in the form of spin-off technologies useful to Canadians, such as telemedicine.

There are also a number of global benefits to be achieved by commercializing space exploitation. Developing profitable ventures attracts partners, which provides an increasingly strong basis for international cooperation. Furthermore, focusing development efforts on commercially sound undertakings generates increased knowledge of practical science applications, as well as increased availability of low cost technology.

5.4 Applications

Identifying areas of interest to Canadians where benefits are conceivable is not sufficient to determining what applications should be developed. Detailed market studies are essential not only to gain confidence that the potential for profit exists, but also to ensure the profit can be made from space. One has only to consider the example of Iridium to understand that useful applications of space technology with the potential for profit are not commercially sound if terrestrial alternatives can be developed more quickly and inexpensively.

There exist broadly based applications that have been proven to have a market both domestically and internationally. These include agriculture, geology, environmental monitoring, and navigation. A wealth of exciting new application ideas also exists, such as space tourism, space entertainment, and extensions of blue-tooth technology.

In addition to proven interest, in order for a space application to be commercial, user costs must be kept low. High user costs dramatically decrease the potential market, making it impossible to earn a profit return adequate for further development.

Insufficient inclusion of non-space private organizations slows the technology transfer process from space to ground; inadequate popularization of space exploitation and its benefits discourages critical public support; an insufficiently business-like approach results in a slow development of applications likely to result in profit for its partners.

The global space industry remains government-driven, and Canada is no exception. Commercialization of space exploitation is crucial to push the limits of space science and technology to their fullest potential.

5.2 Background

"Commercialization" is a word often associated with greed or unjust exploitation. There are many reasons more compelling than profit to drive technological and scientific advancement, particularly when it comes to space. Reasons such as social progress and amelioration of daily life are why science and technology exist to begin with. Unfortunately, no goal can be accomplished, however noble, without the necessary resources. Prime among those resources is money. Consumers pay for what they want and what they need. Stimulating the intellectual curiosity of the public is admirable, but ultimately what they are not willing to pay for they neither need nor want. Profit is fundamentally a measure of practicality.

In that light, many past and present space science and technology projects have shown a great deal of impracticality. Of course, space is still a fledgling industry and commercialization takes time, but are there ways of accelerating and facilitating the process? Specifically, is Canada on the right path to commercialize space?

The road to space has been paved with stunning successes and shocking failures. Unlike any other industry, space exploitation developed directly in the public eye. Thousands of laypeople watched alongside scientists and engineers as rockets screamed into space and as astronauts set foot on the moon. They also watched as STS-51L exploded, killing its seven passengers, and read about NASA losing millions of dollars on the Mars Climate Orbiter due to unit conversion errors. Many members of the public know about the millions lost on the Mars Polar Lander mission, but comparatively few know about the successful installation of the Mobile Base System (MBS) on the International Space Station (ISS).

Space missions are inherently frightening to the uninitiated. In addition to the widespread popularization of catastrophic failures, space missions involve such highly complex technology that it alienates the public. The expression 'rocket science' is commonly used to describe anything complicated or mysterious, a sign that the public views space technology as cryptic and obscure. This has all led to the development of apprehension and mistrust surrounding the space industry, which is a significant deterrent both to public approval and investment critical to further development.

This problem has been exacerbated in part by the Canadian government's approach. The CSA's strategy has been to focus its modest budget on niche technologies where Canada could gain a foothold in the international space development scene. To a layperson, applications such as space robotics do not readily appear as beneficial to life on Earth. Considering that for many Canadians, the Canadarm is the symbol of Canadian space technology, very few can outline the terrestrial benefits derived from its development. Furthermore, developing this kind of technology costs a significant fraction of the CSA's budget, straining the funding devoted to other, possibly more profitable or beneficial projects.

Les humains dans l'espace

La présence humaine dans l'espace a impliqué la recherche et le développement de plusieurs nouveaux instruments, traitements et stratégies de prévention pour assurer le bien-être des astronautes dans l'environnement extrême qu'est l'espace. De façon analogue, la population canadienne et le système de soins de santé font face à des défis uniques requérants le développement de nouveaux traitements, instruments et moyens de prévention. Les innovations canadiennes assurant une présence humaine sécuritaire dans l'espace peuvent également bénéficier au programme spatial et à la santé des canadiens et devraient être transposées dans le service de soins de santé, où des similitudes peuvent être trouvées.

Ainsi, l'assurance de la santé des astronautes devrait être basée sur un modèle de soins préventifs, incluant la télé-médecine. De plus, les résultats des recherches sur le vieillissement, les facteurs de stress psychologique et physique en plus des maladies, pourraient être directement transposés dans le système de soins de santé canadien.

Géomatique et télécommunication par satellites

Le positionnement stratégique du Canada en géomatique et en télécommunication par satellites entraînera la création de nombreux emplois de qualité et assurera au Canada une visibilité internationale. De plus, les innovations technologiques développées pourront être mises à profit dans des applications connexes (transfert de technologies).

Il faudrait uniformiser les données de télédétection afin de pouvoir les intégrer facilement dans un système d'information géographique et ainsi obtenir une technologie à coûts réduit. Également, il faudrait utiliser la télédétection pour des cas d'actualité important comme les changements climatiques afin d'analyser les impacts.

Le Canada aurait intérêt à utiliser les communications à larges bandes pour répondre aux besoins de sa clientèle. Il serait également bon de rendre accessible le plus possible les données recueillies par télédétection à la communauté dispersée d'un océan à l'autre. Il serait important que le Canada continue la recherche dans ce domaine pour demeurer un chef de file dans la télécommunication.

Nous croyons finalement que le Canada devrait continuer ses recherches en géomatique afin de garder son avancement au niveau international et développer l'expertise des systèmes intégrés pour réduire les coûts de cette technologie tout en augmentant son utilisation. Les entreprise qui envoient des satellites doivent de respecter l'environnement spatial. Ainsi, nous croyons également que le Canada devrait être initiateur et participer activement dans un programme de gérance des débris spatiaux.

Commercialisation et technologies spatiales

Des applications profitables existent et continuent à être développées, et plusieurs nouvelles idées prometteuses émergent. Par contre, pour éviter les erreurs du passé, des études doivent être complétées afin d'assurer non seulement que le potentiel pour générer des profits existe, mais que ces profits peuvent être réalisés de l'espace, en assurant que les coûts de l'usager demeurent minimes.

Le programme de l'Agence Spatiale Canadienne (ASC) dépend sur des accords internationaux et intérieurs pour la majorité de ses projets - une politique brillante. Par contre, la structure du programme comprend aussi des faiblesses notables. La participation insuffisante des industries non-spatiales ralentit l'échange de technologie entre l'espace et la Terre; la promotion inadéquate de l'industrie d'exploitation spatiale et ses bienfaits décourage l'appui important du public; une approche insuffisamment commerciale cause un ralentissement du développement minimisant les profits pour ses partenaires.

L'industrie spatiale globale demeure dépendante des fonds gouvernementaux, et le Canada n'est pas une exception. La commercialisation de l'industrie d'exploitation spatiale est fondamentale afin de pousser les limites de la science et la technologie spatiale vers leur plein potentiel.

Afin de promouvoir la commercialisation de l'espace au Canada, l'ASC devrait considérer les recommandations suivantes:

- Concentrer sur le développement de nouvelles technologies pour réduire les coûts l'applications spatiales.
- Développer systématiquement des produits pour des créneaux ciblés et des services pour de vastes marchés, en incluant les industries spatiales et non-spatiales afin de partager les informations et les risques.

Exploration spatiale

L'exploration d'Europa, la lune de Jupiter, est justifiée par l'information recueillie par la sonde Galileo suggérant la présence d'un océan d'eau liquide sous sa surface glacée. Dans le but d'explorer la possibilité de la présence de vie dans cet environnement liquide, nous proposons une mission d'exploration vers Europa en deux phases. La première consiste à confirmer la présence de cette eau liquide, tandis que la seconde consiste à développer et à utiliser les outils permettant l'exploration de ces océans, s'ils existent. Entre autre, les outils nécessaires pourraient consister en un outil de perforation de type minier pour traverser la surface glacée et un robot de type sous-marin pour explorer et détecter la vie dans l'océan.

* * *

Le rapport expose les recommandations de chaque groupe dans des sections respectives. Néanmoins, des similarités apparaissent dans plusieurs groupes. Parmi celles-ci, notons la volonté de mettre des efforts dans des secteurs en émergence avec des retombées spécifiques pour les Canadiens (agriculture, géologie, surveillance de l'environnement, navigation, télé-médecine, télé-éducation), la nécessité du travail multidisciplinaire et de l'intégration de la technologie, le besoin d'un renouveau de pensée dans l'éducation spatiale et surtout, l'obligation de transparence par rapport au public et de les tenir informés des bénéfices sur terre de l'activité spatiale.

5.0 Commercialization and space technologies

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5.1 Introduction

The space exploitation industry's growth rate remains far below what it could be. An important reason behind this is the widespread disinterest of the general public. Although there have been significant successes in space, everyday Canadians know little or nothing of the past or present benefits space science and technology have provided them.

While promoting the past benefits of space exploitation encourages Canadians to invest in and support space programs, further commercialisation is also key to winning support and approval. Focusing on rendering space ventures profitable will strengthen the economy, without depleting natural resources, creating jobs and encouraging higher education and the retention of bright minds.

Profitable applications exist and continue to develop, and many new promising ideas are emerging. However, in order to avoid repeating past errors, careful studies need to be conducted to prove not only that the potential for profit exists, but also that the profit can be made from space, while maintaining reasonable user costs.

The CSA's program promotes and relies on international and domestic cooperation in virtually every project undertaken, a brilliant policy. However, the program structure also includes notable weaknesses.

They also create high-tech jobs for Canadians and maintain Canada's comparative advantage on an international scale. Finally, geomatics and telecommunications technologies are readily transferable technologies, allowing expertise to be directed from one field to other areas of research.

The benefits of telecommunications are also numerous. This technology allows communication to remote areas, and makes tele-medicine and tele-education possible in these areas. Telecommunications also create jobs, and participate in the area of emergency response. These applications are particularly suited to Canada, given our vast expanse of land and high numbers of rural and remote communities.

4.4 Recommendations

In the area of geomatics, we recommend making spatial data usable to the public by adopting a standard format and by lowering the cost of data. We also suggest an issue-driven use of geomatics, and a selective and strategic development of new technology beyond current expertise. Finally, we recommend an integration of geomatics and telecommunications technologies, which would permit greater advancements and wider applications of these technologies.

In the area of telecommunications, we recommend the development of a wider bandwidth to service remote communities. We also suggest addressing issues that can be solved by geomatics and telecommunications, such as improving remote communications. Finally, we recommend maintaining a leadership role in tele-health and tele-education, which would be an application of the technology with great benefits to many remote Canadian communities. In carrying out these recommendations, we also recommend that Canada participate actively and responsibly in a space debris control program, by respecting the international space environment.

4.5 Conclusions

In conclusion, Canada currently occupies a leadership role in geomatics and telecommunications, and this leadership position needs to be maintained. Technology must be used to offer solutions uniquely applicable to Canada, and an effort to integrate separate and compatible technologies must be made in order for greater progress to be possible. With the current rate of advancement in geomatics and telecommunications, and the wide range of problems that these technologies have the potential to address, there is no doubt that great progress will be made in these important areas of Canada's space program.

Executive Summary

Canada continues to make important contributions to the global space community in terms of both human resources and world class science and technology. Such operations require significant funding and solid strategic planning to ensure that governmental and public support is continued. Thus, development of a long-term strategy for Canada's role in the space industry is vital to continued success. The priorities identified for the Canadian space program in 6 key areas, as perceived by Canadian youth are as follows:

Public Outreach and Education – Build space awareness among both the Canadian youth, and general public then maintain it through increasing the visibility of space-related activities.

Space Science – Focus new research efforts on propulsion, space debris, biological adaptation technologies, and theoretical physics, with continuing research in symbiosis, downstreaming technologies, and meteorological modelling.

Humans in Space – Ensuring a healthy human presence in space should be based on a preventive model of care in which innovations such as telemedicine, and results of research on aging, psychological and physical stressors in addition to illness, can be translated directly to our health care system to address parallel Canadian issues.

Geomatics and Communication – More user-friendly, issue-driven, and integrated use of technologies with strategic development of new technology.

Commercialization and Space Technologies – The Canadian Space Agency should adopt a more business-like approach to space, focusing on developing applications likely to result in commercial gain for its partners.

Space Exploration – Support a 2-phase exploration mission to Jupiter's moon Europa with a view to finding extraterrestrial life.

* * *

Although the report is divided to reflect suggestions put forward by each working group individually, overall several general themes emerged, each supported by multiple groups. These include a desire to focus on developing areas with applicability to the specific interests of Canadians (such as agriculture, geology, environmental monitoring, navigation, telemedicine, teleducation), the need for integration of disciplines and technologies, the insufficient attention to space education and the desire to foster a knowledge-based industry, and the need to increase public awareness of space activities by clarifying terrestrial benefits of space research and technology.

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4.0 Geomatics and communication

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4.1 Introduction

The technologies of remote sensing, geomatics and telecommunications have been developed fairly recently, but they have already seen great advancements. Its applications are widespread and used on a daily basis, such as GPS positioning and long-distance communications. The current rate of progress in this field suggests that geomatics and telecommunications will continue to grow in importance in the coming years. For this reason it is important to have knowledge of the benefits and possibilities of this technology.

4.2 Background

The field of geomatics and telecommunications is relatively new, and thus the full potential of the technology has yet to be attained. Currently, geomatics and remote sensing technologies are used in several domains, such as mapping, navigation and long distance communication. Canada's primary contribution to the field of geomatics is the first Canadian earth observation satellite, RADARSAT-1, which was developed mainly as a means to monitor ice. The success of RADARSAT-1, as well as other geomatics and telecommunications technologies in Canada suggests future applications that could be made.

4.3 Benefits

There are many benefits associated with the technology of geomatics and telecommunications. Geomatics allow easy access to spatial information for Canadians. These technologies play an important role in navigation and position monitoring, natural resource monitoring, and natural hazard management and assessment, to name a few applications.

a) Psychological selection issues – using psychological selection criteria for space missions as well as the psychological conditions faced by astronauts on their mission, Canadian industry can benefit by better understanding the factors that influence those that work in isolated conditions such as in the north, ocean vessels or military operations. Likewise, such scenarios here in Canada could serve as research models that could enhance mission team selection by enhancing our knowledge of group dynamics and isolation.

b) Aging and Illness –The deleterious effects incurred by astronauts' musculoskeletal and cardiovascular systems have provided potential models in which to study aging, osteoporosis and cardiovascular function. These are just a few potential ailments that can be investigated in a microgravity environment, however they are becoming increasingly significant as our "baby-boomer" population grows and the prevalence of osteoporosis and heart disease increases. Thus, ensuring that experimental research in the space program can directly benefit the health of Canadians is imperative.

c) Physical/physiological stressors – Once again the space environment can be harsh with the astronauts required to perform under possible exposure to radiation, heat stress, decompression sickness, noise and sleep impairment. The knowledge gained from developments in these areas may have potential benefits to Occupational Health & Safety programs in Canadian industry. For example, new standards for industrial exposure to heat stress or radiation may be developed or possible protective measures may be improved to enhance ones performance in extreme environments. Also, treatment and prevention protocols in decompression sickness can be improved. A better understanding of sleep disorders and circadian function would benefit shift-workers.

3.5 Conclusions

Canada's unique geography, population and health care system make it an ideal place to apply space-based developments. Parallels between current health care needs in Canada and current operational space medicine practices could be mutually beneficial. While this group focused on the human presence in space it is important to note that such application of space technology to our health care system would require the integration of both health science personnel and those with technical and /or engineering expertise. Cooperation between disciplines would be essential for translating aerospace technologies to the eventual enhancement of health care delivery in Canada.

In addition to improved telemedicine programs, diagnostics and monitoring as a result of space technology, a firm commitment to fundamental research and the advancement of knowledge in the life sciences is essential. It is fundamental research that will improve our understanding of physiologic function and mechanisms of disease, ultimately leading to advanced treatments.

Canadian industry should also cooperate with the space program to improve the quality of health and human performance for workers across Canada. Research of the tremendous physical and physiological stresses of the space environment and Canadian industry should be aggressively shared to enhance the occupational safety and health of Canadians.

While numerous areas of mutual benefit between the Canadian space program and Canadian society have been identified, facilitating the transfer of such benefits is complex. In order for such programs to be realized there must be coordination of committed personnel involved in the Canadian space program, the government and on the front lines of health care. Such a strategic plan would also involve the continued promotion of the space program to young talented students and professionals by Canada's current representatives in the field.

1.0 Public outreach and Education

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1.1 Introduction

Promotion of, and educating Canadians in space science has been less than successful. A greater understanding of the magnitude of impact space science has on every day life could be a key factor in increasing both social and financial investment in space.

Education and public outreach are essential for the success of any space science program. The level of space consciousness of Canadians must be built and maintained in order to ensure the survival of quality programs which directly impact upon daily life. The future of space science is also intimately linked with both knowledge and finances. Because people are at the centre of space exploration, human resources must be nurtured as a viable investment.

1.2 Background

Space content diffusion to Canadians is deficient in both quantity and quality. The responsible agencies have been lagging in their commitment to the promotion of Canadian space science and technology. There is a genuine will from the space organizations – both in government and industry - to achieve this goal. Nevertheless, few definitive and efficient actions have been observed.

General space-related information is available from a variety of sources, but information on Canadian accomplishments and content is sparse and hard to find. In the 1990s, this gap was filled rather successfully by the Canadian Space Resource Centres (CSRCs). However, administrative difficulties led to the closure of the CSRCs, which were replaced by an alliance of science centres and museums.

3.3 Benefits

Presently many Canadians would agree that access to “universal” health care, as stated in the Canada Health Act, is substandard and in fact not “universal”. Benefits of implementing telemedicine programs in Canada would improve rural healthcare delivery and patient monitoring. If patients in remote communities could be monitored, diagnosed or even treated via telemedicine protocols “universal” health care to all Canadians could be improved. In addition to giving remote citizens access to better health care, the cost of transporting such patients to major centers can be reduced. Also, if patients can be monitored on a long-term basis, health care professionals would be in a better position to diagnose and treat patients early before ailments become more serious leading to reduced quality of life and more costly treatments. Such long-term monitoring of our citizens’ health is a preventative and cost effective approach to health care.

Research on the function of physiological systems in extreme environments has many benefits. Firstly, increased knowledge of exposure to physical stressors such as radiation, noise and heat can lead to advancements in workplace health and safety in Canadian industry. Such advances might include new standards for exposure to radiation, or heat stress as well as possible treatments for decompression sickness and sleep disorders. Additional benefits from space life science research are advances in the physiological knowledge base (aging, cardiovascular function etc), creation of new disease research models, and innovation of new biological or synthetic products.

3.4 Recommendations

1. The CSA should become a leader in the cross-disciplinary integration of health science expertise and technology. Specifically, telemedicine technologies could be developed to enhance our delivery of health care to remote communities. Required developments here in Canada would include virtual offices, devices/hardware (kit), satellite communication, and emergency treatment protocols. This would allow for long-term monitoring and diagnosis of patients in remote areas as well as the development of emergency treatment protocols thus making emergency treatments possible in under-serviced communities. Just as space doesn’t respect distance, unfortunately nor does the Canadian Health Act at the present time.

2. The CSA should support a health care delivery model that focuses on prevention. This recommendation addresses two issues. Firstly, improvements in medical evaluation associated with astronaut selection might also lead to the advances in screening tests, early diagnosis and job selection procedures useful to all Canadians. Secondly, with the advancement of telemedicine, health professionals can increase their ability to monitor and diagnose patients in remote communities. Improved monitoring and diagnostics will enhance the prevention of more serious and costly illness. Through this approach we can decrease the number of patients requiring immediate hospital care. The prevention of disease (pro-active) has proven to be more cost effective than a treatment system that is reactive in nature.

3. Enhance the transfer of knowledge between the findings achieved in the aerospace medical field and those responsible for human health and performance in Canadian society. Understanding the extreme environment of space can enhance our practices in handling issues for Canadians that work in extreme environments. For example:

3.0 Humans in space

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3.1 Introduction

Ongoing human presence in space has led to research on, and development of many new medical instruments, treatments and prevention strategies to ensure the health of astronauts in the extreme environment of space. Similarly, Canada's population and health care system are facing unique challenges requiring the development of new treatments, instrumentation and preventative measures. Canada's innovations to ensure a healthy human presence in space could be mutually beneficial to the space program and the health of Canadians and should therefore be translated to our health care system to address parallel problems.

3.2 Background

Canada is unique in a variety of ways including its geographical size, multiculturalism, and universal health care system. Health care issues facing the Canadian population include access to medical care, an increasing elderly age group and a presently reactive rather than proactive process of patient care and disease treatment. Current health science issues might be addressed by advances in aerospace medical technology.

Areas of current interest at the Canadian Space Agency (CSA) include decompression sickness, nutrition, crew selection, countermeasures, acoustics, radiation, telehealth, psychology, and sleep/fatigue. While these areas can be specific application to aerospace medical operations, results of research in these domains should also be translated into the Canadian health care system to benefit workplace safety, healthcare and human performance in Canadian society.

Unfortunately, most of these institutions have a broader mandate to promote science and technology in general. The result has been a loss of focus toward space science content. Currently despite mitigation efforts, significant improvement in public awareness has not occurred, nor is it expected to, so as long as the programs remain out of the public eye.

1.3 Benefits

It is important for the general public to realize the extent to which the space sector affects their everyday lives, through telecommunications, weather forecasting, environmental surveillance, and national security, among other facets. More awareness will undoubtedly result in more appreciation for space science and technology. Once Canadians appreciate the value of this field, they will be able to make informed decisions about their future. This, in turn, will encourage new investment, and provide opportunities for young Canadians to enter this field, therefore keeping our expertise in Canada. There are many benefits to public outreach and education programs. The goals of such programs include:

- To sustain, improve and motivate the next generation of space scientists;
- To create more jobs in Canada;
- To make space, in all its form, attractive;
- To encourage the multi-career aspect of space;
- To bring about more challenges – keep Canadian brains home;
- To encourage idle brains;
- To expose more people to space hence more voters to push the politicians;
- To present information in a more attractive package; and,
- To brings new ideas, opportunities and educated replacements.

1.4 Recommendations

Build the Consciousness ….Maintain the Consciousness!

Governmental organisations such as the Canadian Space Agency (CSA) and educational institutions etc. should strive to build a significant foundation of space "consciousness" in Canada's youth. This could be achieved by supporting activities that promote a space-culture within Canadian schools such as: networking between industry and educational institutions, real time experiments that collect actual data, and use of available resources and media for communicating current space news. This approach will build the consciousness of Canada's youth by using space to generate an appreciation of everyday science.

Once the seed is planted, it is important to maintain this consciousness within the general public. Keeping space initiatives and achievements constantly in the public eye would integrate space technology into our everyday lives. This could be done by having designated CSA positions that package information for various sectors including direct media, regional education, industry, conferences etc. Perhaps a shift in philosophy must occur such that money spent on public outreach and space education is seen as an investment in all facets of Canada's future.

Developing the tools to accomplish these goals will require a definite investment in human resources. We need people to communicate a passion for space. An education department in the CSA that more aggressively builds and maintains this "space consciousness" is needed. An extension of this could be to build an autonomous Canadian Teacher in Space Program which could be funded by a partnership between regional boards of education and industry. We need to bridge the gap between Canadians and the space industry by bringing space down to Earth. Educating the Canadian public will enhance our lives as well as encourage space technology in other countries.

Canadian Youth	Tools	Canadian Public
• Career days with under-grads and professionals • Partnerships between industry and students ("*space for species*") • Science fairs with experts • Young people teach students (peer education) • CSA at teacher conferences • Authentic view of Science – authentic research, real-time science • Exchanges – teachers, students • In class expert visits • Teachers follow space missions – pre and post activities • Many options to compete with interest but Space is a valid option • Newsletters • Interactive computer programs, live links • Get industry involved in the process of education • Parents, siblings, family environment share	• Bring back CSRC • Education dept. of CSA with all provinces • More distributed areas – more people on board • Web site enhancement – tutorials, videos • More qualified educators • Raise % of funding for education • Regional presence of CSA • Bring space down to Earth • Broaden awareness of Space effects in our daily lives • More specific information with Canadian content • Developing countries use other countries space technology • Explain rationale for space	• Justify use of money – information, shift focus and philosophy • Good business investment • Good communicators – help industry employees • More support for conferences – visual print resources • CSA hire media reports for space activities. Keep it in the public eye, increased presence of • Space science to engage public in science

1.5 Conclusions

We believe society will invest in endeavours they understand. It is therefore crucial to ensure the proper dissemination of accurate information. Their support will influence the decision makers whether they are at the educational, corporate or governmental level. Let us remember that knowledge is the only resource that when used, multiplies!

2.4.5 Promote Canadian innovation and creativity into the workplace

The Canadian space industry has a relatively small budget; and small budgets require innovative ideas to solve technological problems. Innovative solutions can be produced by promoting creativity in the workplace. Companies involved in the space industry should be encouraged to designate a specific amount of time during each work week, perhaps a Friday afternoon, for employees to pursue their own research interests on company time, using company resources. Employees would discuss the progress of their projects at monthly meetings. This exercise will promote creativity and the development of new ideas for the company. Company morale and thus productivity will also increase because happy employees are willing to give more back to their place of employment.

2.5 Conclusions

Canada needs to diversify its role in space through broadened R&D efforts on topics such as propulsion, space debris, theoretical physics, meteorological modelling, and biological technologies. In addition, the group also recommends its vision of making the R&D effort visible through approaches such as tailoring research to meet both population and industry needs, enhanced and mass-marketed imagery of Canada in space using popular media, efficient downstreaming of technologies, and industry-wide mechanisms to promote Canadian innovation and creativity in the workplace.

2.4.2 Continuing Research

- **Symbiosis.** Research should continue on the study of interactions between living organisms in space. It is imperative that we understand how human beings interact with other living organisms from plants to insects and animals. As space flight duration increases, so will the need for biological organisms aboard the spacecraft. For long-duration space flight, plants may be used to help provide oxygen, and remove carbon dioxide. For the deep-space missions of the future, it will be necessary for spacecraft to be self-sustainable; therefore food and water will need to be produced aboard the spacecraft. In order for this to be possible we will first need to understand how all biological species interact with each other in a microgravity environment.
- **Down streaming technologies.** The Canadian government does not fund the Canadian Space Agency to the same extent as many other governments fund their respective space agencies. We believe this is due to the fact that the average Canadian does not support space research; at least not when health and education budgets are being cut. Many of the advances from space science benefit the average Canadian, however this information is not readily available. We propose that the Canadian Space Agency develop a program to introduce the public to current and past developments in space science, as well as the technological advances that have resulted from space science. It can then be shown how these advances impact the life of the average person. An example would be earth-bound applications of medical research conducted in space.
- **Meteorological modelling.** Canada has a very unique geography due to its vast size and northern latitude, making it especially susceptible to changes in weather patterns. With global warming reaching record highs, scientists are having difficulty predicting yearly climate change. The long-term effect global warming on the Canadian climate is unknown. Canada is the current world leader in remote sensing; therefore this technology should be used to gather data on Canadian climate changes. This information could then be used to form meteorological models to be used to predict both short-term and long-term climate changes.

2.4.3 Diversification of Canada's role into space arena

The Canadian space industry relies heavily on its partnership with the United States. Although this partnership is both necessary and mutually beneficial, Canada is undeniably the more dependant partner. Currently Canada is given access to the space shuttle and international space station (ISS) in return for its contribution to the ISS project, namely the SRMS. Although Canada will likely remain the world leader in space robotics for some time, this may not always be enough to ensure our place in the global space arena. Canada needs to diversify its role in the space partnership. By having more to offer in the way of technology, Canada could ensure more Canadian content on space missions. This would enable the launch of more Canadian experiments. The Canadian space industry would also benefit from having a Canadian launch vehicle capable of launching satellites with experiments that are pertinent to Canadian people.

2.4.4 Private funding for the CSA

The CSA is currently working with a modest budget, due to a lack of government funding. Therefore it is necessary for the Canadian space industry to approach the private sector for funding. By sharing technology, companies could partner up to cover the cost of research and development for space applications. For example, the robotic technology used for the Canadarm 1 & 2 may have applications here on earth. If a mining company was interested in this technology, they could help to fund the R&D costs for future developments and use that information for their own applications.

2.0 Space Science

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2.1 Introduction

In an era of international level competition in space research, we feel the need for a more self-reliant space program in Canada, with less reliance on foreign assistance, particularly from the United States. This will encourage a stronger feeling of community in our nation. In turn, this encourages more private funding and public awareness of technological advances. With this increase of both revenues and interests, the Canadian Space Agency (CSA) will be better focused on the desires of society.

Canada needs to continue developing its strength in space science in the research and development of new propulsion technologies, launch systems, spaces debris management among others. "Knowledge for Knowledge" is the motto adopted by our Space Science group in this workshop.

2.2 Background

The basis for all the sciences is a curiosity to acquire new knowledge and ideas, which in turn promotes innovations and competitiveness. Canada is focussing on training and its “retention of brains" policy, as well as the expansion of national pride of a Canada into space. Applications currently being developed by Canada in the space science field include:

- Astronomy: with new Earth observation missions and microsatellite projects;
- Space and atmospheric environment studies to understand global environment changes;
- Microgravity sciences to improve our understanding of material structure and behaviour in space environment.

Trends and tendencies in the Space Science Technology Program are founded on cost-efficient experiments in the niche areas Canada has carved for itself: robotics and remote sensing. These trends should be supported, as should ongoing research and development to maintain Canada as a world leader in these fields.

2.3 Benefits

The benefits of space science research in Canada can be grouped into short and long-term effects. Some areas which benefit immediately from space science include the study of the earth’s atmosphere and global warming, microgravity studies and the near-space environment which includes the topics of orbital debris and the earth’s magnetic field. Also, the many unanswered questions about the history of our planet and of the universe can only be explored with the use of space science. One of the most beneficial aspects of space science, however, is its effect on non-space related technologies for the betterment of mankind. If Canada continues to show leadership in space robotics, satellite imagery, and telecommunications, then other industries which use similar technologies downstream would only be strengthened.

Long term benefits will be realized by learning more about other bodies in space such as Mars or Europa, through which we can learn more about the earth and thereby improve our quality of life. The search for life within our solar system can only be initiated with the use of space science research, just as the results of such a search can be explained by it. Space science will also provide answers to questions regarding interplanetary human space travel, which will soon become a reality. The overall long-term benefit is that space science is aimed at improving the well-being of society as a whole.

2.4 Recommendations

2.4.1 New Research

Emphasizing Canada’s heritage of innovation in the face of harsh climatic conditions for the betterment of society’s needs in communication, transportation and materials processing, new research efforts should be enhanced in 5 areas:

- **Propulsion**. Canada should prepare to become a world leader in new propulsion technologies. This is key and analogous to the United States early Goddard rockets experiments. The group recommends using new propulsion technologies, particularly nuclear propulsion, for niche space exploration areas such as lunar launches and space debris handling. This field, although not completely new, can have far-reaching benefits and enable more players to actively participate in space exploration.

- **Space debris**. Space debris manipulation and handling are wildly untouched areas of study. Two areas of interest include the analysis of debris from planetary bodies for studying and retrieving information and ores, and issues related to man-made space debris ethics and law. Where do Canadians stand on this topic? Getting in on the ground floor of this issue can assure a uniquely Canadian vision. Industrial, commercial and public pollution issues should be addressed through a platform based on a thirst for knowledge, duty and responsibility.
- **Biological adaptation technologies.** This is the most logical and important mid to far-term aspect of human exploration in space and should be Canada’s priority in research. Canada should strive to become the leader in this field because the future of human space exploration is highly dependent upon it. Plants can serve as filters, food, and sensors, and the extension of the symbiotic relationship existing here on earth to space exploration is a necessary step.
- **Theoretical physics.** Going further in theoretical physics could lead Canada towards new discoveries in many fields i.e. propulsion. Advancing knowledge in fundamental physics leads humanity toward great accomplishments. Efforts should be focussed on developing new physics related-concepts to enhance the efficiency of space applications (eg launch, space traveling, orbital and trajectory control, spacecraft attitude control and applications).
- **Tailor to Canadian needs.** This means 4 things: 1. Make the R&D effort visible to the public. 2. Downstream technologies as efficiently as possible. 3. Prioritize R&D efforts to middle and far term needs and 4. Identify needs, trends, and wants of society.

    1. Of primary importance, because an informed public is an investor, making the R&D effort visible means dramatically enhancing the image of space exploration, studies, research, technologies and accomplishments. This may be accomplished by the creation of T.V. shows and movies for a mass audience. Although the documentary style of presentation is still needed, attempt to capture an entire nation’s imagination constantly and in a new way. The relationship between space research and societal benefits needs to be clearly drawn, much like a clear line can be seen between Formula I racing and the evolution of automotive technology.
    2. Downstreaming technologies to the private sector and academia on a grand scale is a must. Based on the principle of freedom of information, the more rapid and easy the dissemination, the better. For example, every crew member’s bio-rhythm during launch, extra-vehicular activities (EVA), re-entry diffused freely to academia can help entire departments in kinetics, life sciences, nutritionists. The group recommends widely accessible information.
    3. The prioritizing of R&D funding should focus on middle and far-term needs. Canada is a world leader in robotics principally because of this vision. Blending robotics expertise with mineral extraction (another Canadian expertise) is a logical step. For every near-term R&D investment, a conscious effort to couple it with far term technology is key. For example: robotics and mineral extraction, plant life expertise in space flight for environment control coupled with off-world greenhouses and habitat.
    4. Determine needs and wants. Trends and tendencies are often difficult to pinpoint, but an active “eye on society” could sharpen R&D efforts to anticipate and answer a “barely perceptible call”. Technology should be subserviant to the needs of society which can be identified through public forums and interactions under the supervision of trend-analysts.