Canada Foundation for Innovation
Fondation canadienne pour l'innovation

Project Module
New Initiatives Fund (NIF)

Date submitted (dd/mm/yyyy): **Project no.:** 19280

Project title: Canadian Spallation Ultracold Neutron Source

Language of application:

☒ English ☐ French

Applicant institution: The University of Winnipeg

Designated Project Leader

Name:	Jeffery W Martin
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Project Funding

Total project cost:	$13,580,000
CFI Request ($):	$4,225,000
CFI Request (%):	31.11 %

Proposal focus: Research proposal

Research discipline/field

Primary:	PHYSICS
Primary sub-discipline:	Nuclear Physics
Secondary:	PHYSICS
Secondary sub-discipline:	Particle Physics
Tertiary:	PHYSICS
Tertiary sub-discipline:	Weak Interactions

Area of application

Primary:	Other research
Secondary:	

Keywords: ultracold neutrons, spallation, neutron physics, neutron moderators, surface nanoscience, materials science, electric dipole moments, weak interactions, beta decay, gravity

Signature of the applicant institution: It is agreed that the general conditions governing the partner contributions, and the use of CFI funds as outlined in the Institutional Agreement and the CFI Policy and Program Guide apply to the infrastructure project outlined in this application. These conditions are hereby accepted by the administering institution.

Name: ____________ **Signature:** ____________ **Date:** ____________

President/CEO of the institution (or authorized representative)

Applicant institution: The University of Winnipeg **Project no.:** 19280

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Collaborating Institutions

The following eligible institutions agree that the general conditions governing the partner contributions and the use of CFI funds, as outlined in the Institutional Agreement and in the CFI Policy and Program Guide, apply to the project outlined in this application and are hereby accepted by each institution.

Institution: University of Manitoba

Name (CEO, President or authorized representative):

Signature: ____________________ **Date:** ____________________

Institution: Simon Fraser University

Name (CEO, President or authorized representative):

Signature: ____________________ **Date:** ____________________

Institution: University of Northern British Columbia

Name (CEO, President or authorized representative):

Signature: ____________________ **Date:** ____________________

Institution: TRIUMF

Name (CEO, President or authorized representative):

Signature: ____________________ **Date:** ____________________

Applicant institution: The University of Winnipeg **Project no.:** 19280

Project title: Canadian Spallation Ultracold Neutron Source

Project Summary

We propose the construction of the world's highest density source of ultracold neutrons (UCN), the Canadian Spallation Ultracold Neutron Source (CSUNS). The project would be a collaborative effort between Canada, Japan, and the US.

A window of opportunity exists to capitalize on the successes of Japanese collaborators developing new technology to produce UCN, allowing the Canadian project to surpass other proposed sources elsewhere. The UCN source would be located in Canada at TRIUMF, Vancouver, BC. This location is ideal because of the high-intensity high-energy proton beam available, which is used to drive the UCN source. The truly high density that could be obtained at TRIUMF would allow a class of precision measurements of the fundamental properties of the neutron to be conducted with significantly higher precision than any other UCN source. The project would therefore make a major impact on studies of fundamental physics with UCN. Funding for physics experiments would be requested in the future from a combination of NSERC, Japanese, and other international sources. Being the most intense source of ultracold neutrons in the world, the source would attract many international users to Canada.

The UCN source technology is a so-called superthermal source based on downscattering of cold neutrons (CN) in superfluid liquid helium. Neutrons are liberated by proton-induced spallation from a tungsten target. The neutrons are moderated in room temperature and 20 K cold moderators. The resultant cold neutrons are down-scattered by phonons in superfluid 4He (He-II) to UCN energies. UCN are transmitted through guide tubes to experiments.

The experiments that would be conducted initially at CSUNS would be measurements of the neutron lifetime, of neutron energy levels in the earth's gravitational field, and of the neutron electric dipole moment. These are the highest priority experiments for this field, and would represent a long-term experimental program in Canada.

The CSUNS project is a collaborative effort between Canada, Japan, and the US, and would be located at TRIUMF. The infrastructure that is required is as follows: a fast kicker magnet to divert the proton beam to the UCN source, a fully instrumented beamline to deliver the proton beam, a tungsten spallation target and associated handling and cooling equipment, the cryostat containing the UCN source itself and associated cryogenic equipment, and, finally, radiation shielding in the form of steel and concrete blocks. In-kind and matching funds would be supplied by a combination of TRIUMF (NRC) and Japanese sources.

The fundamental neutron physics experiments that would be conducted using the UCN source are as follows:

* A precision measurement of the neutron lifetime, a critical parameter in astrophysics and for searches for new physics beyond the standard model of particle physics.

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Project Summary

* Precise spectroscopy of the quantized energy levels of neutrons confined above a mirror in the earth's gravitational field. This experiment would test theories of modifications to gravity, predicted by string-theory motivated models involving extra dimensions.

* A search for a non-zero neutron electric dipole moment. Such an experiment aims to search for an explanation of the predominance of matter over antimatter in the universe, and is a very sensitive probe of new physics.

The project would represent a new direction in subatomic physics in Canada, and would increase involvement in Canada's scientific program from new users outside Canada.

Unique technologies used in this proposal are cryogenics, vacuum technologies, nuclear instrumentation, RF technology, and superconducting technology. Many of these technologies are common to the medical field, and there is typically a large cross-over in personnel. Neutron transport issues in the UCN source are similar to those encountered in the design of future nuclear reactors. Acsion Industries, a Manitoba business with expertise in this area, has therefore expressed a strong interest in the project and it is probable that some in-kind contribution to the project would come from Acsion. The project therefore satisfies the People, Knowledge, and Entrepreneurial Advantages mentioned in Canada's S&T priorities. It also promotes world-class excellence by targeting an area of strength in basic research.

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Institutional Priority and Commitment

Criterion Standard:

The proposed project is of strategic importance to the institution. The institution has made and will continue to make tangible and significant commitments in support of this area of strategic priority. These commitments are, or will be, of direct benefit to the proposed project, including the attraction and retention of the best researchers.

Each of following aspects must be addressed:

1. Describe the significant support that the institution has provided to this area of research (e.g., institutional resources committed to capitalize on the proposed infrastructure, the creation of new research positions, or research chairs in these areas, etc.).
2. Describe the significant and tangible contributions that the institution will make to the current and on-going needs of the proposed project.
3. Explain why this project is important to the fulfillment of the institution's strategic research plan.

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Quality of the Research or Technology Development

Criterion Standard:

The research opportunity is timely and has the potential to lead the breakthroughs in research or technology development. The proposed research or technology development is innovative and at the leading edge internationally.

Each of following aspects must be addressed:

1. Describe the proposed research or technology development activity and the potentially transformative and innovative aspects of this endeavour.
2. Explain why it is important to pursue the proposed research or technology activity at this time.
3. Explain how the proposed research or technology development activity complements or differs from comparable research or technology development being conducted nationally and/or internationally.

1. Introduction: Ultracold Neutrons and Sources Worldwide

Ultracold neutrons (UCN) are neutrons of such remarkably low energies that they are totally reflected from the surfaces of a variety of materials. Hence, they can be confined in material bottles for long periods of time. Typically, UCN have kinetic energies less than 300 neV. Correspondingly, UCN are strongly affected by various fields, such as the Earth's gravitational field, and by strong magnetic fields (7 T).

UCN sources are often characterized and compared by the limiting UCN density achieved. The UCN source proposed for TRIUMF would have a density of 10,000 UCN/cc, which is a factor of 100 greater than any UCN source ever operated. In a future upgrade, the source would use a liquid deuterium cold moderator, giving a factor of five in UCN density, resulting in 50,000 UCN/cc. Currently there is one UCN source in the world, at Institut Laue-Langevin (ILL) Grenoble, that is operating in production mode. The source at ILL typically achieves 40 UCN/cc at the exit of the source. Typically 1-2 UCN/cc is achieved in experiments, such as in the completed ILL n-EDM experiment.

With the advent of superthermal sources of UCN, a new generation of UCN sources using this technology are under development at various laboratories. For a list of these sources, please see Table 1 (in the attached pages).

The Canadian Spallation Ultracold Neutron Source (CSUNS) project would exceed the capabilities of all planned future UCN sources worldwide. It is important to note that all the sources competitive with this project are future sources that have not demonstrated any superior density to the original ILL source. Additionally all the other sources use different technologies to the one proposed for CSUNS. We believe that it is our technology, ultimately, that will prove the most successful of all future projects worldwide. A comparison of the proposed infrastructure to those planned projects will be given in the "Need for the Infrastructure" section.

2. Proposed Research Activity at CSUNS

Given this breakthrough in UCN production that is imminent worldwide, a variety of new UCN experiments can be envisioned that are now only possible with the new generation of sources. We have considered a variety of physics experiments that could be done with the Canadian source. Emerging from these discussions, we have decided to focus in on the following possible physics experiments:

* a precise measurement of the neutron lifetime,

* characterization of the recently discovered UCN quantum states in the Earth's gravitational field

* a search for a non-zero neutron electric dipole moment,

Each project has its own physics interest and timeline, so that, in time, a series of UCN experiments would be performed at the CSUNS facility.

Please note that these experiments are significant undertakings themselves and would require their own funding, which would be sought from a combination of NSERC, Japanese, U.S., and other international sources once the infrastructure project (the UCN source itself) has been funded by CFI. These cutting-edge experiments, each with their own physics interest in searches for new physics beyond the Standard Model, justify the construction of CSUNS.

In this spirit, we now briefly describe the physics motivation, timeline, and the current status and collaborators involved in each experiment, assuming the UCN source (CSUNS) were to exist. (We return to the discussion of the UCN source itself in the section "Need for the Infrastructure", and in the "Budget Justification" modules.)

2.1 Neutron Lifetime

Precise measurements of the neutron lifetime are of physics interest primarily for two reasons:

* The neutron lifetime is an essential parameter for Big-Bang Nucleosynthesis (BBN) calculations, and is currently the dominant uncertainty for accurate BBN predictions [1].

* The neutron lifetime can be used, in combination with measurements of angular

correlations in neutron decay, to extract the CKM matrix parameter V_ud. V_ud is the most precisely measured, large parameter in the CKM matrix and is useful for a variety of tests of the unitarity of the CKM matrix. Lack of unitarity would signify new physics beyond the standard model. Currently, V_ud is most precisely determined from superallowed nuclear decays. UCN lifetime experiments offer an independent check of the nuclear extraction, free of nuclear corrections.

Figure 1 (in the attached pages) displays the current status of the CKM matrix element V_ud. It also displays the current status of previous experimental results for the neutron lifetime. Currently there is a seven sigma discrepancy between the most recent precise measurement of the neutron lifetime (878.5 +/- 0.8 s, [2]), and the average of all previous measurements (885.7 +/- 0.8 s, [3]). The most recent precise measurements have been performed in traps formed by the mean Fermi potential of material walls [4, 5] or material walls in combination with gravity [2]. The largest systematic uncertainties in these experiments arise due to effects of the interactions of the UCN with the material walls of the trap. At TRIUMF, a magneto-gravitational trap would be used to confine the neutrons, thus removing such effects. While similar projects with magnetic trapping of UCN have been discussed in the context of experiments at LANL [6], and elsewhere [7, 8, 9], they are as yet at a very premature stage relative to material traps.

The new magnetic trap experiments have identified an important new systematic effect specific to magnetic traps: marginal trapping of UCN energies larger than the trap depth. The marginally trapped UCN can escape from the trap with timescales similar to the neutron lifetime, potentially giving a large systematic effect. These UCN must therefore be removed from the trap rapidly so that measurements of the UCN lifetime can be performed. The LANL trap design deals with this problem by introducing chaotic neutron orbits within the trap so that the marginally trapped UCN rapidly sample their allowed phase space and escape. An experiment performed at TRIUMF could build on the preliminary work done at LANL.

2.1.1 Neutron Lifetime Experiment for CSUNS

The magneto-gravitational trap from LANL [6] is designed to contain so-called field-repelled neutrons, i.e., neutrons in a positive-energy eigenstate of the spin-field interaction. Figure 2 (found in the attached pages) shows the proposed trap for CSUNS, which would be based on the LANL design. The design calls for an open-top magneto-gravitational bowl trap with two independent magnetic-field-generating components: high-strength neodymium-iron-boron (NdFeB) permanent-magnet (PM) Halbach arrays [10, 11] that form the open-top bowl-shaped trap surface, and a enveloping set of current-carrying window-frame coils outside of the bowl.

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The PM arrays produce a field in the trap volume that is approximately 1 T at the surface and falls off exponentially in normal distance from the PM array surface with a characteristic length of about 1 cm; the PM field is the main confining field of the neutrons. The effective trap volume is 0.6 cubic metres. The window-frame coils produce a field of approximately 0.05-0.1 T that is everywhere perpendicular to the dominant component of the PM-array field and performs two essential functions: first, to guarantee that the trapped neutrons never encounter a zero field magnitude, and second, to guide the decay electrons to the detectors at the two ends of the trap. Under these conditions, neutrons with low enough kinetic energy are perfectly reflected from the field near the trap surface, and if their kinetic energy at the bottom of the trap is small enough to not exceed the trap height, they would stay in the trap for an effectively infinite time, except for their natural decay.

Neutrons are fed into the trap with a mechanically operated trap door at the bottom of the trap. The upper surface of the trap door is covered with a Halbach linear PM array in such a way that when the door is closed, the combination of the trap-door PM array and the PM arrays on trap surface around the door opening forms a continuous Halbach array without gaps. The trap door will be opened and closed by an actuator below the bottom of the trap. Calculations have shown that forces on the trap door are manageable from the point of view of the mechanical actuator (on the order of about 800 N in the worst-case position).

Quasi-trapped neutrons are removed during the filling/cleaning phase of operation by a neutron-absorbing cleanout surface that is lowered to a height that is approximately 5-10 cm below the top of the bowl. The cleanout surface is then withdrawn to a level above the top of the trap after the trap door is closed and before counting of neutron decays for the lifetime measurement is started. In order to facilitate removal of quasi-trapped neutrons, the bowl has shallow inclination angles on one side and at both ends that force neutrons to acquire a large vertical velocity component at some point along their trajectories and then reach a sufficient height to strike a cleanout absorber. Moreover, chaotic orbit behavior is induced by ripple in the permanent-magnet field.

A prototype of the trap is under construction at Los Alamos. Individuals from that collaboration have joined the TRIUMF UCN effort: J.D. Bowman, B. Filippone, T. Ito, and B. Plaster. Since it is already in development, and would have a relative short running time, the neutron lifetime experiment is a candidate for the first fundamental physics experiment at CSUNS.

A measurement of the neutron lifetime with precision <1 s, but performed in a magnetic trap free of the systematic uncertainties which hinder material traps, would be a very exciting achievement for this field. Such an experiment could be completed at CSUNS in the 2013 timeframe. The superior UCN density achieved there would be instrumental in achieving the < 1 s statistical error bar required.

2.2 Gravity Levels Experiment and Plans for CSUNS

Recently, a group at ILL has successfully observed the quantization of the energies of neutrons confined above a UCN mirror in the Earth's gravitational field [12]. The experiment is an interesting application of quantum mechanics to micron-sized quantum states. The experimental result has been used to place limits on modifications to the short-range (10 micron) behavior of gravity. The result therefore has impacted theories involving micron-scale extra dimensions. The result has also been used to constrain axion models [13].

The same group at ILL is mounting a more advanced setup (the GRANIT experiment) where they would attempt to excite resonant transitions between gravitational levels in a UCN bottle, achieving better resolution in the level spacing and hence placing tighter constraints on theories.

These experiments are limited in their scope by the UCN density available at ILL. TRIUMF therefore would have a distinct advantage for a new experimental effort. Additionally, this is a relatively new avenue of research in the UCN community, and much progress is being made rapidly. A timely experiment at TRIUMF would have a large impact on the field.

The experiment would take roughly one year to complete. The design of this experiment and the main detector are underway in Japan. This being the case, and owing to the short run time for the experiment, this experiment is therefore also a candidate to be one of the first fundamental physics experiments to be conducted using the UCN source at TRIUMF.

2.3 Neutron Electric Dipole Moment (n-EDM)

Electric dipole moments for fundamental particles are forbidden by time-reversal symmetry. The small amount of CP violation in the standard model leads to very tiny EDM's (for the neutron EDM, 10^-31 e-cm. However, new sources of CP violation beyond the standard model are required to account for the observed baryon asymmetry of the universe (BAU). In many models of physics beyond the standard model, extra sources of CP violation are often present. Such models often naturally generate neutron EDM's at the 10^-27 e-cm level [14]. The current experimental limit on the n-EDM is d_n < 3x10^-26 e-cm [15]. The next generation of experiments at ILL, PSI, and SNS aim to constrain the n-EDM to the 10^-27-10^-28 e-cm level. The aim of an experiment at TRIUMF would be at the 10^-28 e-cm level.

2.3.1 Experimental Principle

Neutron EDM measurements use Larmor precession under a static magnetic field and a static electric field. The effect of an EDM is extracted upon electric field reversal. The phase shift that would be induced by a non-zero electric dipole moment in the electric field is measured by means of neutron polarimetry and hence the neutron electric dipole moment d_n is extracted.

The statistical uncertainty on the EDM is minimized for the largest number of neutrons sampled. For experiments where the experimental volume is smaller than the UCN source volume, it is UCN density that is therefore the most important factor, and CSUNS will be the world leader in UCN density.

Systematic errors that reverse sign with E reversal must also be carefully controlled. Systematic effects arise due to magnetic field instability, due to changes in magnetic field induced by leakage currents, and due to motional magnetic fields in the rest frame of the neutron. To correct for magnetic field instabilities, a "comagnetometer", a different nuclear species which samples the same fields as the neutrons experience, is often used.

In the highest precision experiments, an additional systematic effect must be considered which arises from magnetic inhomogeneity and relativity: the recently discovered "geometric phase effect" [16, 17, 18]. This effect arises due to a combination of magnetic field inhomogeneity and neutron motion effects for neutrons confined to a trap.

2.3.2 Previous n-EDM experiments

In the previous ILL experiment, UCN were confined in a 50 cm diameter, 12 cm tall cell, in a 1 uT magnetic field and a 12 kV/cm electric field. The result for the upper limit on the n-EDM was d_n<3x10^-26 e-cm, with the precision limited by statistics. The UCN density in the EDM cell was 0.7 UCN/cc.

A co-magnetometer of 199Hg was used; hence magnetic field fluctuations were well normalized. Systematic errors associated with E reversal, were controlled to better than 10^-27 e-cm. The false EDM due to the geometric phase effect was characterized as a function of the field gradient so that the systematic error could be reduced.

2.3.3 Future n-EDM Experiments

A new EDM measurement at ILL ("CryoEDM") will use a double cell (24 cm diameter and 4 cm height for each cell) with UCN of density 1,000 UCN/cc. The cell will reside in a superfluid helium bottle. In this way, an electric field can be applied with lower leakage current. A superconducting magnetic shield will minimize systematic errors associated with field instability. For one cell, an electric field of 40 kV/cm will be applied while, for the other cell, no electric field will be applied. Neutrons in the second cell will hence be used as a magnetometer, but no co-magnetometer will be present in the measurement cell in the initial phase of the experiment.

A group using the future UCN source at PSI is also preparing an n-EDM experiment. They will carry out a preliminary measurement at ILL with the previous EDM cell of ILL, and then a measurement of 5x10^-27 e-cm at PSI from 2009 to 2010. The UCN density in the EDM cell will be 1,000 UCN/cc. The experiment will employ several magnetometers outside the EDM cell. They are aiming for a precision of 5x10^-28 e-cm in measurements from 2011 to 2015 [19].

A new n-EDM measurement employing a unique experimental technique is also in preparation for the SNS. A cold neutron beam from the SNS will impinge upon a volume of superfluid 4He creating 150 UCN/cc. The n-EDM measurement will be conducted in the same volume. A small amount of polarized 3He introduced into the superfluid 4He will act as a co-magnetometer. A "dressed spin" technique will be used, where the neutron spin precesses with the same frequency as the 3He spin. The neutron spin will be aligned with the 3He spin, so that essentially no neutron captures will occur. Any small effect caused by a non-zero EDM will modulate the capture rate on E-reversal. The capture rate will be sensed by sensing the scintillation light produced by the capture products. The goal precision is 10^-28 e-cm. Many technical challenges must be overcome for the experiment to be successful. The geometric phase effect for the 3He magnetometer can be large compared with 199Hg, but is mitigated because of collisions with the surrounding 4He [17, 18]. Measurements at the SNS will begin in 2013 [20].

2.3.4 Plans for n-EDM at CSUNS

We envision that any n-EDM effort at TRIUMF would occur after the completion of this new round of n-EDM measurements at ILL, PSI, and SNS, in the time frame of 2015 and beyond. It is difficult to say at this time which of these differing techniques would be shown to be the most successful by that time, and which would be best able to use the increased statistical precision which would be possible at TRIUMF. One possible scenario for the initial and fast completion of an EDM project at TRIUMF would be to

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simply move one of the devices from e.g. ILL or SNS, similar to the initial PSI strategy. To take advantage of the higher density at TRIUMF for systematic error reduction, a new and significantly smaller measurement cell would need to be designed.

3 Experimental Schedule

Not all experiments listed above would occur on the same time scale. We envision an initial flagship experiment, which would be either the neutron lifetime, or the gravity experiment. In tandem we would use a second UCN beamline to conduct R&D related to the n-EDM experiment. Issues associated with experiment approval and scheduling are discussed in the "Management Plans" section.

This section is continued in the attached pages.

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Researchers (Principal Users) *

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Title:	Senior Research Scientist
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Department:	Science

Name:	Charles Davis
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Name:	Michael Gericke
Title:	Assistant Professor
Institution:	University of Manitoba
Department:	Physics and Astronomy

Name:	Michael Hayden
Title:	Professor
Institution:	Simon Fraser University
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Researchers (Principal Users) *

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Researchers (Use of the Infrastructure)

Criterion Standard:

The principal users of the infrastructure are experts in the relevant research or technology development domain. The research group has the expertise and experience to lead the proposed endeavour.

Each of following aspects must be addressed:

1. Demonstrate that the research group is comprised of highly accomplished researchers and may also include new researchers who have demonstrated potential for excellence and leadership in all the proposed field(s), or experts in technology development who have been recognized for their accomplishments. If any principal users are to be recruited, describe the recruitment plan.
2. Explain how each principal user will use the infrastructure to contribute to the proposed research or technology development.
3. Describe the existing or emerging collaboration and complementarity among the principal users.
4. Demonstrate that the principal users/team have the research or technical expertise to capitalize on the use of the requested infrastructure.

Introduction and Leadership Overview

Thus far groups at Canadian universities, TRIUMF, at KEK, at Japanese universities, and at institutions in the U.S. have joined the project. J.W. Martin (U. Winnipeg) is the collaboration spokesperson. Y. Masuda (KEK) is the leader of the UCN source development project in Japan. W.D. Ramsay (U. Manitoba) is the liaison to TRIUMF for the project. C. Davis (TRIUMF) is envisioned to become the UCN project manager, once the project is underway.

Canadian Grant-Eligible Collaborators

The Winnipeg/Manitoba/UNBC/TRIUMF group (the grant-elegible members on this proposal are J.W. Martin, C. Davis, M. Gericke, E. Korkmaz, S.A. Page, and W.T.H. van Oers) has successfully completed difficult parity-violation experiments at various labs. With recent arrival of new faculty members (J.W. Martin and M. Gericke) the group has renewed its interest in fundamental physics with ultracold and cold neutrons. The group is currently involved in a large project to make the world's most precise determination of the weak mixing angle from e-p elastic scattering at Jefferson Lab.

J.W. Martin was involved in the construction of the UCN source at Los Alamos National Lab (LANL) and has been a leader in the experiments subsequently conducted there. The LANL UCN source currently holds the world record for highest UCN density ever achieved. This has served as the first and to date most impressive validation of the new

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Researchers (Use of the Infrastructure)

technique that will be used to produce UCN $-1òùs at TRIUMF. Additionally, J.W. Martin has been a leader in detector development in the UCNA project at LANL.

M. Gericke, S.A. Page, and J.W. Martin are involved in future experiments at the SNS (Spallation Neutron Source, Oak Ridge, TN), as well, primarily neutron beta-decay and parity-violating neutron hadronic weak interactions. M. Gericke, in particular, is the spokesperson of an experiment to measure parity-violating capture of neutrons on 3He. He also serves on the executive committee of the npdgamma experiment.

J.W. Martin and M. Gericke each have successfully obtained funding from the CFI Leaders Opportunity Fund (LOF) for laboratory grants for detector fabrication and testing facilities at their respective universities. Infrastructure for these laboratories will be used to support detector fabrication for the future experiments at CSUNS.

C. Davis, S.A. Page, and W.T.H. van Oers have been involved in experiments at TRIUMF to measure medium-energy neutron scattering from light nuclear targets to study the strong force.

M. Hayden (SFU) is a leader in UCN production in superfluid He and has recently authored a paper in PRL on the characterization of 3He impurities in superfluid 4He. This paper is related to the development of the SNS n-EDM project. He is also an expert on NMR techniques and on novel magnetic field sensors (SQUID's) used in such experiments.

L. Buchmann (TRIUMF), has been the main proponent of the potential use of this UCN source as a free neutron target. He has been instrumental in the development of the physics case and facilities case. He is currently a collaborator on the DRAGON and TUDA projects at TRIUMF.

There is also a great deal of expertise available at TRIUMF. The laboratory clearly has the capability to construct the proposed source, and the commitment to the project has been demonstrated by the cash and in-kind contributions. It is likely that future manpower would become available over time with future hires, since the complementarity in terms of physics goals with the TRIUMF ISAC project (primarily in the so-called "fundamental symmetries" research discipline) is significant.

U. Manitoba is also pursuing full membership in TRIUMF (which is owned and operated by a consortium of university, where U. Manitoba is currently an associate member). It is likely that a future joint faculty hire (TRIUMF-Manitoba) would also support the "fundamental symmetries" discipline and would therefore impact Canadian grant-elegible manpower for the project.

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Researchers (Use of the Infrastructure)

Japanese collaborators

Y. Masuda (KEK) is the leader of the UCN source development project in Japan. He is a well-recognized researcher in the field of neutron physics. It is his successful and published technique of coupling a superfluid 4He UCN source to a spallation-driven target that has been selected for the CSUNS project. Prof. Masuda, through researchers at TRIUMF, was able to make contact with Prof. Martin. It is through this burgeoning collaboration that the CSUNS project was born.

The KEK and other Japanese collaborators have generally been involved in the development of Y. Masuda's UCN source at RCNP. In terms of physics experiments, these collaborators view the neutron EDM experiment as their top priority.

New collaborators, mainly from Tokyo (S. Komamiya and collaborators), have joined this effort more recently, with the goal of completing a neutron gravity-levels measurement at CSUNS.

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Need for the infrastructure

Criterion Standard:

The infrastructure requested is appropriate and essential to support the proposed activities. It will establish or enhance a unique and important institutional capability in an area of leading edge research or technology development.

Each of following aspects must be addressed:

1. Explain why the requested infrastructure is appropriate for the proposed research or technology development.
2. Explain why the proposed research cannot be supported using existing infrastructure.
3. Describe the availability of similar infrastructure within the institution, the region, the country, and/or internationally and address any issues of accessibility, complementarity, duplication, and sharing.

Introduction

The fundamental physics experiments envisioned for CSUNS (described previously) all have one feature in common: they are currently limited by the statistics achievable in the experiment. For this reason, it is the achievement of the highest possible densities of UCN which is the most important factor.

The UCN source technology proposed is a superthermal source based on downscattering of cold neutrons (CN) by phonons production in superfluid 4He [22]. Fig. 4 (found in the attached pages) displays a schematic diagram of the proposed UCN source.

Neutrons are liberated by the highly efficient process of proton-induced spallation from a tungsten target using the 500 MeV TRIUMF proton beam. It is the combination of these two features (spallation, combined with 4He technology) that set the CSUNS project apart from the all other sources worldwide. This source technology has been developed by Y. Masuda's group in Japan. Using a prototype source at the Research Center for Nuclear Physics (RCNP) Osaka, a UCN density of 10 UCN/cc has already been achieved.

It is primarily the superior proton beam power in Canada (at TRIUMF) that would lead to the creation of truly high densities of UCN. Since UCN production scales with beam power, this results in a predicted increase in UCN density by a factor of 51 when operated in Canada. This, coupled with incremental gains from changes in geometry and UCN guide technology, will give rise to UCN densities exceeding 10,000 UCN/cc at CSUNS.

UCN Production

A new generation of UCN sources is being developed at many institutes in the world, and

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these developments make neutron physics an exciting and vibrant field. In the previous generation (e.g. the turbine source at Institut Laue-Langevin, ILL, Grenoble, France) the UCN density was limited by Louisville's theorem. The new UCN sources use phonons for neutron cooling, and are free from the phase space limitation of the neutrons themselves.

UCN are created in these source by transporting cold neutrons (CN) into a region of material where phonons can be created. Important parameters for a source of this type are:

* CN flux

* lifetime of UCN in the material

* production rate of UCN from CN

For higher UCN production, a higher cold neutron flux is preferable. However, with higher CN flux comes a higher heat load, which is dominated by gamma's from neutron capture in the surrounding material. For a 4He production volume, the UCN storage lifetime is limited by phonon up-scattering, which strongly depends on temperature, and the lifetime would be severely affected if the heat transport out of the source material couldn't be dealt with. Fortunately, the superfluid 4He has essentially infinite thermal conductivity, and heat can be removed very effectively. The UCN production rate is given mainly by CN's producing single phonons in the 4He. Multiphoton excitations also contribute, making effective use of higher-energy CN.

After production, UCN are extracted to a UCN guide and a storage bottle for experiments. Extraction efficiency from the source material to the UCN guide and transport efficiency to the storage bottle are important parameters to obtain higher UCN density for experiments.

Summary of Other New Generation Sources

A list of new generation sources is presented in the list below.

* CSUNS (TRIUMF), spallation 4He, 10,000-50,000 UCN/cc.

* ILL, CN beam 4He, 1,000 UCN/cc.

* SNS ORNL, CN beam 4He, 150 UCN/cc.

* Munich FRM-II, reactor SD2, 10,000 UCN/cc.

Need for the infrastructure

* NCSU Pulstar, reactor SD2, 1,000 UCN/cc.

* PSI, spallation SD2, 1,000 UCN/cc.

* LANL, spallation SD2, 145 UCN/cc.

The sources listed are the Canadian Spallation Ultracold Neutron Source (our project), and future sources at Institut Laue-Langevin (ILL, Grenoble, France), the Spallation Neutron Source at Oak Ridge National Lab (SNS ORNL, Tennessee), the Munich Forschungsneutronenquelle Heinz Maier-Leibnitz (FRM-II, Germany), the North Carolina State University Pulstar reactor (NCSU), and the Paul-Scherrer Institut (PSI, Villigen, Switzerland). The Los Alamos source (LANL, New Mexico) is currently in operation on a testing basis.

The existing LANL source and the future Paul-Scherrer Institut (PSI) source use solid deuterium SD2 as the UCN source material. The Los Alamos source is currently in operation in a testing mode. In SD2, the UCN storage lifetime is only 24 ms at 8 K. The small value of the storage lifetime for this type of source arises from a combination of phonon up-scattering (40 ms), up-scattering from para-D2 molecular states (100 ms), and nuclear absorption (150 ms) [23]. Therefore these sources use a storage bottle which is separated from SD2 by a UCN shutter. The shutter is opened briefly when a beam pulse arrives so that UCN are extracted to the storage bottle. Despite these lifetime and transport problems, SD2 has the advantage of having a large number of phonon states available from which CN can scatter, thus giving rise to a larger UCN production rate. The difficulty for these sources is to get the UCN out of the SD2 as efficiently as possible before the UCN are lost, and then not allow the UCN to move back into the volume of SD2 again. Another issue for a solid source is ice quality, and significant R&D at LANL, Mainz, Munich, and PSI has gone into achieving crystalline deuterium for optimal UCN production. Such considerations are of no concern for superfluid 4He technology.

At the LANL source, an 800 MeV proton beam is used for spallation neutron production off a tungsten target. The SD2 is a disk 7.8 cm in diameter and 5 cm in height. Typically a 30 uC pulse of protons is delivered to the source for one second in every fifteen [24]. The short lifetime in the SD2 is not an issue for the LANL source because the UCN flow continually through the UCNA experiment, which is a polarized neutron beta-asymmetry experiment. I.e. the source is not optimized for density. In the UCNA experiment, if the UCN were stored, they would depolarize at an unacceptable rate on collisions with the cell walls. Despite this, a world-record density of 145 UCN/cc was achieved in the prototype source, which served as the first and to date most impressive validation of the superthermal production technique [25]. In the UCNA apparatus, densities of 1 UCN/cc are typically achieved, giving rise to neutron beta-decay rates of 10 Hz.

Need for the infrastructure

The PSI UCN source will be driven by a 600 MeV proton beam at 2 mA, operated at low duty-cycle. A proton beam pulse of 4 s every 400 s will be to fill a 2 m^3 storage bottle. The volume of SD2 is a disk 50 cm in diameter and 15 cm tall. UCN will be transported from the bottle to an EDM cell, where the expected UCN density is 1,000 UCN/cc. The construction of the UCN source will be complete in 2009 [19]. The UCN source at PSI, despite using a larger instantaneous beam power, uses a shorter pulse structure because of the shorter UCN lifetimes owing to the use of SD2. Note also that though the instantaneous beam power is large, the duty-cycle of the source is 1%; the time-averaged beam power (12 kW) is not so different from the TRIUMF source (5 kW). The low duty cycle at PSI must be enforced because of the tremendous heat load implied by the very intense beam.

The Munich FRM-II reactor, a 20 MW reactor, will also have a UCN source employing SD2. A prototype UCN source for this project was constructed at the 100 kW TRIGA reactor in Mainz where 8 UCN/cc were obtained in a volume of 10 L. In that experiment, UCN with energies below 250 neV were trapped. This is expected to be improved to a density of 10,000 UCN/cc at FRM-II.

The Sussex-RAL group is constructing a He-II UCN source in the H53 CN beamline at the 60 MW ILL reactor for the CryoEDM experiment. After construction of a more intense CN beamline (which will branch off the H172 beamline), the UCN density anticipated in the EDM cell is 1000 UCN/cc.

A large US group, working at the SNS, is also constructing a superfluid 4He UCN source for the SNS EDM measurement. The cold neutron flux is smaller than ILL. The UCN density is expected to be 150 UCN/cc in the EDM cell [20].

The Prototype CSUNS Source at RCNP, Osaka

The Canadian source will be based on the source of Y. Masuda, which is currently installed at the Research Center for Nuclear Physics (RCNP), Osaka University, in Osaka, Japan. The source uses a Pb spallation target and the UCN production material is superfluid 4He. Results aquired with this source have been published in Ref. [22]. A picture of the source, as it exists in Osaka, is shown in Fig. 5 (in the attached pages).

The UCN production volume is a 10 L vessel containing He-II, located within a 20 K heavy water vessel, in turn located within a 300 K heavy water vessel. The beam is operated at 390 MeV and at 1 uA.

In an experiment conducted at RCNP in 2007, UCN were extracted from the 4He to a vertical UCN guide of 1.2 m height and transported to an experimental port through a

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horizontal UCN guide of 3 m length. At the experimental port, the UCN density was 10 UCN/cc at E_C=90 neV. E_C is the maximum UCN energy, determined by the properties of the guide material used. The UCN storage lifetime was 30 s. The results are consistent with a model of neutron transport and phonon production in the source. For the model, an important consideration is the inclusion of multi-phonon excitations in the superfluid 4He. These excitations allow higher energy neutrons to be downscattered thereby increasing the UCN production rate [26]. The result shows that UCN losses upon extraction from the He-II and transport through the UCN guides are small.

This section is continued in the attached pages.

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Management Plans

Criterion Standard:

The management plans provide for the optimal implementation, operation, and functionality of the infrastructure. The infrastructure requested will be managed effectively and efficiently, in keeping with the size and degree of complexity of the project.

Each of following aspects must be addressed:

1. Describe the management structure to oversee the implementation, operation, functionality and sustainability of the infrastructure.
2. Explain how the institution will address issues of access and utilization, taking into account scientific and user priorities.
3. If applicable, describe any changes or modifications to existing plans as a result of the infrastructure being requested and the integration or linkage with existing infrastructure.

The management structure will be as follows.

The experiments that will be conducted at CSUNS will follow the usual approval process at TRIUMF. Currently, this involves presentation of the proposed experiment to the TRIUMF Experimental Evaluation Committee (EEC). The EEC is comprised of international experts in the field of subatomic physics. The committee makes a decision on the scientific priority of the experiment relative to other possible experiments. This existing structure already, that has already been created by the laboratory, will be a very important way to establish the scientific credibility of the CSUNS program. The CSUNS project itself has already received approval from a special TRIUMF EEC meeting, which focused on projects requesting approval for the next TRIUMF NRC five-year funding period (2010-2015).

Once the scientific approval process is complete, scheduling of the experiments will be decided by the CSUNS collaboration.

There will be a spokesperson for the CSUNS collaboration. Currently that is Jeffery Martin (U. Winnipeg), who will act as spokesperson at least through the completion of the construction and commissioning phases of the experiment. After this time, the position will be decided by the members of the collaboration.

Assisting the spokesperson will be an executive council comprised of members of the CSUNS collaboration. Equity on the council between Canadian and Japanese collaborators will be mandated. In time, we envision expanding the collaboration significantly both within Canada, and internationally.

The spokesperson and executive council will be responsible for the successful operation

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Management Plans

and utilitization of the UCN source.

Within the executive council, there will be members local to the TRIUMF facility, who will be responsible for the construction and day to day operations of the source.

Currently, W.D. Ramsay (a senior research associate in the Winnipeg/Manitoba group) is serving in the position of "liaison to TRIUMF". It is envisioned that this position would continue throughout the construction and commissioning phase of CSUNS. The liaison is responsible for communications between the CSUNS project, TRIUMF management, and the relevant engineering and technical groups at TRIUMF that are involved.

Once construction of the facility begins, C. Davis (TRIUMF) will serve as the technical coordinator of CSUNS. The technical coordinator will be responsible, initially, for overseeing the installation and construction of the UCN source. This will involve supervision of technicians and contractors who will perform the installation. Once the commissioning phase of the experiment would begin, the technical coordinator would be responsible for overseeing day-to-day operations and maintenance. The technical coordinator is also responsible for safety and liaising with the TRIUMF safety office.

The liasion to TRIUMF and technical coordinator positions would be comprised of TRIUMF scientific staff supplemented by research associates within either the Canadian or Japanese groups (similar to the way W.D. Ramsay's position is supported by NSERC project grants). In this way, a local base of individuals responsible for managing the UCN source will be maintained.

Currently, technical developments and design studies are being conducted in Japan. These developments are supervised by Prof. Y. Masuda (KEK). During the installation and commissioning phase, it will be critical for Prof. Masuda to be located at TRIUMF. It is envisioned that his position at TRIUMF would be supported by KEK in Japan, and partially by TRIUMF, likely through a visiting scientist agreement.

For tasks requiring the expertise of physicists, the installation and commissioning manpower will be supported by professors, postdocs, and students from the CSUNS collaborating institutions. Overall coordination of such efforts will be overseen by the technical coordinator.

In discussions with engineering staff at TRIUMF, a Gantt chart has been created showing a schedule for each major infrastructure item requested in the grant. The chart will be discussed further in the financial section. Detailed physicist, engineer, and technician manpower estimates for the project have also been conducted in communication with TRIUMF and will also be discussed in the financial section.

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Operation and Maintenance Plans

Criterion Standard:

The plans for the optimal operation and maintenance of the proposed infrastructure for the first five years of operation are appropriate and realistic. They will allow for its sustainable usage as well as provide for future upgrade requirements.

Each of following aspects must be addressed:

1. Describe the significant requirements to efficiently operate and maintain the infrastructure (e.g., personnel, utilities, supplies, upgrades, etc.).
2. Outline the sources of support for operation and maintenance costs and describe the contingency plans should any of this support be unavailable.

Operations and maintenance plans will be conducted as follows.

Operation of the UCN source will be the responsibility of the CSUNS collaboration. Maintenance of CSUNS will have shared responsibility with the TRIUMF laboratory.

The TRIUMF 500 MeV proton beam is generally operated 24 hours a day, seven days a week, in eight-month periods. The four-month period is used as a maintenance period.

Operations during the eight-month running period will also be conducted on a 24 hour a day basis, dependent on the run schedule of the particular experiment being conducted using CSUNS. During such times, a three-person shift crew will be responsible for running the UCN source and experiment. (This is typically what is done at the LANL UCN source, and at other nuclear physics experiments, dependent on the complexity of the experiment.) The crew will be comprised of members of the CSUNS collaboration, including professors, research scientists, postdocs, graduate students, and undergraduate students.

Operations, when running, will be overseen by a run coordinator. This will be a rotating two-week position staffed by members of the collaboration at the PhD level or higher (postdoc and above). The run coordinator will report to the liaison to TRIUMF, and will be responsible for communications with accelerator division at TRIUMF.

Utilities will be paid by the TRIUMF laboratory.

The dominant expense in supplies for the UCN source is potentially in the supply of liquid helium for cooling. A system that does not reclaim the helium is wasteful and not sustainable. The consumption of the UCN source is 200 L/day during operation. A new liquifier system will be present at TRIUMF by 2011. All helium used in the experiment will be recovered to the liquifier. This is a highly sustainable practise done at most universities and laboratories requiring large amounts cryogenic helium.

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Operation and Maintenance Plans

All potentially radioactively contaminated items would be dealt with according to TRIUMF policies and procedures.

Eventually, an upgrade would be requested through CFI for a cold liquid deuterium (LD2) moderator. This would increase the UCN density by a factor of five, but involves a significant increase in the scope of the project in terms of safety (because gaseous LD2 is flammable), and complexity, and materials costs. For these reasons, it will be pursued in the future. The upgrade will be pursued through future discussions between the CSUNS collaboration and TRIUMF.

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Training of Highly Qualified Personnel (HQP) Through Research

Criterion Standard:

The infrastructure requested will create or enrich a stimulating and innovative training environment that attracts high quality trainees and imparts new high-level skills to HQP for research and other careers.

Each of following aspects must be addressed:

1. Describe the benefits of the proposed infrastructure for research training and career development.
2. Outline the extent to which the proposed infrastructure will be accessed directly by research trainees.
3. Describe the impact of the proposed infrastructure on future training of HQP as well as the impact that not having access to the proposed infrastructure would have on training. Include an estimate of the number and type of HQP (e.g., undergraduate and graduate students, postdoctoral fellows, technicians, technologists, other trainees/students) to be trained.

The project would contribute to the training of a large number of undergraduate students, graduate students, and postdoctoral fellows from across Canada. The project has attracted a world-class group of scientists, and will therefore attract HQP from around the world to Canada. In fact, postdoc applications to the U. Winnipeg group have already been received citing interest in the UCN project (from ILL Grenoble and from Indiana U.).

Performing research on neutron physics experiments is excellent training for problem-solving in real-world situations. Students and postdocs in nuclear physics must use a variety of resources in order to achieve highly complex tasks. In the course of an experiment, personnel can be trained on design of future experiments, computer simulation, design and construction of custom hardware, installation and commissioning of hardware, acquisition and analysis of data, and effective communication of progress at meetings and of results through authorship of publications. Unique technologies used in this proposal are cryogenics, vacuum technologies, nuclear instrumentation, RF technology, and superconducting technology. Many of these technologies are common to the medical field as well, and there is typically a large cross-over in personnel.

In addition to traditional research positions in nuclear physics, students trained in experimental nuclear physics have gone on to leadership and technical positions in a variety of industries. Known to me personally are those with positions in: medical physics research, materials research, quantitative analysis of the stock market, management consulting, internet start-up companies, and aerospace engineering. This incredible diversity in possibilities, in such a large variety of highly technical fields, represent the possibilities available to one who possesses the training obtained as an experimental nuclear physicist.

University of Winnipeg students trained in J.W. Martin's CFI-funded subatomic physics

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Training of Highly Qualified Personnel (HQP) Through Research

detector lab, and stationed at remote facilities such as LANL and Jefferson Lab, have received offers of employment advancing their positions in physics, and have presented at meetings of physics societies of Canada, Japan, and the U.S. This group of students includes a Rhodes Scholar, two Stevenson awardees (awarded for high academic standing and citizenship, and considered to be the top undergraduate award at the University of Winnipeg), and an NSERC PGS-D awardee.

TRIUMF Aboriginal Students scholarship.

Acsion work and training for related industries.

Japanese and U.S. HQP in Canada

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Collaborations and Partnerships

Criterion Standard:

The project will establish or enhance major collaborations and partnerships. The infrastructure requested will further strengthen multidisciplinary approaches, collaborations among researchers and users of research results, as well as partnerships with different institutions and sectors, where appropriate.

Each of following aspects must be addressed:

1. Describe the nature of the major collaborations that already exist, and that are planned, both within and external to the institution (beyond those between the principal users, as addressed in the "Researchers (Use of Infrastructure)" section in terms of:
   a) ensuring that the proposed research or technology development can be pursued successfully;
   b) promoting synergies among research disciplines and sectors (public, private, NFP).
2. Describe the nature of the major partnerships that already exist, and that are planned, with users of the research results, including the extent of the engagement of these partners.
3. Outline the steps that have been taken, or that will be taken, to create or strengthen collaborations, partnerships, and/or networks.
4. Explain why the proposed infrastructure is important to these collaborations or partnerships.

The University of Winnipeg is leading an international group of scientists in this world-class project in basic research. This is truly a unique and important opportunity for the university. The benefits in terms of attraction of HQP to Winnipeg are likely to be immense.

Thus far groups at Canadian universities, at TRIUMF, at KEK, at Japanese universities, and at institutions in the U.S. have joined the project. J.W. Martin (U. Winnipeg) is the collaboration spokesperson and has been responsible for this success in attracting such an excellent list of collaborators. Y. Masuda is the leader of the UCN source development project in Japan.

The proposal would strengthen a pre-existing collaboration between the subatomic physics groups at U. Winnipeg, U. Manitoba, and U. Northern British Columbia. These institutions already collaborate on neutron experiments and on electroweak physics experiments in electron scattering, and are already linked through joint Subatomic Physics Project Grants (a special category of NSERC Discovery Grants). The proposal would forge a new collaboration with M. Hayden's group at Simon Fraser University and with additional new collaborators at TRIUMF, for example L. Buchmann.

The KEK and other Japanese collaborators have generally been involved in the development of Y. Masuda's UCN source at RCNP. New collaborators, mainly from Tokyo (S. Komamiya and collaborators), have joined this effort more recently, with the goal

Collaborations and Partnerships

of eventually completing a neutron gravity-levels measurement at TRIUMF.

The U.S. collaborators have been attracted because of their collective strong desire to be involved in the next big UCN project in North America. In particular, we note the involvement of R. Golub (NCSU) who has been one of the chief proponents of the field of UCN physics over the past several decades, coauthor of the seminal book ``Ultracold Neutrons''. Prof. Golub has been involved in many of the most important experiments performed using UCN over the past 30 years, for example, previous measurements of the neutron EDM at ILL. He has stated strongly that the CSUNS project will result in the world's highest density UCN source, hence his interest and involvement.

U.S. collaborators

Though collaborators from the US have been listed as "Other Users", this is only due to the format mandated by CFI. Their expertise will be invaluable in the successful first operation of CSUNS. Additionally, many of them are heavily involved in planning for the physics experiments that will eventually be conducted there.

R. Golub (NCSU) has been one of the main proponents of the field of UCN physics over the past several decades, and in the development of superthermal sources of UCN. He is coauthor of the seminal book "Ultracold Neutrons". He has expressed a strong desire to participate in the development of Masuda's spallation-driven UCN source at TRIUMF, and has also expressed a strong belief that this will result in the world's highest density UCN source. He has been involved in many of the most important experiments performed using UCN over the past 30 years, for example, previous measurements of the neutron EDM at ILL.

E. Korobkina (NCSU) is an expert on UCN production and storage experiments. She has designed a UCN ISR apparatus, and collaborates on the SNS EDM project, and the NCSU Pulstar reactor UCN source project.

J.D. Bowman (ORNL) is a recipient of the prestigious Bonner prize of the APS. He is the main proponent of the magneto-gravitational UCN lifetime experiment.

B.W. Filippone (Caltech), T.M. Ito (ORNL), and B. Plaster (U. Kentucky) have most recently brought about the successful completion of the first round of physics measurements with the UCNA apparatus. They are also all collaborators on the SNS EDM project, and are responsible for the inner detector system and the magnetic field system. They are also involved in preparatory work towards the UCN lifetime experiment.

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Collaborations and Partnerships

Researcher Expertise by CSUNS Experiment (Neutron Lifetime, Gravity, and n-EDM)

CSUNS Neutron Lifetime Experiment

Currently there are several US collaborators involved in CSUNS who are preparing the UCN lifetime experiment: J.D. Bowman (ORNL), B. Filippone (Caltech), T. Ito (LANL), and B. Plaster (U. Kentucky). Additionally, the expertise of J.W. Martin (U. Winnipeg) and M. Gericke (U. Manitoba) with detectors for both neutrons and betas from neutron decay would be required for successful completion of this project.

CSUNS Gravity Levels Experiment

A large group of Japanese collaborators, led by S. Komamiya (U. Tokyo), has expressed interest in conducting the gravity levels experiment at TRIUMF. The group is currently developing neutron detectors with a spatial resolution of order microns to directly observe the height distribution of neutrons confined above the mirror in the experiment. This new technology, combined with the high fluxes of UCN available at TRIUMF, would enable a new precision test of gravity and a search for extra dimensions. The design of the experiment and of the main detector are underway in Japan.

CSUNS n-EDM Experiment

The TRIUMF UCN source project has already attracted a number of collaborators who are experts in the n-EDM experiment at SNS: B. Filippone, R. Golub, T. Ito, E. Korobkina, M. Hayden, and B. Plaster. R. Golub in particular was instrumental in the successful completion of the previous generation of n-EDM searches, and has been a leader in the design of the SNS EDM project.

Y. Masuda and Japanese collaborators are currently conducting measurements of the Ramsey resonance technique at the UCN source in Japan. The expertise that they are developing there will be invaluable to the success of the CSUNS n-EDM project.

It is envisioned that this nucleus of individuals, supplemented by very interested parties from Japan and Canada would grow into the eventual EDM collaboration for TRIUMF.

This section is continued on the attached pages.

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Benefits to Canada

Criterion Standard:

The proposed activities have the potential to lead to:

- significant improvements to society, quality of life, health, and the environment, including the development of new practices and public policies; and/or
- improved economic activities through development of new products, services and/or technologies, greater resource efficiency and productivity, and job creation in strong or emerging areas of the Canadian economy.

Each of following aspects must be addressed:

1. Describe the expected benefits to Canada, including why they are significant, how they will be realized, and the timeframe over which they are expected to be realized.
2. Describe the institution's plans to transfer the research results to potential users. Where appropriate, these should include plans for knowledge mobilization or transfer of technology and the commercialization of products, services and processes.
3. Demonstrate that the team has the skills and experience, or has identified the relevant partners, to ensure the successful transfer of the research results.

The CSUNS project addresses the core principles of Canada's Science and Technology (S&T) priorities. The project promotes world-class excellence through the construction of the highest density UCN in the world. The project has already attracted a large number of excellent international collaborators. The project targets an area of strength in basic research in fundamental physics, while at the same time addressing applied research in materials science, particularly surface nanoscience. Partnerships between Japan, Canada, and the U.S. clearly will be enhanced by the project, and significant funding will be committed to the CSUNS project by Japanese sources. The physics experiments that will be performed at CSUNS will likewise be funded by a combination of Canadian (NSERC) and international sources.

Canada's Science and Technology Strategy identifies three distinct Canadian S&T advantages that it aims to foster: a People Advantage, a Knowledge Advantage, and an Entrepreneurial Advantage. The UCN project addresses these priorities in the following ways:

People Advantage

* The UCN source project, coupled with the world-class physics experiments that will be conducted there, will attract excellent scientists from around the world to Canada. This is particularly true of Japanese and U.S. scientists.

* Many undergraduate student research opportunities would be created by the project.

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Benefits to Canada

The project will train two to three graduate students per year. Typically three postdoctoral scholars would be working on projects at the UCN source.

* TRIUMF and the University of Winnipeg both are committed aboriginal science education. At TRIUMF, a new initiative has been launched in aboriginal recruiting for coop students, many of whom would be recruited for this project.

Knowledge Advantage

* Many of the technologies used to conduct the physics experiments are intimately linked to medical technology. For example, the Hayden research group at SFU additionally conducts research on low-field MRI imaging, because exactly this technology is used in the neutron electric dipole moment experiment.

* The surface nanoscience experiments that would be conducted at the UCN source relate to the characterization of large hydrogenous molecules for ``smart surfaces'', where an example in medicine in drug delivery exists. We anticipate that should the UCN ISR technique prove successful, that a large number of users from across the world would be interested in using the technology to study smart surfaces.

Entrepreneurial Advantage

* The UCN project has already attracted the interest of a small business in Pinawa, MB, Acsion Industries. Physicists at Acsion design neutron moderators for nuclear reactors, and the same technology and innovation is required for the neutron moderators used in the UCN source. Acsion scientists have already contributed to the project by beginning to study neutron transport in the source. It is possible that Acsion would also supply some small amount of CFI matching to the project. This is just one example, and more industry partners are expected once the project begins.

* Another technology used extensively in the UCN source is cryogenics. Spin-offs of this technology and of the afore-mentioned technologies used in the physics experiments, that relate to medical applications, could result in new enterprises.

Since the proposal has been pursued through the University of Winnipeg, we furthermore consider the impact on the Strategic Priorities listed in the Manitoba Innovation Framework. The proposal primarily impacts the Advanced Manufacturing aspect of the province's priorities. In fact, Acsion Industries is featured on the Manitoba Science, Technology, Energy, and Mines website (at time of writing), under the heading of advanced manufacturing, based on their application of nuclear physics technologies to

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Benefits to Canada

manufacturing. The CSUNS proposal also partially addresses life sciences, through the anticipated spin-off technologies and highly-related techniques. Also, as mentioned previously, the development of a skilled workforce through basic research is a primary goal of this proposal. More information can be provided on the project's relationship to the six-point action plan of Manitoba's Innovation Framework.

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Suggested Reviewers *

The CFI reserves the right to make its own selection of reviewers.

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Applicant institution: The University of Winnipeg **Project no.:** 19280

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Suggested Reviewers *

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Applicant institution: The University of Winnipeg **Project no.:** 19280

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Suggested Reviewers *

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