WIRELESS LOCATION RESEARCH GROUP

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This iCORE Chair award, which began in January 2001, focuses on research related to outdoor and indoor wireless location, high performance navigation and positioning using satellite and ground-based Radio Frequency (RF) techniques, integration with self-contained sensors for personal navigation, and the development of innovative applications. The various projects conducted during the reporting period consisted of a mix of long-term basic research projects and projects arising from the constant interface with existing, and new, industrial partners.

EXECUTIVE SUMMARY

Strong collaboration with several faculty members within the University of Calgary and one at the University of Alberta, in addition to a wide range of external partnerships and strategic alliances with industry and goverment, significantly contributed to the progress achieved on 10 major research projects. These ranged from studies on the impact of RF interference on satellite-based navigation signals to the development of advanced signal processing techniques for implementation in a software Global Navigation Satellite System receiver for GPS and Galileo. These research projects resulted in personnel training, publications and intellectual property transfer. Personnel training directly by the Chairholder consisted in the completion of four MSc and three PhD students, the hiring of several senior research associates and the supervision and co-supervision of 35 MSc and PhD candidates, and internship and visiting students. Eleven papers were published and eight were accepted for publication in refereed journals, and over 30 were presented at conferences and published in conference proceedings. The Chairholder made numerous invited oral presentations in Canada and abroad. Intellectual property transfer consisted in the licensing of software and in technology transfer through external contracts and grants. New collaborations were added to the existing ones, namely with Northrup Grumman, U.S.A, the Italian Government, Navtech Seminars Inc, U.S.A, and an Alberta-based agricultural company. In recognition of their efforts, numerous members of the research team and collaborators received research excellence awards and accolades.

Thanks to the success of the Chairholder and his collaborators in securing external sponsors for the above research activities, $1.2M was raised in external funding over the past year, in addition to the iCORE grant of $0.5M. In addition, the licensing of intellectual property in the form of software generated $0.5M. The objective

to use the iCORE grant to leverage additional funds has been exceeded with approximately $3.5 dollars attracted for every dollar of iCORE investment.

The objectives for the forthcoming 12-month period are to conduct a mix of planned and opportunity-driven research and development. The latter is considered most important for the overall activities of the Chairholder's group to remain relevant, innovative, and to maximize economic benefits that contribute to Alberta's development.

RESEARCH PROGRAM OVERVIEW

The specific research objectives for this reporting period were as follows:

- Study the propagation properties of RF waves at 1.5 GHz through various materials for outdoor-to-indoor ranging purposes;
- Study the feasibility of integrating self-contained MEMS sensors with RF techniques for personal and vehicular location and navigation in urban canyons and indoor;
- Continue the development of the multiple reference station technique MultiRef™ for GPS real-time kinematic positioning and proceed with the deployment of a test and demonstration network in Southern Alberta;
- Continue investigations of ground-based cellular telephone CDMA location techniques;
- Continue the development of Galileo and combined GPS/Galileo technologies;
- Continue investigations related to the use of high sensitivity GPS receivers under outdoor and indoor signal masking conditions and design new applications;
- Initiate the development of a software GNSS transmitter and receiver to conduct fundamental research on GNSS performance and under interference and jamming sources;
- Seek, create and exploit new opportunities related to wireless location, positioning, navigation and innovative applications as they arise, for example, application of GPS to intelligent transportation systems and wireless location and communication application to the Alberta agriculture industry.

These objectives were achieved partly as a result of effective collaboration with other faculty members in the Department of Geomatics Engineering and strategic alliances with outside partners and sponsors.

RESEARCH PROJECTS

The following 10 major projects were the focus of the Chairholder's team during the reporting period:

1) Indoor GPS Location

This research activity remains central to the activities of the research group. Investigations into the performance of high sensitivity equipment were continued under a variety of actual and simulated RF environments at 1.5 GHz. The investigations were sub-divided into three sub-tasks, namely field testing, propagation channel modeling and hardware simulations. The field tests consisted of static and kinematic measurements made in selected environments to assess signal fade and noise, carrier phase, range and Doppler measurement quality, and related location availability and accuracy. They included selected downtown and campus buildings such at the Calgary Centre for Innovative Technology and the Olympic Oval. These measurements are being used to characterize the GPS signal propagation channel and its stochastic properties under these environments. The second sub-task, still on-going, consisted in designing theoretical propagation channel models with adaptive parameters to account for different RF environments. In the third sub-task, the possibility of reproducing in a stochastic sense various indoor RF environments using a GPS hardware simulator, was investigated. This research is important as it will allow high sensitivity GPS receiver manufacturers and cellular telephone service providers to conduct performance analysis and compliance testing under known and controlled conditions. Such compliance testing is required by the U.S. FCC and will likely be required by other regulatory agencies.

This work was conducted in cooperation with Professors Cannon and Klukas, Department of Geomatics Engineering; Spirent Communications, U.K.; Nokia Mobile Telephone Company, Finland; and with the assistance of SiRF Technology Inc., CA.

2) Outdoor/indoor vehicular and personal location and navigation using GPS integrated with self-contained sensors

Methods to estimate the performance of HSGPS in signal degraded environments for improving pedestrian and vehicular navigation were investigated. Receiver Autonomous Integrity Monitoring (RAIM) techniques to improve the accuracy and reliability of stand-alone HSGPS in various signal-degraded environments (indoor, suburban, urban canyons) were designed and evaluated using actual measurements made outdoor and indoor in pedestrian and vehicular modes. Due to the harsh RF environment present in the environments described above, it was shown that RAIM methods

are generally insufficient to improve performance. The design and evaluation of a foot-mounted system consisting of an array of accelerometers and magneto-resistive sensors to improve the relative movement of the pedestrian outdoor or indoor was completed. Investigations into thermal effects on accelerometers and gyros were continued. Several strategies to augment HSGPS with self-contained miniature MEMS sensors, either foot or torso mounted, to improve performance were designed and are being evaluated. In the vehicular case, augmentation with electronic maps was evaluated and a novel application to traffic congestion analysis was developed. One of the papers presented on this work received an award at the GPS 2003 international conference held in the U.S.A.

This work was partly conducted in cooperation with Professor Cannon and Professor El-Sheimy, Department of Geomatics Engineering, SiRF Technology Inc., U.S.A., Professor K. Fyfe, Department of Mechanical Engineering, University of Alberta; Professor A. MacIver, Department of Civil Engineering, and with some financial support from industry; and the Auto 21 National Centre of Excellence.

3) High performance GPS and GPS/INS integration

Methods to improve differential carrier phase GPS navigation and guidance accuracy and reliability performance were further investigated, with emphasis on real number carrier phase ambiguity positioning accuracy using augmentation with tactical grade inertial systems. Much of this research was conducted in collaboration with the U.S. Navy to autonomously land aircraft on aircraft carriers. In this context, the benefits of an inertial system under jamming and other harsh RF environments were investigated. The implementation of an in-flight alignment process for inertial systems was also initiated to allow for the use of GNSS/INS integrated systems under a wider range of applications. Previously developed SAINT™ (Satellite And Inertial Navigation Technology) software was enhanced and licensed to several organizations.

This work was conducted in cooperation with Professor Cannon, Department of Geomatics Engineering. Financial assistance was received from the U.S. Navy through a contract with ARINC to test algorithms and methods.

4) Assessment of GPS II/III and Galileo Signal Performance

GPS II/III and Galileo signals will use two important innovations in their signal structures aimed at reaching better ranging performance, namely Binary Offset Carrier (BOC) modulation, and a pilot (data-less) channel operating in quadra-phase with the data channel. BOC modulation provides an efficient spectral separation from current signals as well as better inherent tracking, multipath and narrow-band interference mitigation, but faces a ranging bias threat due to its multi-peak autocorrelation functions. The development of novel and effective algorithms to remove completely this tracking ambiguity has been initiated. The availability of a pilot signal will have a tremendous impact on tracking performance as no data transition, which limit the gain in the signal-to-noise ratio, will be present in this channel. Development of an inno-

Gérard Lachapelle and some members of the research team at the 2004 Banff Informatics Summit

vative combination of data/pilot channels to achieve better tracking with low-power signals and improve multipath mitigation is under way. A patent application is being submitted for this work.

Likewise, the GPS L5 signal, which will be in a protected civil aviation frequency band, will be encoded by a Neumann-Hoffman code to mitigate narrow-band interference that is a serious threat in an airport environment. This code, however, raises problems when trying to acquire the signal, as it creates small correlation spikes that might fail the acquisition process and it increases the mean acquisition time. New algorithms to improve signal acquisition performance are being developed and tested.

5) High precision multiple reference station GPS real-time kinematic positioning and GPS meteorology

Continuing research into the use of multiple reference station for precise kinematic carrier phase GPS positioning has been conducted. A network of 14 GPS stations, 11 of which are reporting data in real-time, is now operational in southern Alberta and being actively used by a group of eight graduate students supervised by three faculty members. Ten of these fourteen stations are equipped with meteorological measurement instruments for water vapour and atmospheric studies. This network is assisting with the development of advanced multiple reference station precise positioning methods as well as the development of real-time multiple reference station software. This exposes the operational consideration involved with this method. In addition, two alternatives multiple reference station approaches are in development, which are significantly different than the traditional approaches.

A novel integration of the multiple reference station approach with atmospheric correction provided by the National Oceanic and Atmospheric Administration (NOAA) has been successfully tested using a variety of GPS reference station networks supported by the US Coast Guard. This and ongoing tests are the first of a series of tests of the NOAA correction grid model. Investigations into using the Southern Alberta medium scale network to estimate atmospheric water vapour variations in real-time and contribute to meteorology were continued. This effort is expected to contribute to meteorological research in the long term. Numerous parts of software MultiRef™ were enhanced as a result of this research and more powerful real-time software functions were developed. The developed methods were the central contribution of two journal publications and five conference proceedings papers.

The above research was conducted in cooperation with Professors Cannon and Skone, Department of Geomatics Engineering; the Universita' Degli Studi di Napoli Parthenope, Italy; and with the assistance of the Applanix Corporation, Toronto; and the Korea Astronomy Observatory.

6) Wireless location using ground based systems

Works to provide outdoor and indoor location were continued and selected key techniques were the focus in these investigations, such as non-recursive TDOA/AOA location solution, array signal processing techniques for NLOS (Non line-of-sight) error mitigation, NLOS error modelling in typical urban area, and vector channel estimation approaches. The integration of ground-based solutions with GPS was also further studied using simulated ground network and actual GPS measurements. The test results demonstrated the effectiveness of the method and a project was later initiated to develop a prototype receiver capable of making measurements on 1.9 GHz CDMA cellular signals, to test the above approaches in the field. A best paper award was received at the GPS 2003 international conference held in the U.S.A. for this work.

This research was conducted partly in cooperation with Professor Klukas, Okanagan University College and Adjunct Professor in the Department of Geomatics Engineering; Professor J. Nielsen, Department of Electrical and Computer Engineering; and with some financial assistance from the Department of National Defence. Further support from DND to pursue this

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research will be received during the next twelve months.

7) Development of a GNSS software transmitter and receiver

The development of GNSS software transmitter and receiver capable of operating with the current GPS and the forthcoming GPS II and III, as well as the forthcoming Galileo system was continued. Two versions of post-mission GPS L1 C/A code software receiver, namely a MATLAB and a C version were developed. These fulfill most of the key functions of a hardware receiver, such as IF signal acquisition, tracking, data demodulation, navigation solution, and are currently used in several research projects to improve the signal processing performance. The multi-threaded software approach, where subsystems are realized through independent threads, makes the receiver a very valuable tool for a variety of research tasks.

This project is being conducted in cooperation with Professor Cannon and has been entirely funded by the Chairholder's iCORE grant. Several organizations have already expressed interest in this research and external funding is likely to result from this investment during the next twelve months.

8) GPS Interference and Jamming

GPS receiver performance is affected by unintentional and intentional RF interference sources. These can result in loss of signal tracking and/or tracking errors, depending on the severity of the effect and receiver signal tracking sensitivity and other signal tracking characteristics. Undetected tracking errors can result in large position errors. Partial loss of tracking also results in geometry degradation, which affects position accuracy. Research was conducted to develop procedures to test GPS receiver performance under a variety of unintentional and intentional interference sources and to apply these procedures to test specific military and high-end civilian receivers through a series of hardware in the loop simulations. Interference sources were characterized and specific tests were developed utilizing the Spirent GSS-6560 GPS Simulator and the GSS-4765 Interference Suite. Jamming and anti-jamming techniques were analysed. These tests are being used to develop and further test interference mitigation techniques utilizing the GNSS software receiver being developed by the group.

This research was conducted partly in cooperation with Professor Cannon, Department of Geomatics Engineering; Professor J. Wight, University of Carleton; and with the Department of National Defence as part of its involvement in specific military programs with NATO allies.

9) Use of Navigation in Intelligent Transportation Systems

The development of algorithms for probe vehicle-based traffic monitoring, in particular real-time traffic incident detection, was the focus of this research. Two primary traffic incident indicators were developed using probe vehicle tracking data. The performance of the system with varying GPS performance levels and different probe penetration levels was addressed. A proof-of-concept study was conducted with field surveys in collaboration with Calgary Transit, Calgary's transit authority. Further performance issues were analyzed using a traffic microsimulator with a wide range of incident scenarios. The analysis has found that traffic incidents can be detected at over a 90 percent success rate with less than a 5-minute time lag between the incident occurrence and the detection with only a 5 percent probe penetration level.

As an integral part of the research, a High Sensitivity GPS (HSGPS) and map-matching augmented vehicle tracking algorithm was developed. The algorithm was analyzed using transit and non-transit vehicle tracking data from downtown and suburban Calgary and resulted in a 90 percent success level in correctly identifying the vehicle location at street level. Augmentation with low-cost self-contained sensors was also investigated as a part of an extension to the vehicle-positioning algorithm.

This research was conducted in cooperation with Professor Andrew MacIver, Department of Civil Engineering.

10) Development of a Professional Course on Indoor GPS Location

A three-day course consisting of 600 slides dealing with fundamental theory, case studies and advanced applications was developed to promote the capability of the Chairholder's group and intellectual property. The course was given in the U.S.A., Denmark and Finland to a total of 100 attendees during the reporting period, in collaboration with Navtech Seminars Inc., U.S.A. One software license and research funding are already being negotiated as a result of this new and effective marketing thrust.

OBJECTIVES FOR THE NEXT YEAR

The planned objectives for the forthcoming period can be sub-divided into two groups, namely planned and opportunity-driven R&D, as described below. The latter group is considered most important for the overall activities of the Chairholder's group to remain relevant, innovative and to maximize economic benefits that contribute to Alberta's development.

Planned Research and Development

- Continue several of the projects in progress described above.
- Given the proven importance of the GNSS software receiver development initiated during the previous period, accelerate its development and testing, and design and start the development of a GNSS software receiver that can be integrated with self-contained sensors in an ultra-tight mode. Discussions with a Canadian industry partner to leverage iCORE funding for this project are underway.
- Develop novel and diverse applications of the multiple reference station technique, MultiRef™, for GPS real-time location and applications by possibly forming a strategic alliance with the City of Calgary as part of an emerging Calgary: An Urban Laboratory project.
- Accelerate research on various aspects of Galileo and seek collaborative opportunities with countries involved in the Galileo program to develop highly qualified personnel that will subsequently help the Canadian wireless location and navigation industry to compete effectively as Galileo-related products and applications start to be developed on a large industrial scale within the next five years. Protect intellectual property being developed in this area through patenting.
- Seek partners and sponsors to procure a new generation of GPS II/III – Galileo simulators in order for the group to remain in the forefront of academic wireless location and navigation research worldwide. The total cost of this unique infrastructure will be of the order of $2M.
- Continue to support the Department of National Defence's NAVWAR goals.

Opportunity-Driven Research and Development

- Continue to monitor evolving location and communication technologies, especially disruptive technologies, and emerging novel applications and markets.
- Conceptualize and design innovative methods, algorithms, processes and applications for niche markets.
- Match the above potential thrusts with current personnel capabilities and acquire new in-house expertise and/or develop new collaborations as required.
- Form strategic alliances to develop and test the above, maximize the creation of new intellectual property in the process and create new business opportunities for the Alberta high technology industry.
- The above may include for instance the design and use of new combined location/communication technologies for agriculture, energy exploitation and homeland security.

RESEARCH TEAM MEMBERS AND CONTRIBUTIONS

The on-site and off-site research team members, including their role and research topics are listed in the tables below. Another table list the awards received by team members.

It should be noted that since most graduate students are not Canadian, they are not eligible for NSERC scholarships. In addition, since they are studying in Geomatics Engineering, the few Canadians who receive NSERC scholarships are not eligible for iCORE supplements. Thus 90 percent of these students must be funded by the Chairholder's grants.

Many PhD and MSc students are in co-supervision. This is done for three reasons, namely (1) to enrich the learning and research experience of the students, (2) to assist the Chairholder in managing his workload, and (3) to provide inexperienced faculty members in the department with graduate student supervisions. Co-supervision is also used very effectively to develop collaboration with other academic departments on campus, nationally and abroad.

Team Members on Site

NAME	ROLE	TOPIC
G. Lachapelle,	Team Leader	
M.E. Cannon, Geomatics Engineering	Faculty Team Member	Satellite-based location, positioning and navigation, interference, integrated systems
N. El-Sheimy, Geomatics Engineering	Faculty Team Member	GPS/MEMS sensor integration
S. Skone, Geomatics Engineering	Faculty Team Member	GPS meteorology
R. Klukas, Adjunct Professor, Geomatics Engineering and Associate Professor, Okanagan University College, B.C.	Faculty Team Member	RF propagation, GPS indoor location, ground-based cellular telephone location systems
J. Nielsen, Electrical and Computer Engineering	Faculty Team Member	Design, prototyping and evaluation of CDMA equipment for wireless location

Research Associates, Internship and Visiting Students

NAME	ROLE	TOPIC
M. Petovello	Senior Research Associate	Design of advanced GPS/INS integration algorithms and carrier phase GNSS positioning
C. Ma	Senior Research Associate	GNSS software receiver development and ground-based wireless location
J. Schleppe	Senior Research Associate	Wireless location/communication integration and system testing
G. MacGougan	Research Associate	Indoor GPS location evaluation
A. Morton	Senior Research Associate	GNSS software receiver development*
L. Dong	Research Associate	GNSS software transmitter development and GNSS simulations
A, Wieser	Visiting Scientist	Design and reliability of GPS/INS integration algorithms
J. Park	Visiting Scientist	GNSS high precision positioning and GPS meteorology
Lance de Groot	Internship Student	Precise multiple reference stations DGPS RTK software testing
Daniel Lemmon	Internship Student	Precise multiple reference stations DGPS RTK software development
C. Karunanayake	SAIT Internship Student	System testing and software development
V. Schwartzendruber	Summer Student	Wireless location/communication system testing
L. Encinas	Visiting International Student (Brazil)	Navigation and timing systems
P. Stein	Visiting International Student (Brazil)	Pedestrian navigation systems
F. Masquarenc	Visiting International Student (France)	RF signal interference effects
C. Mongredien	Visiting International Student (France)	Galileo BOC signal tracking performance

PhD Candidates

NAME	TOPIC
C. Ma (with co-supervisor)	Advanced ground-based techniques to improve wireless location performance
K. O'Keefe (with co-supervisor)	Investigation into potential navigation systems for the planet Mars
M .Rajabi (co-supervisor)	Use of satellite imagery for digital terrain modeling
O. Julien (with co-supervisor)	Development of Galileo BOC signal acquisition and tracking techniques
B. Zhen	Development of GPS L5 signal acquisition and tracking techniques
O. Mezentsev	Integration of GPS and inertial navigation systems for personal outdoor/indoor navigation
C. Basnayake (with co-supervisor)	GPS-based transit probe system for an advanced traveler information system
Y. Ahn	High performance multiple reference station GNSS RTK
P. Alves (with co-supervisor)	High performance multiple reference station GNSS RTK
Walid Abdel-Hamid (co-supervisor)	MEMS-based INS/GPS for vehicular positioning and navigation
J. Collin (co-supervisor, Tampere Univ. of Technology)	Integration of GPS and MEMS sensors for personal outdoor/indoor navigation
H. Kuusniemi, (co-supervisor, Tampere Univ. of Technology)	Reliability of personal navigation and location systems
R. Edwards (co-supervisor, Carleton University)	RF interference and jamming and counter-measures

MSc Candidates

NAME	TOPIC
G. MacGougan	High sensitivity GPS receiver performance evaluation under signal masking
C. Wang	Attitude determanation system development using GPS integrated with low cost sensors
R. Stirling	Foot-mounted pedestrian navigation system development and testing
L. Dong	GPS software signal transmitter development
R. Watson	Indoor GPS propagation channel modeling
D. Karunanayake (co-supervisor)	Assisted-GPS performance analyses
D. Dao	High performance multiple reference station GNSS RTK
P. Lian	GPS signal tracking loop performance enhancement
J. Zhi	GPS signal interference analyses
B. Lin	GPS/communication integration
M. Guojiang	Development of GNSS software receiver aiding methods

NAME	TOPIC
L. Encinas	GPS/INS integration system performance evaluation
S. Srinivas	Ground-based wireless location system analyses
T. Hu	Indoor GPS propagation model evaluation and enhancement
J. Angelo, MEng (co-supervisor)	GNSS signal tracking and interference effects

AWARDS

AWARDEE	AWARD
G. Lachapelle	Fellow, Canadian Academy of Engineering, May 03
G. Lachapelle	Fellow, U.S. Institute of Navigation, Jun 03
G. Lachapelle	Honorary Professorship, Universita' Degli Studi Di Napoli Parthenope, Naples, Italy, Oct 2003
M.E. Cannon (Collaborator)	NSERC Steacie Followship, 2002-2004
M.E. Cannon (Collaborator)	Faculty of Engineering Departmental Research Excellence Award, 2003
M.E. Cannon (Collaborator)	Faculty of Engineering Research Excellence Award, 2003
C. Ma, PhD candidate	Best Student paper award, GPS 2003 International Conference, Portland, OR, September 2003
G. Pugliano, PhD candidate	Best Student paper award, GPS 2003 International Conference, Portland, OR, September 2003
N. Nicholson, V. Hoyle, S. Skone, M.E. Cannon and G. Lachapelle	Best Paper Presentation Award, GPS 2003 International Conference, Portland, OR, September 2003
G. Lachapelle, H. Kuusniemi, D. Dao, G. MacGougan, and M.E. Cannon	Best Paper Presentation Award, GPS 2003 International Conference, Portland, OR, September 2003

COLLABORATIONS

Active collaboration in the form of joint research projects and/or funded research projects took place with a variety of individuals on the University of Calgary campus and external organizations, as listed in the table below.

INSTITUTION	RESEARCHERS	NATURE OF COLLABORATION
PROVINCIAL		
Dept of Geomatics Engineering, University of Calgary	M. E. Cannon, N. El-Sheimy and S. Skone	GNSS and MEMS sensors
Dept of Mechanical Engineering, University of Alberta	K. Fyfe, R. Stirling	Personal location using self-contained sensors
Dept of Civil Engineering, University of Calgary	A. MacIver	Use of GPS for traffic modeling
Dept of Electrical and Computer Engineering, University of Calgary	J. Nielsen, G. Jullien, J. Haslett, M. Okoniewski	Development of firmware for communication and wireless location
Calgary Transit		Traffic monitoring experiments
National		
Dept of Electronics, Carleton University	R. Edwards, J. Wight	GPS interference analysis
Dept of Electrical and Informatics Eng, University of Sherbrooke	J. de Lafontaine, F. Michaud	NCE Auto 21 collaborative vehicular driving systems and integrated systems
DND/DRDC-Ottawa	J. Bird, M. Vinnins	RF interference studies in GNSS
INTERNATIONAL		
Universita' Degli Studi di Napoli Parthenope, Italy	G. Pugliano	Multiple reference station GPS RTK positioning
Tampere University of Technology, Finland	J. Takala	Personal location and navigation
U.S. Navy - NAWC	J. Davis & W. Gelatka	Aircraft buffeting measurements
Navtech Seminars Inc., U.S.A.		Indoor GPS location professional course
Ministry of Finance, Govt of Italy	R. Capua	Multiple reference station GPS RTK positioning
Korea Astronomy Observatory	J. Park	Multiple reference station GPS RTK positioning and GPS meteorology
INDUSTRIAL		
Nokia Mobile Telephone Company, Finland		Wireless location of cellular telephones
SiRF Technology Inc, U.S.A.	G. Turetzky, L. Garin	Assisted GPS receiver evaluation
Spirent Communications, U.K.	P. Boulton, A. Read	Indoor location simulation enhancements
ARINC U.S.A./U.S. Navy	F. Allen, R. Brashears	Joint Precision Approach and Landing System
NovAtel, Calgary	T. Murfin	GPS/Galileo performance analyses
Applanix Corporation, Toronto	B. Scherzinger	GPS RTK and software GNSS/INS receivers
Northrup Grumman, U.S.A.	P. Brunner	GPS/INS integration algorithms

INTELLECTUAL PROPERTY

Significant intellectual property was created during the reporting period and transferred to industry using two mechanisms, namely research contracts and software licenses. The latter are summarized in the table below, together with potential company spinoff. University Technologies International, the licensing arm of the University of Calgary, licensed the software to third parties. Over $500k of revenue was generated by software licenses during the reporting period. In addition to the above, some of the intellectual property developed by the grant holder was transferred to third parties (industry and Canadian and foreign government agencies through grants and contracts. The value of this activity during the reporting period was of the order of $500k. The total value of intellectual property transfer during the reporting period was therefore of the order of $1M.

	NAME AND DESCRIPTION	STATUS
	LICENSES	
MultiRef™	Multiple GPS reference station software for high precision positioning and navigation – software initiated in 2000 and being continuously enhanced. Authors: G. Lachapelle and M.E. Cannon	Third license in so many years, to a European government agency, for $230k, plus on-going discussions with a European group of universities for a multiple-site license
SAINT™	Satellite And Inertial Navigation Technology, new algorithms for the real-time processing of combined GPS and inertial navigation system measurements. Software initiated in 2002 and still be enhanced. Authors: M. Petovello, M.E. Cannon and G. Lachapelle	Licensed to 3rd parties in three different countries, for an aggregate amount of $170k
HEADRT+™	GPS software for the determination of a mobile platform's attitude parameters. Second generation software initiated in 2000 and enhanced in 2003 to include integration with low-cost MEMS sensors.Authors: G. Lachapelle and M.E. Cannon	Technology successfully embedded in a commercial product by a major U.S. corporation.
NDL™	Navigation Development Library. Software initiated in 2001, and being continuously enhanced. Authors: G. Lachapelle, M.E. Cannon, M. Petovello, G. MacGougan, J. Liu, P. Alves and K. O'keefe	One license to a foreign company, $70k
FLYKINRT+™	GPS software that uses carrier phase measurements for high accuracy navigation in real-time. Second generation software largely completed in 2003	License revenue of $28k during reporting period
GNSS Software Receiver	Software initiated in late 2002. The current version is already used by many students for their thesis research in interference, signal processing, etc. Final name to be assigned	On-going discussion with two Canadian and one foreign organizations
GNSS Software Transmitter	First version of software initiated in 2002 and completed in 2003. Final name to be assigned	On-going discussion with one foreign companies
Other software	Includes C3NAVG2™, SEMIKIN™, etc	Revenues still generated from previous licenses

INTELLECTUAL PROPERTY		
SPINOFF COMPANY		
Alberta-based company	Intense research efforts with an Alberta-based company are taking place to develop new ICT technologies to apply to the Alberta agricultural sector. In view of the potential of these technologies and the competition from outside the province, this major effort is being kept highly confidential	Project was initiated in October 2003 and will go on until at least September 2005

FUNDING

Gérard Lachapelle leads a team that receives funding from a diverse set of partners including various industry partners (~$130K), the Department of National Defense ($60K) and the US Navy and Coast Guard ($300K). He and his team receive funding from NSERC (over $500K) and participate on the Automobile of the 21st Century National Centre of Excellence. Dr Lachapelle is a Tier 1 Canada Research Chair which is worth $200K per year.

PUBLICATIONS

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