ISS NATIONAL LABORATORY PROJECT CONCEPT SUMMARY

Technology Advancement and Applied Research Leveraging the ISS National Lab

ISS National Lab Research Announcement 2023-8

(Do not exceed 3 pages when complete)

Proposed project name: Experiments with Silicon Quantum Dots and Silicon Quantum Dots spin qubits in the Microgravity Environment.	
Principal investigator (PI): iLAKKUVASELVI MANOHARAN	**Project type:** ✔ Flight ✔ Ground ☐ Other
Email address: ilakk2023@gmail.com	**Space experience:** ☐ High ☐ Low ☐ None
PI citizenship status: ☐ U.S. citizen ✔ Permanent resident ☐ Non-U.S. Person	**PI country of citizenship (if non-U.S.):** India
Organization legal name: Bubbles & Cafe, Inc	
Organization status: ✔ U.S. Entity ☐ Non-U.S. Entity	**Organization address:** 990 Shoreline dr Aurora IL 60504
Organization type: ✔ Commercial ☐ Academic ☐ Government ☐ Nonprofit	
Organization Unique Entity ID: C7Y5XP1FBXY7 / **Organization CAGE code:**	
Is this research or technology subject to U.S. export laws and regulations? ✔ No ☐ Yes, explain below	
How did you hear about this research announcement? ✔ ISS National Lab website ☐ Email ☐ News article ☐ Advertisement ☐ NASA ☐ NSF ☐ ISS Research and Development Conference ☐ Other conference ☐ Other (please describe):	

- Vision: Study silicon quantum dots and spin qubits in a microgravity environment to advance quantum computing and explore novel quantum phenomena.
- Rationale: Microgravity experiments will provide unique insights into the behavior of quantum systems and their potential applications in fault-tolerant quantum computing.
- Objectives: Investigate quantum coherence, assess fault-tolerance, discover novel quantum phenomena, advance quantum device engineering, and foster interdisciplinary collaboration.
- Impact: The project aims to revolutionize information processing and contribute to fields like cryptography, materials science, drug discovery, and engineering problem-solving.

Objectives:

- Coherence and Stability Analysis: Evaluate the coherence and stability of silicon quantum dots and silicon quantum dot spin qubits in a microgravity environment. Compare the results with those obtained in terrestrial laboratories to assess the impact of reduced gravity.
- Quantum Information Processing: Investigate the performance of silicon quantum dots as qubits in quantum information processing tasks, such as quantum entanglement generation, gate operations, and quantum error correction, in the microgravity setting.
- Scalability and Integration: Examine the scalability of silicon quantum dot systems in the microgravity environment and explore possibilities for their integration into large-scale quantum processors and quantum networks.
- Fundamental Quantum Phenomena: Probe fundamental quantum phenomena, such as quantum entanglement, superposition, and tunneling, in the context of silicon quantum dots and spin qubits under microgravity conditions. Investigate how these phenomena behave in the absence of gravitational interference.
- Technological Advancements: Identify any potential technological advancements and discoveries resulting from the experiments, such as improved quantum coherence times or enhanced control techniques, which could have broader implications for quantum technologies.

Explain how it demonstrates effective use of the International Space Station (ISS) National Laboratory. Include goals and deliverables.

1. Effective use of ISS National Laboratory: Utilize microgravity to study silicon quantum dots and spin qubits for advancing quantum computing and exploring novel phenomena.
2. Goals:
   - Characterize the behavior and properties of silicon quantum dots in a microgravity environment.
   - Investigate the coherence and stability of silicon quantum dots as spin qubits in microgravity.
   - Explore potential applications of silicon quantum dot spin qubits for quantum computing and communication in space.

3. Deliverables: Coherence analysis, fault-tolerance insights, observations of novel phenomena, improved quantum device engineering, scientific publications, practical applications, and space collaboration.
    - Detailed analysis of the quantum dot behavior in microgravity, including measurements of their physical characteristics and interactions with electrons.
    - Assessment of the coherence times and entanglement capabilities of silicon quantum dot spin qubits in the microgravity environment.
    - Insights into the suitability and challenges of utilizing silicon quantum dot spin qubits for quantum information processing and communication tasks in space.

State the test objective and the starting and ending technology readiness level (TRL).

Starting Technology Readiness Level (TRL): TRL 3 or 4: Basic research and experimentation on silicon quantum dots as spin qubits in laboratory settings.
Ending Technology Readiness Level (TRL): TRL 5 or 6: Demonstrates feasibility of using silicon quantum dots as stable spin qubits in microgravity

Describe how the project utilizes the conditions of a space-based laboratory or environment (e.g., extended access to microgravity, extreme environmental conditions).

- Extended Access to Microgravity
- Reduced Convection and Sedimentation
- Enhanced Coherence and Quantum State Control
- Lower Temperature Fluctuations
- Reduced Electron-Phonon Interactions
- Longer Experimental Durations
- Minimal Background Noise
- Opportunity for Novel Research

Describe how the project's outcome will further technology development that will ultimately lead to a commercial product or solutions offering.

- Quantum Computing Advancements: Improved coherence and stability for more powerful and reliable quantum computers.
- Quantum Communication and Encryption: Advanced quantum communication protocols and secure encryption systems.
- Quantum Sensing and Metrology: More sensitive and precise quantum sensors for various applications.
- Quantum Memory and Data Storage: High-capacity, ultra-secure quantum data storage solutions.
- Materials Science and Nanotechnology: Advances in nanoscale materials and their properties.
- Space-based Technologies: Enhanced performance of quantum-based systems in space missions.
- Commercial Partnerships and Startups: Attraction of investors and creation of startups focused on quantum technologies.
- Global Technological Competitiveness: Establishing a competitive edge in the global technology landscape.

Concept of Operations:

Provide a basic description of the project's in-orbit requirements and experimental setup.

In-Orbit Requirements: Stable microgravity environment; Secure payload integration for launch; Reliable power supply and thermal control; Communication link with ground control; Microgravity isolation and safety measures

Experimental Setup: Production of silicon quantum dots; Initialization and manipulation of spin qubits; Control electronics for magnetic fields and microwave pulses; Optical system for probing and readout; Sensors for monitoring parameters; Data acquisition and storage; Software for experiment control; Testing and calibration; Contingency plan for unexpected situations.

In-Orbit Timeline: Launch and deployment; Initialization and calibration; Execution of experiments; Real-time monitoring from ground control; Deactivation and data preparation for downlink; Payload retrieval (if applicable)

Describe any specific hardware or in-orbit facilities necessary to support this project, if known.

1. Essentials: Payload Integration System, Power Supply System, Thermal Control System, Communication System, Control Electronics, Optical System, Sensors and Instrumentation, Data Acquisition and Storage, Microgravity Isolation System, Safety Mechanisms, Ground Control Center.
2. CAL (Cold Atom Lab) - Refer to the attached document
3. Tec-Masters, Inc. (TMI)'s Microgravity Research for Versatile Investigations (MaRVIn) system installed in the MSG facility. - Refer to the attached document by Tec-Masters, Inc

Define the logistical support and payload return requirements.

Logistical Support and Payload Return Requirements:

ISS National Lab Use Only:
Complexity: R C A S
IP Portal Needed: Y N

Operations Lead: _____
Science Lead: _____

- Launch and Integration: Coordinate launch with providers; Ensure secure integration with the launch vehicle.
- Mission Planning and Execution: Schedule experiment in microgravity environment facility; Develop a detailed timeline for execution.
- Ground Control Center: Establish a qualified ground control center; Ensure real-time communication with the space platform.
- In-Orbit Monitoring: Implement a comprehensive monitoring system; Regular communication with the crew (if applicable).
- Data Management and Storage: Develop a robust data management plan; Implement onboard data storage and backup.
- Contingency Planning: Prepare for unforeseen issues and anomalies; Define troubleshooting and corrective procedures.
- Experiment Deactivation and Stowage: Plan safe deactivation and stowage; Ensure secure storage for the return journey.
- Payload Retrieval and Return: Coordinate retrieval of retrievable spacecraft; Ensure compliance with safety protocols.
- Post-Mission Analysis: Analyze collected data thoroughly; Compare with expected outcomes and ground experiments.
- Regulatory Compliance: Ensure compliance with relevant regulations and safety standards.

Identify any preliminary discussions the offeror has had with an Implementation Partner, including evidence that the Implementation Partner can meet the proposed technical and schedule requirements.

Please refer to the attached documents from the implementation partners.

If known, provide an in-orbit operations timeframe (i.e., desired launch date and flight duration).

Successive Experiments for Iterative Microgravity Studies:

- Baseline Earth-based Experiment: Gather data on silicon quantum dots and spin qubits under normal gravity.
- First Microgravity Experiment - Initialization and Manipulation: Test spin qubit initialization and manipulation in microgravity and compare with Earth-based results.
- Microgravity Isolation Experiment: Study effects of microgravity isolation on spin qubit stability.
- Quantum Dot Production in Microgravity: Investigate silicon quantum dot production in microgravity.
- Second Microgravity Experiment - Coherence Time Enhancement: Optimize coherence times of spin qubits in microgravity.
- Spin Qubit Readout in Microgravity: Develop accurate spin qubit readout methods in microgravity.
- Quantum Error Correction in Microgravity: Explore quantum error correction techniques.
- Third Microgravity Experiment - Quantum Entanglement and Superposition: Study quantum entanglement and superposition in microgravity.
- Scalability and Quantum Information Processing: Assess scalability and quantum information processing tasks in microgravity.
- Fourth Microgravity Experiment - Quantum Communication: Investigate quantum communication protocols in microgravity.
- Comparative Study and Return: Conduct a comprehensive comparative study and return the experimental setup for post-flight analysis.

Benefits/Business Case:

Why this proposed project important?: Advancing Quantum Computing; Coherence Enhancement; Novel Phenomena Discovery; Quantum Error Correction; Space-Based Quantum Tech; Fundamental Physics Insights; Collaboration Potential; Commercial Applications; Long-Term Space Exploration; Inspiring Future Scientists.

Researching silicon quantum dots and spin qubits in low Earth orbit can lead to disruptive products and services: Ultra-fast Quantum Processors; Space-Based Quantum Communication; Quantum Sensing and Imaging: Precise sensors for geophysical exploration, medical imaging, and environmental monitoring; Quantum Navigation; Space-Optimized Quantum Tech: Miniaturized, low-power quantum systems for long-duration space missions; Quantum-Enhanced Materials and Manufacturing: Advanced materials impacting electronics, aerospace, and energy storage; Quantum Gravitational Wave Detection: Next-gen sensors for studying gravitational waves; Quantum-Based Satellite Navigation: Improved satellite systems for global positioning and communication; Quantum Cryptography: Unbreakable security for data transmission and cyber protection; Quantum AI and Machine Learning: Accelerated algorithms transforming finance, logistics, and healthcare.

The products resulting from this proposed project will be used by: Quantum Computing Industry; Space Agencies and Exploration; Telecommunication and Data Security; Earth and Environmental Sciences; Satellite

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Operations Lead: _____
Science Lead: _____

Navigation and Communication; Aerospace and Defense; Academic and Research Institutions; Public and General Population.

Estimating revenue from this proposed project includes:

- Short-term (0-2 years): Research grants and collaborations.
- Mid-term (2-5 years): Technology licensing and consulting services.
- Long-term (5+ years): Quantum computing and space-based services, quantum sensors, and materials.
- Disruptive products: Potential for high-demand products with quicker revenue generation.
- Indirect impact: Stimulating related industries and attracting investors for additional funding.

The commercialization of the resulting product and/or application from this proposed project may involve: University or Research Institution; Private Quantum Technology Company; Startups and Entrepreneurial Ventures; Joint Ventures and Partnerships; Government and Space Agencies; Industry Collaborators and Investors; Technology Licensing and Royalties; Government Grants and Funding Agencies.
Funding will be obtained through a combination of these sources to support the successful commercialization of the research outcomes.

Budget Narrative:

- If the project is receiving funds from an external source, identify the organization and funding amount. Currently fundraising
- Does the offeror require support from the ISS National Lab to identify potential investors or to obtain additional funding? Yes
- Does the offeror or any funding partners have the intent, resources, or experience to develop and/or commercialize project outcomes? Yes

Item	Description	Amount ($K)
1	Project Costs	250K
2	Implementation Partner (Mission Integration & Operations) Costs	350K
3	**Total Project Funding Required (1 + 2)**	600K
FUNDING SOURCES		
4	Funds Provided by PI's Organization	0
5	Funds Requested from CASIS (5a + 5b)	600K
5a	Project Funding Requested from CASIS	250K
5b	Implementation Partner (Mission Integration & Operations) Funding Requested from CASIS	350K
6	Funds Provided by Other Sources	N/A
7	In-Kind Contributions	
8	**Total from All Funding Sources (must equal Item 3)**	600K

Signature: _____

Prepared By: ILAKKUVASELVI MANOHARAN

Title: CEO, Bubbles & Cafe, Inc

Date: 08/06/2023

Guidelines and Helpful Links (Do not include this page in the Concept Summary submission)
All offerors must complete and submit for review a Step 1: Concept Summary form. The purpose of Step 1 is to evaluate an offeror's concept for operational feasibility, scientific, technological, and economic/business merit, compliance with the CASIS Cooperative Agreement, and alignment with the scope of the solicitation. Concept summaries must use the template provided in this document, and all sections must be completed. As funding is limited for this research announcement, the level of funding requested will be a factor in concept approval.

Offerors are strongly encouraged to begin now during Step 1: Concept Summary preparation to identify and consult with an Implementation Partner—organizations that work with the ISS National Lab to provide services related to payload development. For more information, see the Instructions to Offerors for this research announcement.

The U.S. General Services Administration (GSA) has officially transitioned the System for Award Management (SAM.gov) to no longer use data universal numbering system (DUNS) numbers from Dun & Bradstreet (D&B) and instead use government-issued Unique Entity IDs. GSA implemented the change effective April 4, 2022. The new ID can be found on the offeror's SAM.gov profile.

It can take several weeks or longer to apply for and receive a Commercial and Government Entity (CAGE) Code. If an offeror is unable to obtain this code in time for submission of the concept summary, indicate the date one was applied for on the concept summary form. To obtain a CAGE code, go to https://cage.dla.mil/request or apply to the System for Award Management Registration at https://sam.gov/content/home. Before one can register with SAM or obtain a CAGE code, he or she will need to first obtain a Unique Entity ID.

Offerors should note that CASIS funding is to be allocated toward Implementation Partner costs only. All other costs will be covered by the principal investigator. Concerning the In-Kind Contribution line item in the budget table, this value should include the estimated value of any facilities, hardware, or support services provided by the offeror's institution to support the project.

Useful Links:

ISS National Lab Project Overviews: www.issnationallab.org/projects
ISS National Lab Implementation Partner Database: www.issnationallab.org/implementation-partners
NASA's Export Control Program: www.nasa.gov/oiir/export-control
NASA Designated Countries: www.nasa.gov/oiir/export-control
Click here for Frequently Asked Questions