Budget Justification

The Canadian Spallation Ultracold Neutron Source (CSUNS) is a large, multi-year project with contributions from both Canada and Japan. To help to understand the project, we provide several summary tables at the end of this section. We provide a schedule overview of the project in Table 2 showing a list of major infrastructure items and milestones associated with them. In the chart, year 1 is assumed to start in the second quarter of the fiscal year of 2009, or July 2009. The schedules of CFI Items 1 through 6 are displayed. Item 7 "Physics Design of Moderators and Source" will be discussed in a separate section.

In Tables 3 to 5, we list detailed materials costs and for all the various parts of Items 2 through 5, which are the main hardware contributions of the Canadian portion of the CSUNS collaboration (through CFI) and of TRIUMF to the project. Additionally, the tables display human resource requirements (listed in person-months) which we explain when describing Item 6 "Engineering, Design, and Technical Human Resources".

We now describe each item shown in the table "Cost of Individual Items" on Page 3.1 of the Financial Module.

Item 1. Ultracold Neutron (UCN) Source System

The UCN source will be a superthermal source based on downscattering of cold neutrons (CN) in superfluid 4He. Fig. 1 on page 8.2 displays a schematic diagram of the UCN source.

Neutrons are liberated by proton-induced spallation from a tungsten target. The neutrons are moderated in room temperature heavy water and then 20 K heavy water ice down to CN energies. The moderator system is surrounded with a graphite reflector to reflect as many neutrons as possible back into the source assembly. The CN are down-scattered by creating phonons in superfluid ^{4}He (He-II) to UCN energies. Heat is removed via heat conduction in the He-II to the ^{3}He cryostat and the ^{4}He-^{3}He heat exchanger. UCN are transmitted horizontally through a series of valves to experiments.

The project is benefiting from a very large, secured, in-kind contribution from our Japanese collaborators. The existing Japanese UCN source will be modified in Japan. Once the modifications are complete, it will be tested in Japan in the low-intensity proton beam readily available at RCNP, Osaka. The UCN source will then be transported to Canada for installation and commissioning at TRIUMF. Only once the UCN source is installed in Canada will we be able to make use of the high-energy high-intensity proton beam already available at TRIUMF to produce the world's highest UCN density.

The existing Japanese UCN source therefore represents an in-kind contribution to the project. The existing source is worth $2M according to our collaborators from Japan, as determined directly from the costs they incurred in constructing the source. In Japan, this is done in close communication with private industry.

The Japanese UCN source, as it exists today, will be modified for horizontal extraction, involving a significant reorganization of the various pieces of the source. This modification will be complemented by a completely new neutron guide system including the UCN production volume. Taken together, these modifications will improve UCN transport and the storage lifetime for UCN in the system, hence increasing the UCN density by a factor of twenty. Improvements in the cooling system for the superfluid ^{4}He will be made to handle the intense proton beam available in Canada, and when moved to Canada this will give an additional factor of fifty increase in the UCN density, resulting in 10,000 UCN/cc.

The modifications to the existing source will cost $2M, and will be provided from a combination of grants from Japanese funding sources, and from internal funds from the collaborating Japanese institutes. Thus the total in-kind contribution from the Japanese to the project will be $4M. In addition, the Japanese are providing a huge commitment in terms of testing the source in Japan before sending it to Canada. We will therefore receive a fully operational UCN source, ready to be installed in Canada. This is a huge commitment to which we assign no in-kind value. Additionally, the Japanese will provide in-house engineers and technicians (typically one engineer and two technicians over the course of the project) free of charge and no in-kind value has been assigned to this either. We can say with certainty that if we were to attempt to construct such a source in Canada starting from scratch, the cost would be far in excess of the stated in-kind contribution of $4M.

The Japanese will also provide engineering and technical personnel support in Canada once the UCN source is installed in Canada. No in-kind contribution has been assigned to this considerable effort either.

It is important to make clear the distinction between Japanese and Canadian responsibilities. We therefore provide here a list of all the equipment that will be provided by the Japanese. It is essentially the equipment represented schematically in Fig. 1. This includes: the thermal moderator (300 K D_2O), the cold moderator (20 K D_2O), a Gifford-McMahon (GM) refrigerator (indicated by SRD220 on Fig. 1), the vacuum system, a temperature monitoring system, the UCN production volume and guides, an isotopically pure ^{4}He handling system, a ^{3}He cryostat, ^{4}He and ^{3}He pumps, a ^{3}He circulation system, and a UCN valve system.

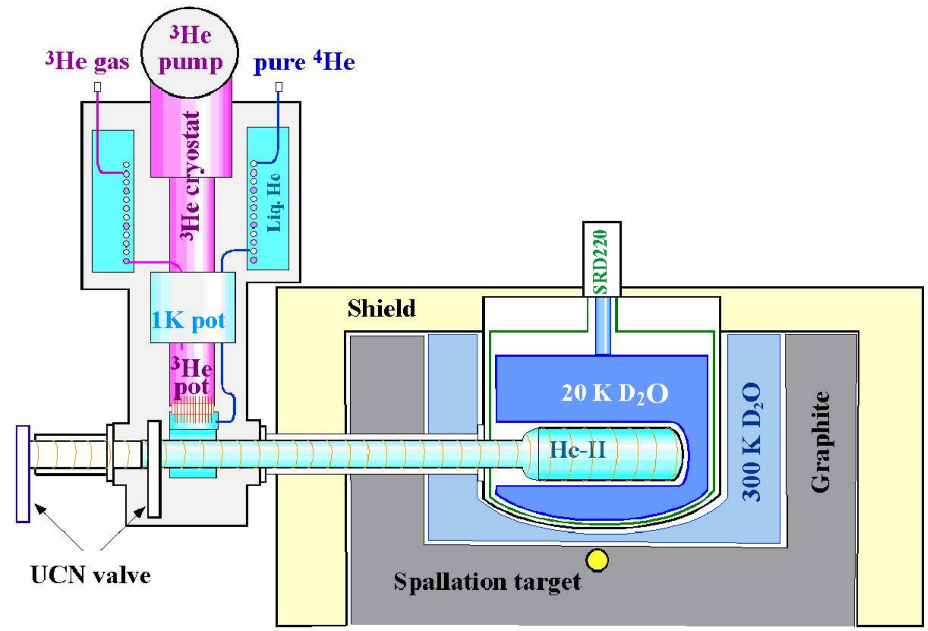

Figure 1: Schematic diagram of the UCN source system for CSUNS. The proton beam would impinge into the page upon the cylindrical spallation target.

In addition, the Japanese are preparing several test experiments related to the n-EDM experiment and related to the efficient polarization of the UCN using magnetic fields (required for the neutron lifetime and n-EDM experiments). All this equipment would be shipped to Canada for experiments once the source is in operation. The equipment includes: a superconducting coil for UCN polarization, an RF system for neutron spin reversal, a coil and power supply for the homogeneous magnetic field for using the NMR technique, a nuclear spin magnetometer, a permalloy magnetic shield, a superconducting magnetic shield, a high-voltage system, and an appropriate neutron storage volume.

We again assign no in-kind contribution dollar value to these considerable costs either. However we note that the n-EDM is a particularly challenging experiment which will require a significant effort over many years. It is for this reason that we intend to keep n-EDM efforts going at a small level in tandem with the neutron lifetime experiment.

The dedication of the Japanese UCN source to the Canadian project is an immediate and firm in-kind contribution of \$2M. The modifications of that UCN source (totalling another \$2M) would begin immediately upon approval of the CFI grant. The UCN source would be tested and ready for installation in Canada by early 2012.

The Canadian collaboration will also participate in the tests of the UCN source in Japan. We are requesting funds from NSERC GSC-19 (Subatomic Physics) this year to conduct those tests. A precursor to the grant is a grant from the Japan Society for the Promotion of Science to Y. Masuda and J. Martin for a 23-day trip to Japan by J. Martin which will occur in Feb. 2009. The development work that the Canadians will conduct in Japan will give us the required expertise to make rapid progress when the source arrives in Canada for installation and commissioning. We therefore are confident in our schedule for progress shown in Table 2 on page 8.8.

Item 2. Proton Beamline

The UCN source would be located in the Meson Hall at TRIUMF. A schematic diagram displaying the floor plan was presented attached to the project module.

One attractive feature of this location has been the cost savings that can be achieved by reusing a great deal of existing infrastructure. For example, there is already a considerable amount of shielding in the area, which shields experiments and experimenters from the proton beamline BL1A which will be used to drive the experiment. Additionally, should radioactive components need to be handled, there is easy access to remote handling hot cells. These would be used for servicing, for example, components of the spallation target. There is also an existing 50 ton crane in Meson Hall, which would be used, for example, for stacking shielding blocks. The central location of the Meson Hall site-wide would also allow easy access to the future helium liquifier for TRIUMF. Note that we are not considering any of this considerable amount of infrastructure as the in-kind contribution from TRIUMF. **We only consider items purchased, fabricated, or refurbished expressly for this project as TRIUMF's in-kind contributions.** TRIUMF has committed a $2M in-kind contribution towards the materials required for the construction of our beamline. The remainder of the funds required for beamline materials ($330k) would come from CFI (U. Winnipeg) funds. Human resource requirements for infrastructure acquisition and development for this effort will be discussed separately (see Item 6).

The UCN facility would be installed in Meson Hall after the completion of Pi-e-nu in late 2011. In early 2012, the area would be cleared to make space for the UCN source, and a new proton beamline would be constructed to deliver proton beam from BL1A onto the spallation target. A considerable amount of preparatory work must be done before that time, so that installation of the UCN source can take place on schedule.

One of the primary reasons for the choice of the Meson Hall location is the ability to switch the beam periodically onto the UCN target in a one minute on, three minutes off fashion, similar to the operation of the prototype source in Japan. The beam-off periods are required to achieve low background rates for the sensitive physics experiments that would be conducted at CSUNS. Often these experiments require counting mode detection of UCN, neutron decay products (electrons or protons), or gammas resulting from UCN or CN captures in materials. A distinct advantage of this pulsed operation of the spallation source is that the experiments have lower background when compared to experiments conducted at reactor UCN sources. Generally, those types of sources are plagued by large backgrounds simply because the neutron source cannot be switched off rapidly. This would be true of both the ILL, and Munich reactor sources. In contrast, experiments at TRIUMF would be conducted when protons would not be striking the spallation target, consequently with a considerable reduction in backgrounds from both fast neutrons and gamma rays.

Beam pulsing would be achieved as follows. The proton beam in Meson Hall would be operated as usual, running down the beamline BL1A line across the south side of Meson Hall, most of the beam being dumped into the high-power beam dump at the far southeast corner of the hall. Periodically, a portion of the beam would be "kicked" from BL1A to UCN through the use of kicker magnets that will be described momentarily. The rest of the time the beam to other users in Meson Hall would be completely undisturbed from normal operation.

The floor plan presented in the project module (Fig. 6, attached to the end of the project module) shows the layout in the Meson Hall and was created by a TRIUMF designer [1]. Beam would be delivered to the UCN source by a kicker and septum system. A beamline would be constructed to divert 40 μA of the 500 MeV proton beam onto the spallation target of the UCN source.

The beamline shown in the floor plan is based on design work and an optics study presented in Ref. [2]. The results indicate that the beam spot size on the spallation target can be controlled reliably using the focusing elements as designed. The design note thereby specifies the parameters of the magnets required for the beamline. In the following we refer to several beamline elements that can be found on the floor plan (Fig. 6, attached to the end of the project module).

Located upstream of the experiment on BL1A is a new fast kicker magnet (1AK1). When energized, it deflects the proton beam by 10 mr (milliradians), offsetting the beam by 65 mm at the start of a new magnetic septum (1U septum). The septum then bends the beam by a further 115 mr, displacing the beam from the BL1A axis by 220 mm at the dipole 1UB1. This dipole deflects the beam by a further 15 degrees. The final dipole magnet, 1UB2, deflects the beam by 45 degrees. Following those magnets, smaller steering magnets (1USM1 and 1USM2) are required to position the beam accurately on a tungsten spallation target at the centre of the UCN source. Two quadrupole magnets (1UQ1 and 1UQ2) are sufficient to provide focusing.

An important consideration for the UCN source is to minimize conflicts in proton beam sharing with other TRIUMF users. In the Meson Hall, we will impact mainly

μSR users using muon-spin relaxation (μSR) for condensed matter and materials science studies. These users are accommodated by the M9, M15, and M20 muon production targets and beamlines. The primary impact of the UCN source is an overall sharing arrangement with μSR users, so that the two sets of users would receive beam simultaneously. On average, 7% of the beam would be delivered to the UCN spallation target, the remaining 93% being delivered as usual to the μSR users. Meson production targets and beamlines located downstream of the UCN source would therefore remain unaltered and would continue to operate as usual.

The details of this beam sharing arrangement are dictated by the beam conditions as they exist at TRIUMF. The macro-structure of the proton beam is described pictorially in Fig. 2. The normal time structure of the proton beam is shown on the top panel of Fig. 2. A 1 kHz pulser in the injection line interrupts the beam once per millisecond for a short time of 10 μs to 40 μs. The exact time of the beam-off gap can be adjusted, and this is normally done in relation to beam tuning for ISAC.

The fast kicker magnet, with a rise time of 5 μs, would turn on during the brief beam-off interval and would remain on for 1 ms, directing beam to the UCN source. The kicker magnet would then turn off in the next beam-off interval. By adjusting the duty cycle, one can vary the split between UCN and downstream users. The lower two panels of Fig. 2 illustrate a 2:1 split, for example simultaneous 80 μA delivery to downstream users and 40 μA to UCN. This scheme makes no change to the BL1A optics and does not affect the instantaneous beam current to other users. The UCN source would typically take beam at 40 μA for 1 minute, then receive no beam for a further 4 minutes, during which time the UCN experiments would take data.

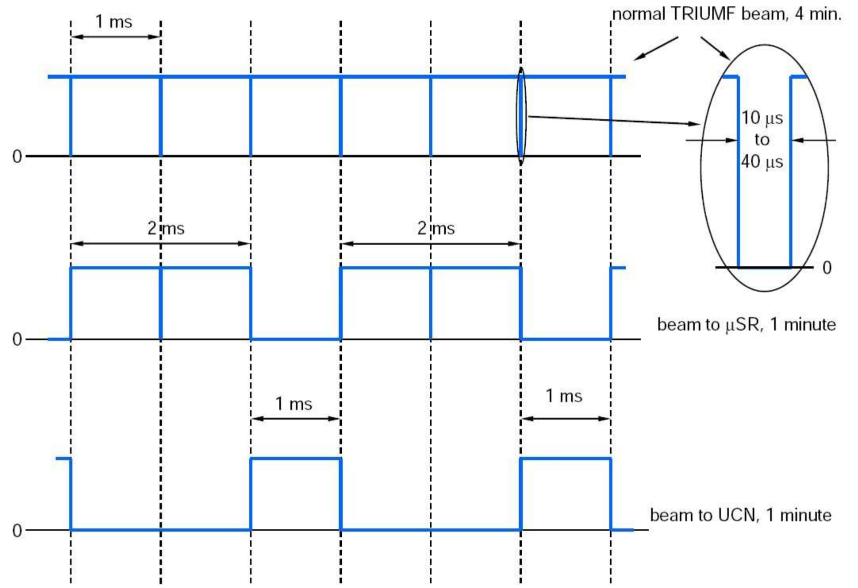

Figure 2: Method of sharing the proton beam between the UCN source and other Meson Hall users. Every 4 minutes, the UCN source takes a minute of beam in the form of a 1 ms burst every 3 ms. The instantaneous beam current is not affected and the total loss of integrated beam to downstream users is about 7%.

An expert TRIUMF engineer, who designs kicker magnets, has stated that the technical requirements for our kicker magnet (rise and fall times on the order of a few μs and a flat-top of 1 ms or more) are achievable [3]. TRIUMF engineers have therefore already begun the design process for this magnet and for the fast, high-current power supply that will be required.

The materials and human resource requirements for the proton beamline are displayed in Table 3. Below, we discuss the material costs. Human resource contributions will be discussed as a separate line item (see Item 6).

The kicker magnet 1AK1, the 1U septum, and the two dipole magnets (1UB1 and 1UB2) will be purchased new. The quadrupoles 1UQ1 and 1UQ2 will be reused from a decommissioned beamline. Existing power supplies from the M11 (to be decommissioned) are suitable for the quadrupoles and for the dipole 1UB1. The larger dipole magnet 1UB2 is a higher power magnet and requires a new power supply. (Labels refer to the floor plan, Fig. 6, attached to the end of the project module.)

The main cost of 1AK1 is in its special fast pulsed power supply. The power supply must also be located as close to the magnet as possible so that inductance can be minimized. The magnet will be custom fabricated at TRIUMF. Based on the cost for similar projects and on the advice of experts at TRIUMF [3], the kicker magnet will cost \$250k and the power supply will cost \$400k.

The septum magnet is more specialized and is consequently more expensive. A septum magnet that is not susceptible to radiation damage is required. Based on the costs of comparable radiation-hard septum magnets at TRIUMF (e.g. the septum downstream of T1), our 1U septum magnet will cost $520k [4]. Based on the cost of previous dipole magnets purchased by TRIUMF (the TRIUMF 2AB1/2 dipoles), the dipole magnets for the UCN proton beamline will cost $125k each [4]. In cases where existing magnets and power supplies will be used, we have made allowances for moving and re-connecting. Also included are a number of new smaller magnets, beamline instrumentation, and safety systems (see Table 3 on page 8.9). Overall, this results in the cost of $2,330,000 for the beamline components. As stated earlier, $2M of this cost will be supplied by an in-kind contribution from TRIUMF, and the remainder will be supplied by CFI funds. Human resource requirements will be discussed and are included as a separate line item (see Item 6).

Item 3. Spallation Target and Remote Handling

The spallation target itself will be made of one stopping length of tungsten, 2 cm in diameter. The target requires a mounting system, and a cooling system, and must be designed in such a way that safe extraction can be conducted for servicing.

Fortunately, TRIUMF has successfully designed and constructed several spallation targets in the past. We have determined that a previously designed spallation target system can be used for CSUNS. This has therefore resulted in significantly reduced design and construction time, since the system will be a copy of something previously constructed at TRIUMF. The entire system will be custom fabricated at TRIUMF. The cost of the target system is also well-known for the same reason: similar ones have been constructed recently for other experiments that are currently running.

The cost breakdown for the spallation target and associated systems is shown in Table 4 on page 8.10. The materials cost is $130k and will be supported by CFI funds. Human resource requirements (also presented in Table 4) will be discussed as a separate line item (see Item 6).

Item 4. Shielding

This project will strictly adhere to radiation safety procedures at TRIUMF. Radiation shielding will be used to ensure human safety, and to reduce backgrounds for experiments. The shielding must encase the spallation target and, to a lesser extent, the UCN source.

Calculations of the shielding requirements for the project have been conducted by the TRIUMF radiation safety group. Fig. 3 on page 8.6 shows the results of these calculations [5] which give the thickness of shielding in steel and the thickness of shielding in concrete that should be used to ensure that dose rates to humans can be reduced to an acceptable level outside the shield package. The results indicate that 1.5-3.5 m of steel followed by 2 m of concrete would reduce the dose rate immediately outside the shielding to less than 3 μSv/hr. This is safely below the 10 μSv/hr guideline for low occupancy areas such as walkways.

Using these guidelines from TRIUMF, the total volume of shielding required was calculated for our particular geometry for the shield package, using steel and concrete in block form for easy stacking by crane. This results in a requirement of 150 m^3 steel and 450 m^3 concrete.

Blocks will be fabricated with a standard 2'x3'x6' block size and instrumented with I-bolts for easy installation with a crane. The cost of the shielding was calculated based on previous experience at TRIUMF. The newly made steel blocks will cost $14,000/m^3. In cases where the precision and custom shape of new steel is not required, Energy Solutions (Oak Ridge, TN) offers slightly radioactive recycled steel at one dollar per 10-ton block. From a practical standpoint, the cost for such steel is completely determined by transportation charges. Transportation costs to a rail yard in Vancouver are $2000/m^3. For the shielding, we require 50 m^3 of new steel (in the central regions where precise tolerances are required) and 100 m^3 of recycled steel. This results in a cost of $900k for the steel shielding.

For the concrete shielding, we have again based the cost on TRIUMF experience from the on-site fabrication concrete shielding blocks. The cost is $2000/m^3 [4], resulting in a cost of $900k for the concrete volume. Additionally, we require $20k for the staging and installation of this significant mass of shielding materials. These costs are summarized in the lower half of Table 4 on page 8.10, and funding for this part of the project will be supported by CFI funds.

Item 5. Installation of Japanese Sections in Canada

Electrical power, water for cooling, and compressed air systems will be needed to operate the Japanese equipment (the UCN source system) in Canada. The materials costs associated with installation of these services will be $40k and are displayed in Table 5 on page 8.10. Human resource requirements for installation will be discussed in the next line item.

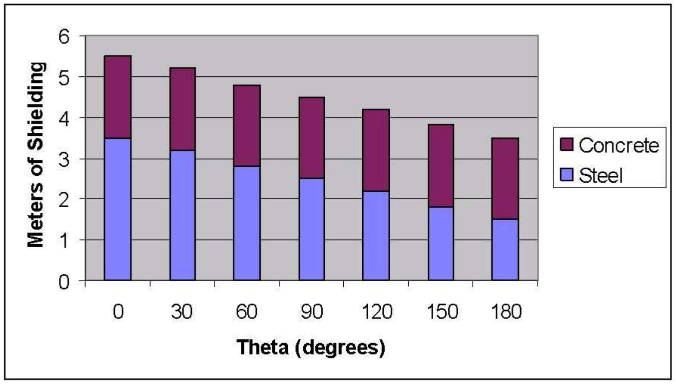

Figure 3: Shielding required for a 40 μA, 500 MeV proton beam incident on a thick tungsten target. The design dose rate is 3 μSv/hr immediately outside the shielding.

Item 6. Engineering, Design, and Technical Human Resources

A detailed breakdown of human resources requirements is shown in Tables 3 to 5, which have been referred to in the previous sections. All the time estimates have been determined in discussions with TRIUMF engineers [5, 6]. Generally, they are benchmarked against the extensive experience of these individuals in completing projects similar in scale to this one.

In Table 1, we have collected together from these tables a summary by major category. The numbers displayed in the table have also been converted to person-years. A total of 33.5 person-years will be required to successfully complete the acquisition and development (including engineering, design, fabrication, and installation) of the infrastructure.

TRIUMF has generously agreed to contribute technical human resource requirements totalling 16.7 person-years to the project. We assign no in-kind dollar value to this contribution, even though it is an eligible expense (it is certainly valued as infrastructure acquisition and development).

Item	Phys	Engr	Desn	Mach	Cntrl	Tech	Total
Proton beamline	1.5	6.0	3.9	2.2	1.1	8.0	22.7
Spallation target	0.3	0.3	0.5	0.5		0.5	2.1
Shielding	0.9	0.7				0.5	2.1
Install Japanese sections	1.6	1.6	1.0	0.5	0.5	1.4	6.6
Total	4.3	8.6	5.4	3.2	1.6	10.4	33.5

Table 1: Canadian human resource requirements for the UCN facility, in person-years. The columns indicate person-years divided into the categories of Physicists, Engineers, Designers, Machinists, Controls, and Technicians. Technician figures include mechanical, electrical, and vacuum technicians.

The remainder of the human resource requirements for infrastructure acquisition and development will be contracted following the policies and procedures of TRIUMF, and will be billed to the University of Winnipeg at a rate of $100k/person-year. This results in a cost of $1,680,000 in cash for engineering, design, and technical human resources. This fraction of the human resource requirements for infrastructure acquisition and development (50%) would be paid from CFI funds.

In the initial stages of the infrastructure acquisition, the human resource requirements are dominated by engineering and design work. In the later stages, it is focused on fabrication, installation, and other technical work. The spending profile will consequently be flat over the four years of the infrastructure project.

Item 7. Physics Design of Moderators and Source

As discussed in relation to Item 1, the Japanese UCN source will be reconfigured significantly before it is installed at TRIUMF. For the optimal and successful operation of the UCN source for maximal density, it is crucially important to maximize the flux of cold neutrons in the UCN production volume (the superfluid ^{4}He). In our source this requires optimizing the detailed geometry of the surrounding graphite and D_2O, which moderate the neutrons. The problem is very similar to the optimization of neutron production and transport in a nuclear reactor. Acsion Industries, a private company located in Pinawa, MB, has copious experience in this field. Acsion has already created a preliminary model of the existing Japanese UCN source, which will serve as a starting point for studying possible modifications.

The University of Winnipeg has signed a memorandum of understanding (MOU) with Acsion, contracting for services in completing this design, and in the completion of an MCNPX (Monte Carlo N-Particle eXtended) computer model of the UCN source. The work will be conducted over the entire four-year course of the infrastructure acquisition because iteration of the design will be required in communication with our Japanese collaborators. The MOU also mentions other services that Acsion will provide, including operational health physics support, government relations, and a significant commitment to training of highly qualified personnel in the use of the MCNPX computer model.

Acsion staff will provide 1000 hours of labor per year towards these activities over four years. The total cost of the work is $900k, of which half ($450k) is contributed in-kind by Acsion. The in-kind contribution consists of 1/3 of the labour cost (normally charged at a rate of $150/hr), access and training on the modelling software valued at $100k, and a license for intellectual property valued at $150k.

The remainder of the costs ($450k) will be paid to Acsion by the University of Winnipeg in monthly installments over 48 months, and will be supported 50-50 by CFI funds and the Manitoba Research & Innovation Fund (MRIF) supported by Government of Manitoba Science Technology Energy and Mines (STEM).

References

[1] S. Austen, TRIUMF Design Office, private communication.

[2] J. Doornbos, TRIUMF Beam Dynamics Group, TRIUMF Design Note TRI-DN-08-3.

[3] M. Barnes, TRIUMF Magnet Engineering Group, private communication.

[4] E. Blackmore, Head of TRIUMF Engineering Division, private communication.

[5] A. Trudel, TRIUMF Safety Officer and Head of Environmental Health and Safety, private communication.

[6] V. Verma, Head of Planning in TRIUMF Engineering Division, private communication.

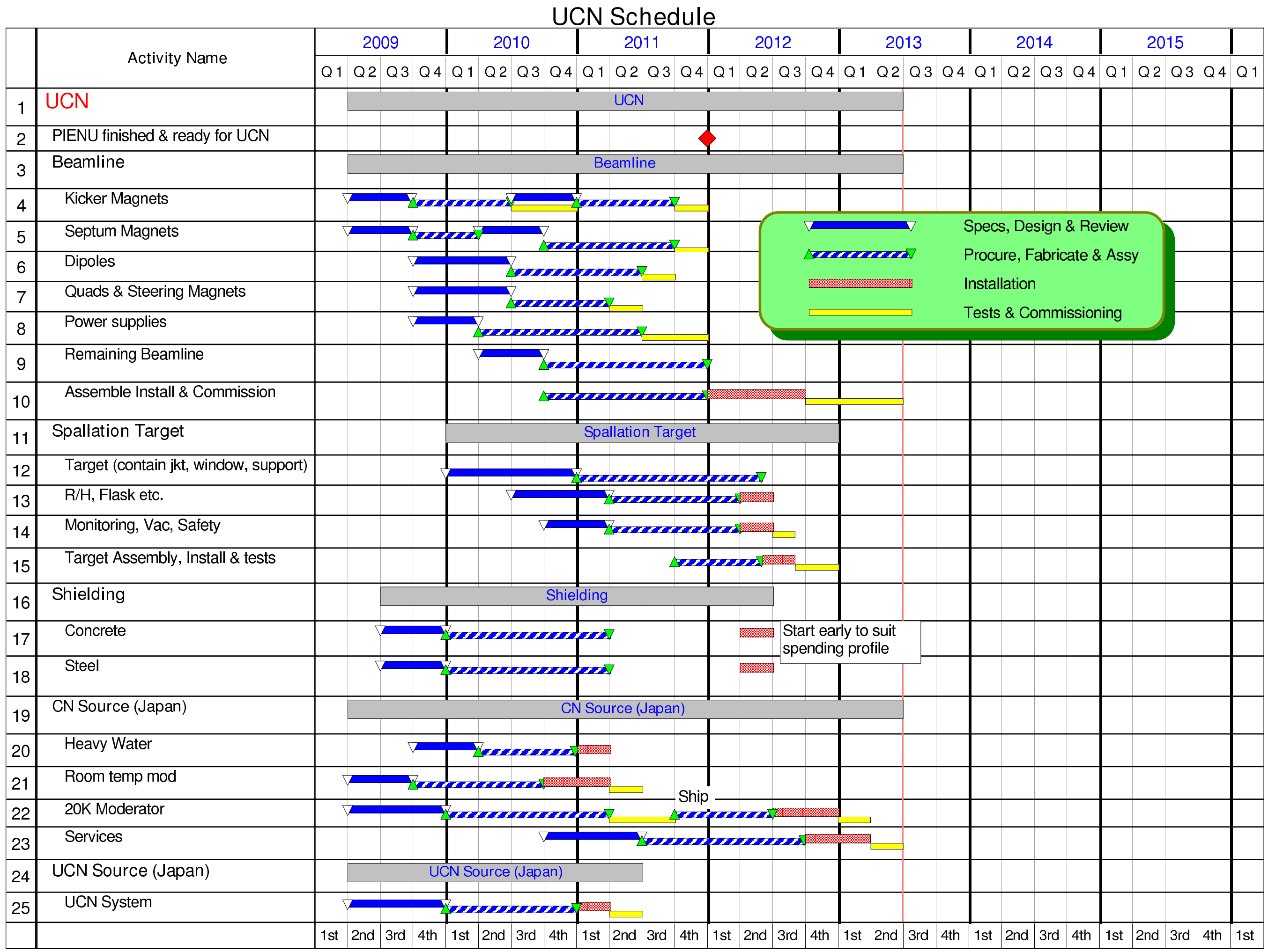

Table 2: Schedule displaying milestones for individual line items. Activities 19-25 refer to CFI Item Reference Number 1 “Ultracold Neutron Source System” and to Item 5 “Installation of Japanese Sections in Canada”. Activities 3-10 refer to CFI Item 2 “Proton Beamline”. Activities 11-15 refer to CFI Item 3 “Spallation Target and Remote Handling”. Activities 16-18 refer to CFI Item 4 “Shielding”. The human resource requirements for all activities are referred to in Item 6 “Engineering, Design, and Technical Human Resources”.

Project: UCN (Beam Line) Date: September 1, 2008 **Rev#3**

	Sub-projects/Work Packages	**Mat'l & Supplies (K$)**	**Human Resource Requirements (Person Months)**											
			Phys	**Engr**	**Design**	**M/Shop**	**Cntrls**	**Technicians**					**Outside**	**Total**
								Mech	**Vac**	**RF**	**Elect**	**Comp**		
1	Beamline:													
2	Kicker magnet	250	6	18	18	6		12			5			65
3	Septum(1) + protection monitor	520	1	9	6	4		4						24
4	Dipoles (2); 15 degree (new) and 45 degree (re-use)	250	1	3	6	2		4						16
5	2 quadrupoles (move from M20)	20		2		1		3						6
6	Steering magnets (4)	5		1		1		2						4
7	Power Supplies (install and connect) -->	30		2	1	1		3			3		3	13
8	P/S for 2 kickers(400k), 1 septum(100k)													0
9	P/S for 2 dipoles (may use M11 and 1B - 10k)													0
10	P/S for 2 quadrupoles (may use M11 suppllies) 5k													0
11	P/S for 5 steering magnets 20k													0
12	Total for all power supplies (to buy)	535		6										6
13	8 inch beam pipe and shine blockers	20		2	3	3		3						11
14	Beamline hardware													0
15	vacuum system	50	1	1	2	1			4					9
16	Move beam monitors	20	0	2		1		3						6
17	Diagnostics - electronics included in above													0
18	controls	250	3	6	1	1	12	1			4			28
19	Safety - ACCS	30	1	2	1	1	1	2			1		1	10
20	Safety - RMS	50	1	2	1	1		4			2			11
21	Services - (electrical)	200	1	2	3	1		1			1		10	19
22	Services - (water and air)	80	1	2	2			1					4	10
23	Vacuum boxes (kickers, septum, dipoles)													0
24	Assembly, installation, and commissioning	20	2	12	3	4		24	6		3			54
25														0
	Total	**2330**	**18**	**72**	**47**	**28**	**13**	**67**	**10**	**0**	**19**	**0**	**18**	**292**

Table 3: Resource estimates for Item 2 “Proton beamline”. Human Resource Requirements are included separately as Item 6 “Engineering, Design, and Technical Human Resources”.

Project: UCN (Spall. Targ. & shielding) Date: September 1, 2008 **Rev# 3**

	Sub-projects/Work Packages	Mat'l & Supplies (K$)	Human Resource Requirements (Person Months)											
			Phys	Engr	Design	M/Shop	Cntrls	Technicians					Outside	Total
								Mech	Vac	RF	Elect	Comp		
1	SPALLATION TARGET													
2	Target (including containment jacket, window and support)	30	2	2	3	3	0.5	3			0.5			14
3	Water cooling (included in "Target")													0
6	Remote handling, transfer flask, target suspension	100	2	2	3	3		3						13
7	Targeting monitor and interlock (incl in above)													0
8	Safety interlocks (incl in above)													0
9	Vacuum system (incl. in above)													0
10	**SPALLATION TARGET TOTALS**	**130**	**4**	**4**	**6**	**6**	**0.5**	**6**	**0**	**0**	**0.5**	**0**	**0**	**27**
11														0
12	SHIELDING													0
13	Removable concrete shielding (450 m3 @ 2k/m3)	900		4	3									7
14	Steel shielding (150 m3) design			4	3									7
15	(100 m3 recycled steel @ 2k/m3 = 200k)	200												0
16	(50 m3 new steel at 14k/m3 = 700k)	700												0
17	Preparation and Installation	20		3	2	1		6					2	14
18	**SHIELDING TOTALS**	**1820**	**0**	**11**	**8**	**1**	**0**	**6**	**0**	**0**	**0**	**0**	**2**	**28**
19														0
	Total	**1950**	**4**	**15**	**14**	**7**	**0.5**	**12**	**0**	**0**	**0.5**	**0**	**2**	**55**

Table 4: Resource estimates for Item 3 "Spallation Target" and Item 4 "Shielding". Human Resource Requirements are included separately as Item 6 "Engineering, Design, and Technical Human Resources".

Project: UCN (Install Japanese Sections) Date: September 1, 2008 **Rev#3**

Sub-projects/Work Packages	Mat'l & Supplies (K$)	Human Resource Requirements (Person Months)											
		Phys	Engr	Design	M/Shop	Cntrls	Technicians					Outside	Total
							Mech	Vac	RF	Elect	Comp		
UCN SOURCE - JAPAN		8	5	3	3		8					1	28
MODERATORS - JAPAN		10	10	5	3		7					1	36
Electrical	30	1	2	2		1				2		4	12
Water and Air	10		2	2		1						4	9
INSTALL JAPANESE EQUIPMENT - TOTAL	**40**	**19**	**19**	**12**	**6**	**2**	**15**			**2**		**10**	**85**
Total	**40**	**19**	**19**	**12**	**6**	**2**	**15**			**2**		**10**	**85**

Table 5: Resource estimates for Item 5 "Installation of Japanese sections in Canada". Human Resource Requirements are included separately as Item 6 "Engineering, Design, and Technical Human Resources".