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LETTER OF INTEREST
LETTRE D'INTÉRÊT

Title - Sujet RFI for QEYSSat	
Solicitation No. - N° de l'invitation 9F064-170198/A	**Date** 2017-07-21
Client Reference No. - N° de référence du client 9F064-17-0198	**GETS Ref. No. - N° de réf. de SEAG** PW-$MTB-545-14436
File No. - N° de dossier MTB-7-40088 (545)	**CCC No./N° CCC - FMS No./N° VME**
Solicitation Closes - L'invitation prend fin **at - à** 02:00 PM **on - le** 2017-09-08	**Time Zone** **Fuseau horaire** Heure Avancée de l'Est HAE
F.O.B. - F.A.B. **Plant-Usine:** ☐ **Destination:** ☑ **Other-Autre:** ☐	
Address Enquiries to: - Adresser toutes questions à: Niquette, Caroline	**Buyer Id - Id de l'acheteur** mtb545
Telephone No. - N° de téléphone (514) 496-3730 ( )	**FAX No. - N° de FAX** (514) 496-3822
Destination - of Goods, Services, and Construction: **Destination - des biens, services et construction:** AGENCE SPATIALE CANADIENNE 9F064 # SPACE SCIENCE & TECHNOLOGIE 6767 ROUTE DE L 'AÉROPORT ST HUBERT Québec J3Y 8Y9 Canada	

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Canada

Request for Information (RFI)

TITLE: Quantum EncrYption and Science SATellite (QEYSSat)

1. Purpose and Nature of the Request for Information (RFI)

Public Services and Procurement Canada (PSPC), on behalf of the Canadian Space Agency (CSA), is informing the Canadian space sector with respect to the Government of Canada's intention to proceed with a possible Request for Proposal (RFP) as part of the CSA's Capability Demonstration program for the development and demonstration of Quantum Key Distribution Technologies on the QEYSSat mission.

The objectives of this RFI are the following:

- To inform the space sector of the posting date scheduled for a potential RFP;
- To inform the space sector on the scope of the work proposed (Appendix A);
- To enable the space sector to suggest ideas for a secondary payload(s) which would be compatible with this flight opportunity and that could serve Canada's interests;
- To enable the CSA to collect potential solutions to reduce development timeline and cost of bringing new innovative technology to space;
- To enable the CSA to collect the information and factors to be considered in a potential RFP and
- To enable the CSA to collect information regarding preliminary cost estimates.

This RFI is neither a call for tender nor a Request for Proposal (RFP). No agreement or contract will be entered into based on this RFI. The issuance of this RFI is not to be considered in any way a commitment by the Government of Canada, nor as an authority to potential respondents to undertake any work that could be charged to Canada. This RFI is not to be considered as a commitment to issue a subsequent solicitation or award contract(s) for the work described herein. **It is important to note that some information provided in this RFI may be subject to change, in part or in its entirety, or could be removed prior to the official publication of a potential RFP. Finally, this RFI is not to be considered as a commitment on any part of the scope of work described.**

Although the information collected may be provided as commercial-in-confidence (and, if identified as such, will be treated accordingly by Canada), Canada may use the information to assist in drafting performance specifications (which are subject to change) and for budgetary purposes.

Respondents are encouraged to identify, in the information they share with Canada, any information that they feel is proprietary, third party or personal information. Please note that Canada may be obligated by law (e.g. in response to a request under the *Access of Information and Privacy Act*) to disclose proprietary or commercially-sensitive information concerning a respondent (for more information: http://laws-lois.justice.gc.ca/eng/acts/a-1/).

Respondents are asked to identify if their response, or any part of their response, is subject to the *Controlled Goods Regulations*.

Participation in this RFI is encouraged, but is not mandatory. There will be no short-listing of potential suppliers for the purposes of undertaking any future work as a result of this RFI. Similarly, participation in this RFI is not a condition or prerequisite for the participation in any potential subsequent solicitation.

Respondents will not be reimbursed for any cost incurred by participating in this RFI.

2. Context

In the 2017 Federal Budget, the Government of Canada introduces its Innovation and Skills Plan, which focuses on people and addresses the changing nature of the economy to ensure it works for all Canadians. The Innovation and Skills Plan aims to grow the next generation of globally competitive Canadian companies and strengthen Canada's economy in an increasingly challenging international environment. Budget 2017 advances an agenda to make Canada a world-leading centre for innovation and includes activities to demonstrate Canadian Innovations in space, notably in the field of quantum technology.

The development of new quantum technologies has the potential to transform markets, create new industries and produce leading edge jobs. Reliable cryptography is an important component of a truly secure communication infrastructure. Cyber security will strengthen our national sovereignty, security and prosperity by protecting our public and private networks from criminals and foreign threats, and other important institutions such as banks, hospitals and other service industries will depend on it.

The QEYSSat demonstration mission will bring Canada a step closer to an operational quantum communications service and a stronger overall cyber security posture for the nation in an age of quantum computing when traditional encryption is rendered obsolete.

3. Potential Work Scope and Constraints

As part of its policy and strategic planning activities, the CSA has identified key technologies and priority missions and now plans to solicit the Canadian space sector in the advancement of these priority technologies. For this solicitation, CSA encourages industry sector collaboration with academia.

Respondents are asked to provide their comments on the information contained in this RFI and its Appendices. It is important to note that these descriptions may be subject to change, in part or in their entirety, prior to the official publication of the RFP, if necessary.

Responses will not be submitted to a formal assessment. However, they could be used in the preparation of a potential RFP. No additional exchange on the subjects raised should be expected, though clarification may be requested as needed.

Respondents shall take care to provide the contact details of a resource person.

4. Trade Agreements, and Government Policies

Trade Agreements, and Government Policies that could impact a potential RFP:

- Trade agreements do not apply;
- The Canadian Content Policy applies;
- The Controlled Goods Program applies;
- The Federal Contractors Program for Employment Equity (FCPEE) applies;
- The Comprehensive Land Claims Agreements (CLCA) do not apply.

5. Schedule

Publication of the RFP

- For guidance, publication of the RFP on the Government's electronic tendering service is planned for the fall of 2017. It is worth noting that several factors may influence this date, and even lead to cancellation of such a publication.

Space sector consultation

- In order to process the information submitted and for it to be considered in the drafting of the RFP, responses are expected by the closing date.

6. Important Notes to Respondents:

Interested Respondents may submit their responses to the PSPC Contracting Authority, identified below, preferably via email: however, paper versions will also be considered.

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Changes to this RFI may occur and will be advertised on the Government Electronic Tendering System. Canada asks Respondents to visit Buyandsell.gc.ca regularly to check for changes, if any.

7. Closing date for the RFI

Responses to this RFI should arrive at the PSPC Contracting Authority identified above no later than September 8th, 2017.

The RFI closing date is the deadline to ensure that the comments received can be processed. Comments will be accepted until the RFP is published (where relevant); however, due to the posting date planned for this RFP, it is possible that the late comments may not be fully considered.

APPENDIX A. Quantum Demonstration Objectives

The objective of the QEYSSat demonstration mission is to create a quantum link between ground and space using polarized photons and to transmit encryption keys to ground based users using this link. These keys will then allow encrypting and transmitting information securely over the public communication infrastructure. These keys can also be used to re-key the satellite itself, or be distributed to one or more ground stations, with the satellite acting as the trusted node. In achieving this goal, the quantum link will be characterized and tested to gain insights into such things as the applicability of different types of photon sources and transmission schemes. The satellite will be used for concurrent scientific experiments with the long distance quantum link. Of particular interest are tests of the entanglement of photon pairs, with one photon remaining on ground and one being sent to the satellite. The insights that may be gained from this demonstration mission will provide information and risk mitigation strategies relevant to future missions, both application and science oriented.

The specific objectives of the demonstration are described below.

A.1. Demonstrate Long-Distance Quantum Key Distribution

Current ground-based quantum key distribution systems can only achieve distances of about 200 km. Employing a space-based platform as one trusted node of a quantum network will enable interconnection of arbitrary distances on the ground. Two or more ground stations can access the satellite, as it passes over, to exchange quantum signals with the satellite at different times.

At a later time, the satellite system will publicly transmit information that enables the ground stations to securely establish a joint key with one other. In principle, this could be implemented through ground stations individually establishing secure keys with the satellite via QKD, the binary difference of which can then be transmitted to the ground stations. Furthermore, by connecting the space-links to terrestrial fibre-based networks, it is possible to establish a secure key between any pair of users of the two, widely separated networks.

A.2. Demonstrate Satellite Re-Keying

The initial quantum key generated between the ground and the satellite can also be useful by itself to regenerate cryptographic keys in an operational satellite. Typically, any cryptographic key used on a satellite must be uploaded before launch and safely stored within the system over the whole lifetime of a mission. The two main challenges are to safeguard the crypto-keys for such a long period, as well as maintain the integrity of the key while in the space environment. Quantum key distribution, on the other hand, offers a method to refresh the key onboard an operational system. One interesting application of this capability is the re-keying of the satellite telemetry, tracking, and command system. Another application could be the generation of keys for the encryption of payload data, e.g. imaging data.

A.3. Test Long-Distance Quantum Entanglement

Quantum entanglement is an intriguing feature of nature, where photons or other particles behave in a strongly correlated manner even when separated by large distances or times. In fact, quantum mechanics theory does not impose any fundamental limits on the separation for which entanglement is capable of being exhibited. By using a space-based quantum platform for entanglement tests, the separation distance between the photons can be expanded drastically beyond what can be achieved over the ground.

This mission will demonstrate the feasibility to establish quantum entanglement between ground and space suitable for a future global network of quantum repeaters, as well as for un-trusted ground stations with hybrid free-space and fibre optics entanglement. Furthermore, these tests of quantum mechanical entanglement in new regimes have the potential to solidify (or disrupt) current theories. In addition, it is expected that interesting scientific results could also emerge if the measurements on the entangled photons are performed at different gravitational potentials and different velocities, regimes only provided by space platforms. Therefore, performing quantum entanglement tests that include a space platform will deepen our knowledge on the interplay of quantum physics with relativistic space-time and confirm the validity of using entanglement for applications such as Quantum Key Distribution. The proofs of security of quantum cryptographic techniques such as QKD are implicitly based on the assumption that the underlying physics is correct in the relevant regime. Testing the theory of entanglement at large distances provides the opportunity to validate the physical assumptions underlying the security of QKD in the regime relevant to space platforms

A.4. Test Various Quantum Sources on the Satellite Quantum Link

A quantum channel between ground and space is comprised of the combination of a quantum source, the optical transmission as well as the quantum receivers. Testing the satellite quantum channel with various quantum sources is a very important aspect of analyzing the performance of such a system. For example, the simplest quantum source, a weak coherent pulse (WCP) source, is suitable to accomplish secure QKD, but it has limited tolerance on the noise and link efficiency compared to an ideal single photon source, such as single photons extracted from entangled photon pairs or single photons emitted from a single atom. Study of such alternative quantum sources could prove advantageous by identifying sources that perform better with the quantum channel than a WCP source.

In addition, the choice of the quantum source is fundamentally connected to the application for which the quantum channel can be utilized. The most important quantum communication applications include a channel using an entangled photon source for quantum entanglement distribution, a channel using a pulsed entangled source for implementing quantum teleportation, and a channel based on a quantum memory to test concepts of quantum repeaters.

Assessing the characteristics of a satellite quantum channel with different quantum sources will therefore provide the most gain in the scientific and applied knowledge of satellite-based quantum key distribution and other quantum communications applications.

APPENDIX B. Mission Requirements

B.1. Mission Success Criteria

[QEYS-MIS-010-1.1] - **[QEYS-URD-0010] - QUANTUM KEY DISTRIBUTION**

Description: ***The mission SHALL distribute at least 100 kbit of secure key between at least two ground stations, with separation of at least 400 km (goal: many 1000's of km).***

Assumptions and Rationale:

- The mission must demonstrate QKD beyond the capabilities of existing technologies, and test the possibility for implementing a global quantum network. To achieve this, the satellite exchanges suitable information with each ground station such that the ground stations subsequently establish a common secure key. The length of this key must reach at least 100 kbit;
- The satellite is not required to perform complete post-processing necessary to determine this secure key for this task—the processing could potentially be performed entirely by the ground stations;
- For short-key between isolated ground stations, it is desirable that the complete processing happens on the spacecraft to facilitate the distribution process.
- The largest separation between any two of these ground stations must be no less than 400 km (which is about two times the current limit for ground based systems). The satellite should engage information exchange with each of these stations consecutively, or if more than two stations are active, non-consecutively;
- The satellite must employ a suitable data management system enabling it to relay the necessary information to the two relevant ground stations such that they can each securely reconstruct a common key, which should be compared to demonstrate that the stations in fact reconstructed the same key;
- The security of the distributed key is to be quantified by the probability that an eavesdropper gains any knowledge of any bit of the key with probability lower than 10^{-9};
- Ground station separation may include intercontinental stations if logistically feasible.

[QEYS-MIS-020-1.1] - **[QEYS-URD-0020] - MISSION DURATION**
Description: The Mission duration SHALL be at least 1 year (goal: 2 years or more).

Assumptions and Rationale:

- To be considered a sufficient starting point for future operational applications of QKD, the system must be sufficiently robust to withstand space conditions for at least 1 year.
- Future applications and science experiments will likely aim for longer durations—as such, the mission should aim for duration of 2 years or more.
- To characterize environmental effects on the quantum link characterization of conditions over a year is needed in various parts of the world.

[QEYS-MIS-030-1.1] - **[QEYS-URD-0030] - Satellite Re-Keying Performance**
Description: The mission SHALL demonstrate exchange of 10-kbit keys within a single pass for re-keying the satellite (goal: key lengths significantly greater than 10 kbit).

Assumptions and Rationale:

- For re-keying of satellites, it is necessary to demonstrate quantum key distribution between the ground and satellite platforms.
- For this task the satellite must perform the required post-processing to determine the secure key.
- To be considered successful, the mission must distribute 10 kbit of secure key (with eavesdropper success probability below 10^{-9}, as in MIS-010-1.1) between the ground and the satellite given a favorable single pass.
- The post-processing to extract the secure key from raw detections should be completed before a subsequent satellite pass over the same ground station.

[QEYS-MIS-040-1.1] - **[QEYS-URD-0040] - Satellite Re-Keying Reliability**
Description: The mission SHALL re-key at least 100 kbit within 30 consecutive days (goal: Keys totaling significantly greater than 100 kbit should be pursued).

Assumptions and Rationale:

- The ability to perform key exchange must be reliable. To demonstrate reliability, secure keys totaling at least 100 kbit in length must be distributed between a ground station and the satellite within 30 consecutive days.

[QEYS-MIS-050-1.1] - **[QEYS-URD-0050] - Short Keys**

Description:* *The mission SHALL demonstrate the capacity to support point-to-point distribution of 256-bit short keys to a network of un-trusted ground stations on a regular basis by establishing a secure key of at least 5,120 bits in a 7-day period.

Assumptions and Rationale:

- The intent is to demonstrate a distribution service between users that are not connected to quantum networks.
- Satellite is a trusted node that establishes keys with isolated stations.
- Requirements would demonstrate a weekly update to a network of about 20 stations. However, stations do not need to be built for the demonstration. Link statistics would be used to size the parameters of a larger system.
- The preferred demonstration is that the keys are generated on-board during the pass to facilitate the key distribution.

[QEYS-MIS-060-1.1] - **[QEYS-URD-0060] - Long-Distance Quantum Entanglement**

Description: The mission SHALL perform a Bell test for entangled photons separated over distance of more than 400 km (goal: 1000 km or more).

Assumptions and Rationale:

- The canonical test for quantum entanglement is a Bell test, where the observed correlations of outcomes of measurements of each photon exceed those that would be expected for an intuitive classical (i.e. not quantum) model. A successful Bell test is one where the measured Bell parameter is strictly greater than 2 (beyond 3 standard deviations, to ensure statistical certainty).
- Long distance entanglement must be demonstrated by conducting a Bell test with photons separated by a distance of more than 400 km, which is about two times the distance achievable by ground based systems.
- The Bell test must be successful unless failure of the apparatus itself can be reasonably eliminated, to the satisfaction of the Users and Science Team, as the cause of a measured Bell parameter less than 2. Such an outcome would indicate a fundamental scientific discovery.

[QEYS-MIS-070-1.1] - **[QEYS-URD-0070] - Quantum Sources**

***Description:** The mission SHALL characterize the performance of the ground-satellite quantum link with at least the following two quantum source types: 1) Entangled photon source, 2) Weak-coherent pulse (WCP) source (goal: the system should be capable of accepting a range of sources)*

Assumptions and Rationale:

- Other sources of interest may include NV-center sources, quantum dots, atomic vapor sources, and solid state quantum memories.

Using an Entangled photon pair source will effectively implement the BBM92 protocol, where one of the entangled photon pair is to be transmitted over the ground-based network, to be measured there, while the other photon is sent to the satellite. This could be used to demonstrate the generation of a key known only to the end user and the satellite, while the ground station does not and cannot know the key

[QEYS-MIS-080-1.1] - **[QEYS-URD-0080] - Photon Detection Records**

***Description:** The data collected by the mission shall be used to improve the knowledge of the environmental parameters and assumptions used in the quantum link budgets in order to facilitate the design of future systems.*

Assumptions and Rationale:

- The collected data should improve the understanding and modeling of background counts, atmospheric losses, timing variations, polarization purity, beam jitter caused by turbulence, etc, as a function of the system and environment parameters.
- Data shall be collected as frequently as possible, without compromising the other science objectives, to generate a maximum of statistics over a period encompassing four different seasons at the same location to characterize all environmental conditions (goal two full seasonal cycles).
- As a goal, the standard deviation of the error relative to the mean should be 5%. (Data collection can stop if this level of confidence is reached).
- As a goal, stations in different geographical and environmental conditions should be used for the characterization.
- As a goal, similar information should be collected for the optical beacon guiding system, also, to enable comparison (particularly link fluctuation, timing) with the quantum link.

APPENDIX C. Mission Goals

[QEYS-MIS-090-1.1] - **[QEYS-URD-0090] - Satellite-Based/Ground-Based Quantum Links Interface**

Description: The mission SHOULD demonstrate the interfacing of satellite-based quantum links with ground- based quantum links.

Assumptions and Rationale:

- Although one ground segment may be sufficient to demonstrate the proof of concept for this technology, the intent of this mission is to perform a representative application demonstration with two ground stations at least 400km apart.
- The deployment of a satellite-based QKD system does not invalidate the utility of ground based quantum links for local applications – indeed; both are needed to allow building a global network and meeting Canadian secure-communication requirements. Although it is important to show this satellite-based QKD system interfaced with a ground-based QKD system for further dissemination of the secure key between user locations, the scope of this mission does not include development of the fiber optic link that connects the ground station facility with a user located within the operating radius of the ground link.
- The preferred demonstration of this link (if ground based quantum link is not available), in the case of the BBM92 protocol, would be for one of the entangled photon pair to be transmitted over the ground-based network, to be measured there, while the other photon is sent to the satellite. This could be used to demonstrate the generation of a key known only to the end user and the satellite, while the ground station does not and cannot know the key.

[QEYS-MIS-100-1.1] - **[QEYS-URD-0100] - Key Confirmation During Satellite Re-Keying**

Description: The mission SHOULD verify that the key exchanged between ground and satellite is intact, and available to the satellite bus.

Assumptions and Rationale:

- When re-keying a satellite, it is vital that the new satellite key be identical to the key on the ground. To show that this is the case, the key computed by the satellite will be transmitted to the ground station for comparison with the key generated there.

[QEYS-MIS-110-1.1] - **[QEYS-URD-0110] - Security Certification**

Description: The mission SHOULD investigate aspects of security certification.

Assumptions and Rationale:

- There is currently a significant interest in the application of security certification processes onto implementations of QKD. While this mission does not aim to satisfy the stringent requirements that such a certification would entail, tests against such requirements and potentially-exploitable device imperfections would be beneficial for development of future deployments. Such tests may include, for example, attempts to temporarily blind the detectors with relatively strong laser pulses directed at the receiver from an alternative ground station.
- QEYSSat itself is not intended to be fully certified.

[QEYS-MIS-120-1.1] - **[QEYS-URD-0120] - Uplink And Downlink Quantum Channel**

Description: The mission SHOULD characterize the quantum channel for both uplink and downlink between ground and satellite.

Assumptions and Rationale:

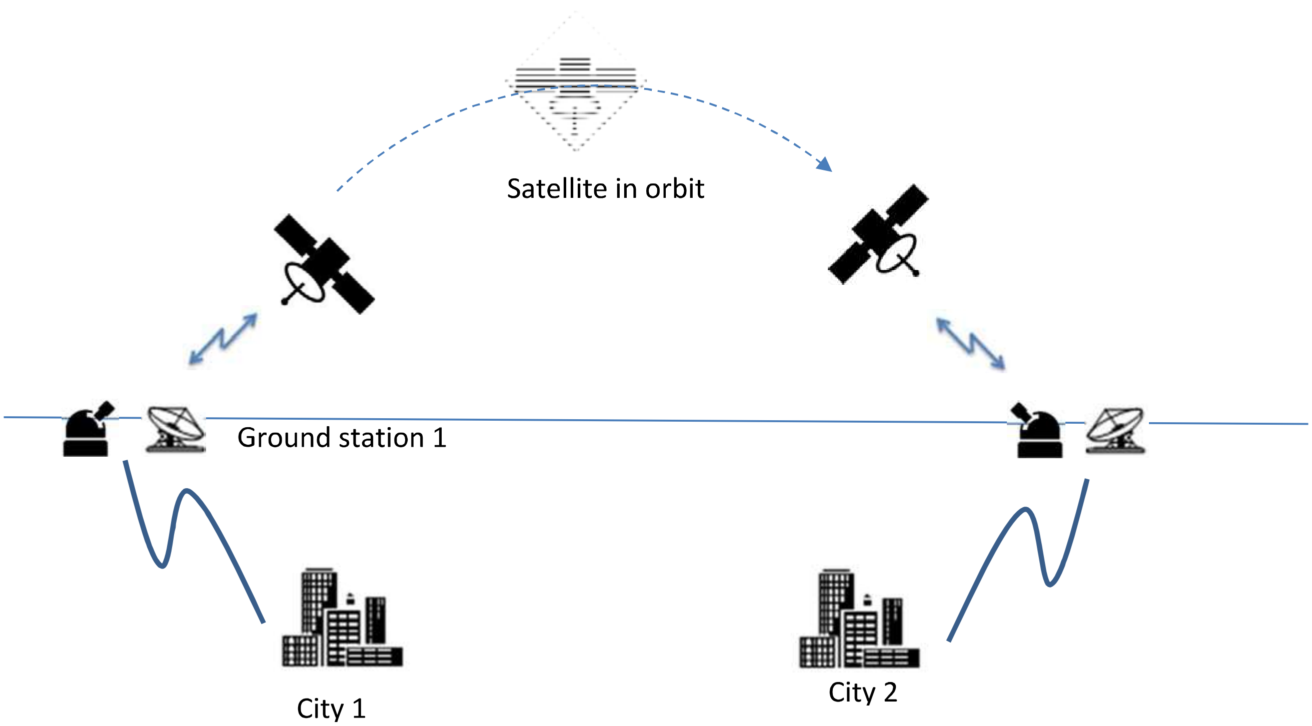
- We expect the primary quantum sources will be situated on the ground. An alternative is to place a quantum source on the satellite (downlink). The satellite platform should contain at least one or more quantum sources (e.g. WCP source, entangled photon source). Link statistics will be collected for this source, with a ground receiver, in order to assess its suitability for quantum communications. This source may be used to demonstrate quantum key distribution.
- Current design would allow adding an extra module. If a partner can be found, it could be a contribution.

APPENDIX D. Concept of Operations for QEYSSat Mission

D.1. Mission Overview

The objective of the proposed mission is to create a quantum link between ground and space using polarized photons and to establish encryption keys for ground based users using this link.

Satellites would be used as a trusted node to bridge the gaps between the distance between geographically dispersed QKD ground networks, for example between cities and continents.



The proposed system is based on a quantum photon uplink from ground to a satellite. The quantum source is located at the ground station and the quantum receiver (photon polarization detectors) is located on the satellite.

In addition to quantum sources and receivers, crucial classical systems for this mission include laser beacon sources and receivers at both ends, for link acquisition, polarization monitoring and compensation, and fine pointing for the quantum link. A clock alignment process for the precise time tagging of photons is also essential. In addition to quantum communication, classical communication using standard Radio Frequency (RF) communication links will be used.

The ground based fiber optic links between trusted nodes will not be demonstrated during this mission.

D.2. Orbit

The primary drivers for the orbit selection are the fact that the optical quantum link will only function when both the ground station and the satellite are in the dark, and the RF system must have sufficient access time to support the required data transfer. Global coverage is also desired. No orbit maintenance is necessary for a one year mission.

The satellite should be placed in a high inclination orbit to provide regular night time passes. A sun synchronous (SSO), 600 km noon-midnight orbit was used for the quantum link analysis, but the final orbit will depend on available launch opportunities. Depending on the actual orbit and ground station locations, one to three dark passes may be possible per night, but only passes with clear skies can be used.

D.3. Space Segment

In its simplest form, the main components of the primary Payload can be described as follows:

- A Quantum Receiver to detect photon polarization;
- A laser beacon receiver and transmitter to assist with pointing and tracking between space and ground;
- The main computer which processes the quantum information, time tags it, produces a Key and packages the information for download.

The spacecraft bus is needed to provide attitude control (pointing), command and data handling, power conditioning, RF communication with the ground, GPS satellites based navigation, structural support, thermal conditioning, etc.

D.4. Ground Segment

The intent of this mission is to perform a representative application demonstration, as such, two ground stations are needed to meet the user requirement of distributing a key to two ground stations located at least 400km apart.

The ground segments consist of:

- A telescope to detect laser beacon photons from the satellite;
- A laser beacon to assist with pointing and tracking of the satellite;
- An RF antenna to communicate with the spacecraft, but it does not need to be co-located with the telescope;

- Ground computers to control telescope pointing, perform QKD processing and eventually, to interface with a ground QKD network.

The ground segment interface to the ground QKD network is not included in the mission requirements.

D.5. Launch Segment

As this is a microsatellite it will not be the primary payload on the rocket that will bring it to space, and the final orbit selection will depend on available launch opportunities.

The prime contractor for QEYSSat Phases B-D will also be responsible for launch procurement. The proposed microsatellite concept should be easily adaptable with different commercially available launchers such as Falcon-9 or PSLV.

D.6. Concept of Operation

In nominal operations, when the satellite is in daylight, it can be oriented to maximize power generation, while protecting its optical systems from the sun. When the satellite is in the Earth shadow, the quantum transmission can be carried out. As it approaches a quantum ground station, it will slew to point the tracking beacon towards where the ground station will appear on the horizon, and then track the ground station during the pass. Once detected, the beacon signals will be used to drive the fine pointing systems and the quantum link will be acquired. Three options are then possible for the pass activity: quantum key generation, Bell test type experiments, or other activities of a commissioning or characterization nature. The pass activity will define what data is communicated to ground, either in near real time to a collocated RF station, or at a later time to an offsite station.

APPENDIX E. Technology Demonstration Opportunity: Potential Secondary Payload

CSA is committed to supporting the development of Canadian industrial capabilities in the area of space technologies for the purpose of increasing the commercial potential of Canadian Industry and secure their fair share of the New Space Economy.

Within Canada's Space Policy Framework, the Canadian Government underlines the fact that space yields more commercial opportunities than ever. It is therefore not surprising that "Positioning the Private Sector at the Forefront of Space Activities" has been identified as one of its core principles. The Framework also mentions that the lifeblood of the space industry is innovation, which in turn rests on research and development (R&D). Working with industry, the Government of Canada will encourage opportunities in R&D and innovation by increasing its support for technology development, especially in areas of proven strength such as robotics, optics, satellite communications and space-based radar, as well as in areas of emerging expertise.

It is indeed paramount that the Canadian space industry remains strong, healthy and relevant, and that it has the required readiness to respond to national demand and the necessary competitiveness to secure its fair share of commercial and institutional markets worldwide. Only through innovation and continued investments in R&D can Canada ensure that it has the industrial depth and breadth to remain a valued player in the international arena.

One of the components of the Capability Demonstration Program of the CSA has the mandate to support the development, sustainment and enhancement of industrial technological capabilities in the space domain that are of strategic importance to Canada through frequent flight opportunities on various platforms. This is intended to support the industry's responsiveness to future market demand and the maintenance of its global competitiveness.

This RFI seeks to identify potential space technologies that could leverage the benefits of a flight demonstration onboard QEYSSat spacecraft as a potential secondary payload. Canadian Industries are encouraged to submit their ideas on the potential secondary payload flight demonstration as a response to this RFI.

It is expected that the proposing party will assume all costs associated with the potential secondary payload including but not limited to development, integration, tests, launch increment and operation. Industry is encouraged to indicate the cost parameters of the potential secondary payload in the response to this RFI. It is important that the potential secondary payload shall not have any cost, schedule and AIT complexity impact on the QEYSSat.

APPENDIX F. Cost Reduction Measures

If Canada is to maintain its competitive edge, increase productivity and spur innovation, we must constantly strive to improve the conditions for doing business. The Government of Canada is committed in finding new ways of working with industry with the goal to streamline mission delivery.

Hence, the QEYSSat mission will endeavor to establish a new standard for conducting Government led R&D missions. We will be using the upcoming Phase A study to identify specific measures that could be implemented in an effort to reduce mission timeline and costs of bringing new innovative technologies to space. These measures could include:

- Streamlining regulatory approval processes;
- Reducing reporting requirements and information demands; and
- Improving the coordination of compliance and enforcement activities.

Specific ideas and suggestions to streamline the management of demonstration mission include:

- Establishment of a mission risk classification system that will guide the design and test philosophy and the appropriate mission assurance and risk management strategies;
- Streamlining and reducing documentation requirements and allowing more flexibility on content and format;
- Using peer reviews rather than formal technical reviews that offers an open-loop “make-it-work” corrective action system;
- Allowing more flexibility through the use of deviations and waivers (as needed) to maximize mission success and promote innovation;
- Instead of CSA-imposed standard, establish a framework for CSA-contractor mutually agreed PA/QA standards
- Using commercial components and low heritage parts.

APPENDIX G. Science Driven Technology Enabled Mission

QYESSat serves as a breakthrough gate to bring the achievements of University quantum research into the realm of space technologies and world wide applications in communications and cybersecurity. As such CSA sees a critical importance that the scientific leadership initially established through previous QEYSSat studies, technology developments and terrestrial field demonstrations is maintained throughout all mission phases [1-5]. To this end, the Institute of Quantum Computing of University of Waterloo (IQC) will lead the QEYSSat scientific support for the Government of Canada stakeholders, QKD application and demonstration development, provide required expertise to industrial team and provide support to CSA project management office.

In order to maintain continuity throughout all mission phases, CSA intends to provide a dedicated science funding throughout Phases A-E, which will be separate from the industrial development contracts.

It is expected that IQC will be supported by other Canadian scientific institutions prominent in the field.

References:

1. QEYSSat web site: https://uwaterloo.ca/institute-for-quantum-computing/qeyssat
2. Pugh, C.J.; Kaiser, S.; Bourgoin, J.P.; Jin J.; Sultana, N.; Agne, S.; Anisimova, E.; Makarov, V.; Choi, E.; Higgins, B.L.; Jennewein, T. “Airborne demonstration of a quantum key distribution receiver payload”, Quantum Physics, https://arxiv.org/abs/1612.06396
3. Bourgoin, J.P.; Gigov, N.; Higgins, B.L.; Yan, Z.Z.; Meyer-Scott, E.; Khandani, A.K.; Lutkenhaus, N.; Jennewein, T. “Experimental quantum key distribution with simulated ground-to-satellite photon losses and processing limitations”, Physical Review A, Vol. 92, 12 pp, (2015).
4. Bourgoin, J.P.; Higgins, B.L.; Gigov, N.; Holloway, C.; Pugh, C.J.; Kaiser, S.; Cranmer, M.; Jennewein, T. “Free-space quantum key distribution to a moving receiver”, Optics Express, Vol. 23, 33437-33447 pp., (2015).
5. Jennewein, T.; Bourgoin, J.P.; Higgins, B.; Holloway, C.; Meyer-Scott, E.; Erven, C.; Heim, B.; Yan, Z.; Hubel, H.; Weihs, G.; Choi, E.; d'Souza, I.; Hudson, D.; Laflamme, R. “QEYSSAT: a mission proposal for a quantum receiver in space”, Advances In Photonics of Quantum Computing, Vol. 8997, 7 pp. (2014).

APPENDIX H. RFI Feedback Form

The respondents to this RFI are encouraged to provide feedback by completing this form. Any other pertinent information may be attached to this form as the respondents may feel necessary.

Name of organization:

Point of contact (name, address, phone, e-mail):

Category (Industry, Science & Application, Other):

Role in QEYSSat (Supplier, System integrator, Service provider, Science support, etc.):

Brief description of the proposed role in QEYSSat project (~1 page):

Development schedule of QEYSSat mission (if applicable):

ROM cost of QEYSSat mission (if applicable):

Anticipated team arrangements (if applicable):

Potential Secondary payload name (if applicable):

Potential Secondary payload description and industrial benefits (if applicable):

Potential Secondary payload Development schedule (if applicable):

Potential Secondary payload ROM cost and funding options (if applicable):

Conditions, ideas and suggestions for reducing delivery timeline:

Other feedback (if any):
