Preliminary Assessment for Implementation of ISS Experiment Payload: Leveraging Spintronics, Spin-Based Quantum Sensors, and Optimization of Fluid Dynamics for Enhanced Nanocrystal Growth in Microgravity

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1.0 INTRODUCTION

Tec-Masters, Inc. (TMI) proposes to assist in the implementation of flight payload(s) to perform research studies in the microgravity environment of the International Space Station (ISS) for an experiment entitled "Leveraging Spintronics, Spin-Based Quantum Sensors, and Optimization of Fluid Dynamics for Enhanced Nanocrystal Growth in Microgravity". The proposed project aims to revolutionize nanocrystal synthesis by harnessing the power of spintronics, spin-based quantum sensors, and fluid dynamics optimization in a microgravity environment. This innovative approach seeks to achieve precise control over nanocrystal properties, including size, shape, composition, and crystallinity, under the unique conditions of microgravity. By integrating cutting-edge technology and advanced control strategies, this project has the potential to unlock new possibilities for materials science and various high-tech applications.

TMI has over 30 years of NASA flight hardware/software development experience with Cost-Plus Fixed-Fee and Firm-Fixed-Price Indefinitely Delivery Indefinite Quantity contracts. Since its founding in 1988, TMI has successfully executed projects for several Government organizations, including NASA, the U.S. Army, Navy, Space and Missile Defense Command (SMDC), Missile Defense Agency (MDA), and National Security Agency (NSA), along with numerous commercial entities. As prime contractor on the $300 million STRICOM Omnibus Contract (STOC), we managed 27 subcontractors. On the SETA contract, we completed over 200 Task Orders (TOs) and managed 17 subcontractors. We also oversaw a $7.3M Engineering Solutions and Prototyping (ESP) program, executing 6 TMI TOs. Our Research, Engineering, and Mission Integration Services (REMIS) contract performance has consistently achieved ratings above 95%. TMI merges the agility and customer-centricity of a small company with a broad experience base, ensuring efficient cost management and quick response times.

TMI has developed, fabricated, integrated, verified, and operated over 100 investigation payloads and ancillary hardware items since 1995 for ground testing, Shuttle, sub-orbital flights, and ISS payloads sponsored by the ISS National Lab (ISSNL). TMI's development experience includes payloads and ancillary equipment hosted in the Microgravity Science Glovebox (MSG), Life Science Glovebox (LSG), Expedite the Processing of Experiments for Space Station (EXPRESS), Blue Origin's New Shepard suborbital rocket system, and Multi-User System for Earth Sensing (MUSES) on the ISS truss. Our experience as MSG and LSG facility Mission Integration and Operations (MI&O) services provider, our Solidification Using a Baffle in Sealed Ampoules (SUBSA) and Pore Formation and Mobility Investigation (PFMI) original equipment manufacturer (OEM) Payload Developer experience, our SUBSA reflight activities, and Implementation Partner history with the ISS National Laboratory (ISSNL) using TMI's Microgravity Research for Versatile Investigations (MaRVIn) commercial payloads architecture development have refined our processes, tools and commercial approach. Our experience includes working with Principal Investigators (PI) to design, develop, integrate and operate experiments with successful results. TMI has worked with PIs from several universities, Government organizations, and commercial companies by processing dozens of science samples.

1.1 Integration and Operations Approach

The flight proven MaRVIn architecture developed commercially by TMI will provide avionics functions such as process control, remote commanding, telemetry, data acquisition, imaging support, and data storage for operation aboard the ISS inside the MSG facility. The MaRVIn architecture has been commercially developed by TMI using corporate resources in tandem with a tech transfer agreement with the Marshall Space Flight Center (MSFC). It operates scientific or commercial payloads on Earth or in microgravity conditions such as, but not limited to, the ISS in the MSG, LSG, EXPRESS Rack, or Maintenance Work Area (MWA) facilities.

MaRVIn consists of processing modules that are configured together in various combinations to implement remotely controlled or automated experiments. Figure 1.1-1 depicts an MSG configuration for the MaRVIn-PCIM investigation operating aboard ISS in August and September 2023. MaRVIn modules include a central control and power distribution unit (MCU) with internal computer system, power modulation and distribution, data and power interconnection cables, remotely controlled pan/zoom/focus imaging subsystem, and interchangeable science apparatus housings called Science Tray Assemblies (STA). The MaRVIn modules are currently optimized for operations in MSG aboard ISS with two manifested payloads including the MaRVIn-PCIM and MaRVIn-TABOOS. The MaRVIn avionics and science apparatus elements are designed with upgradability and maintainability in mind with modular data acquisition and actuator electronics within chassis that are swappable as on-orbit replacement units (ORU).

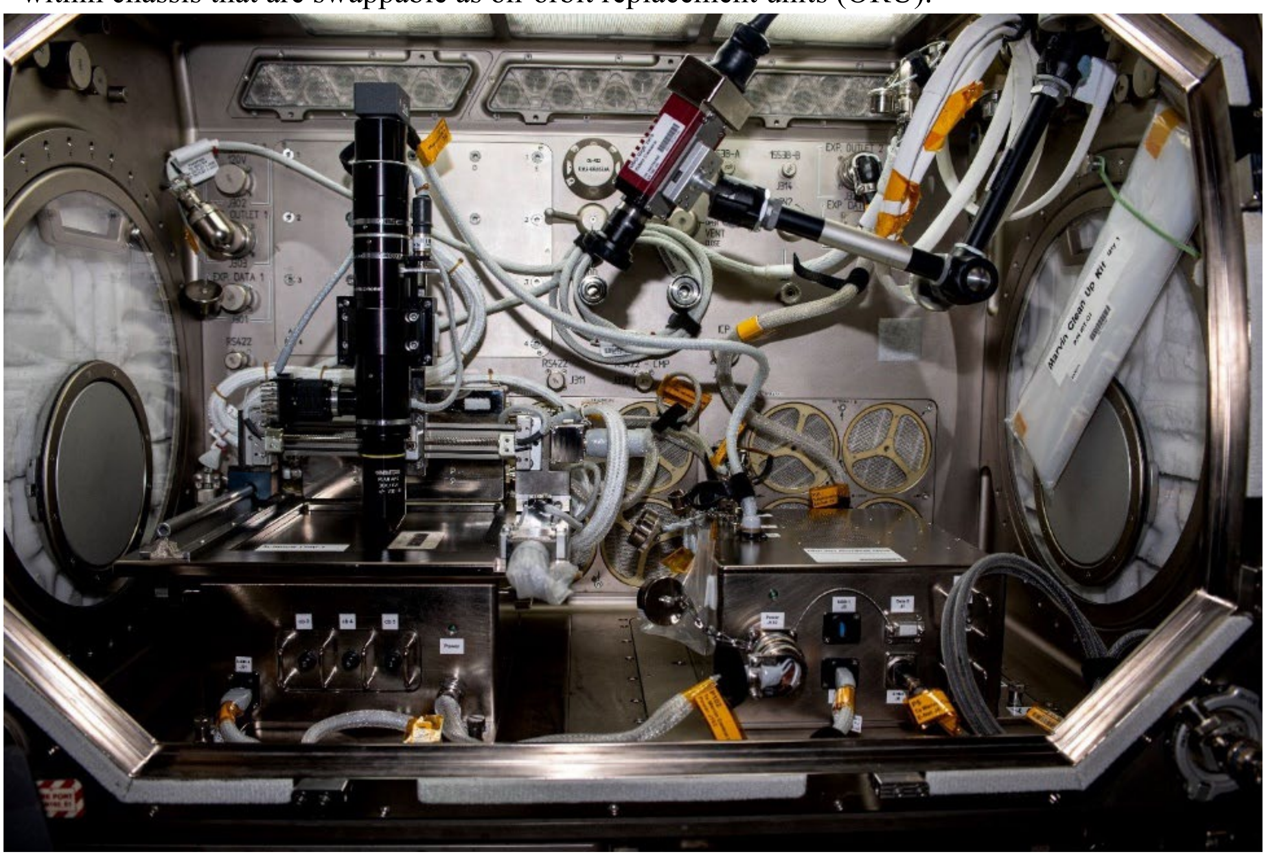

Figure 1.1-1 MaRVIn-PCIM Payload Inside MSG on ISS (August 2023)

TMI will leverage significant analysis, design and development experience with containment systems, fluids and molten materials research to create hardware that safely processes the experiment products. The crew will install the payload equipment, activate its power circuits and then operators will control it remotely from the certified ground workstations located at TMI's Telescience Center in Huntsville, AL. Team personnel will participate in ground testing, project status meetings, Team Integrated Reviews (TIRs), and technical exchange meetings remotely and/or at TMI facilities. Status meetings, TIRs, and technical exchange meetings will be implemented as telecoms via the Teams application for remote personnel participation. Status meetings will be held on a biweekly schedule while technical exchange meetings, safety reviews participation and TIRs will be organized on an as-needed basis. The top-level schedule is shown in Figure 1.1-1, which is implemented with an 18-month duration phased project flow per TMI's Commercial Approach as a veteran flight payload developer and Implementation Partner.

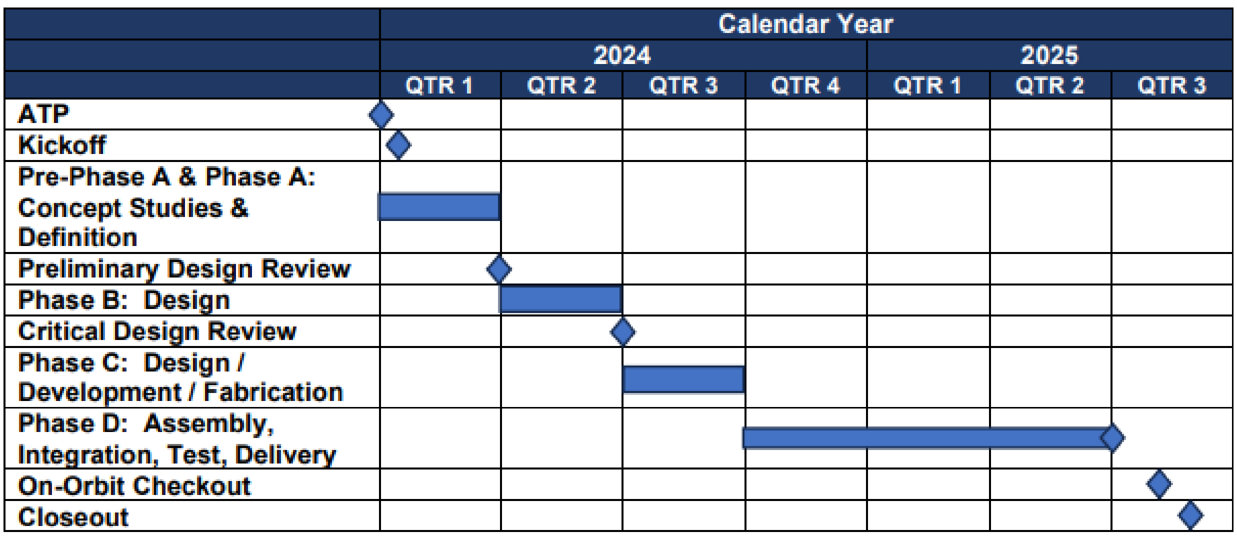

Figure 1.1-2 Payload Hardware Implementation Schedule

1.2 STOWAGE, OPERATIONAL AND ISS INTERFACE REQUIREMENTS

The proposed equipment consists of the items detailed in the hardware resource requirements Table 1.2-1 below. Some of the items are already on-orbit as MaRVIn ancillary support equipment, which was transported to the ISS aboard the NG-19 transport vehicle for MaRVIn-PCIM.

Table 1.2-1. Hardware Resource Requirements

ITEM	UPMASS, Kg	ENVELOPE SIZE	POWER, WATTS	STATUS
Qty of 1: MaRVIn MCU	11.3	10.5" x 10.5" x 7.7"	75	Derivative copy of Flight qualified unit
MaRVIn Cables (5x)	0 (will already be on-orbit)	8" Ziplocks, stowed individually	< 5	Exists, flight qualified

ITEM	UPMASS, Kg	ENVELOPE SIZE	POWER, WATTS	STATUS
Qty of 1: Support Science Tray Assy (STA)	10.0 10.0 subtotal	10.5” x 10.5” x 9.5”	15	New Hardware
Qty of 1: Synthesis Reactor Vessel	9.5 each 9.5 subtotal	10.5” x 10.5” x 9.5”	35	New Hardware
Qty of 1: Imaging Subsystem	8.0 (estimate) 8.0 subtotal	12.5” x 12.5” x 6.5”	25	New Hardware; ancillary support item
Qty of 3: Auxiliary Cables	0.5 each 1.5 subtotal	6” x 6” x 6”, stored inside Ziplock bags	< 5	New Hardware; MaRVIn ancillary support items
Special Needs	None: Standard Soft Stowage is acceptable.			
Subtotal	**40.3**	**N/A**	**160**	**N/A**

Table 1.2-2 identifies the on-orbit ISS operational resources and services as well as ground support services needed to implement the project. TMI will provide support from development through on-orbit operations and return. The PI Team will perform analyses of returned samples.

Table 1.2-2. Required Ground and ISS Services

Ground and ISS Services		
Description	**Notes**	**Crew Time Required**
Host Facility: MSG Transport: TBD	ISSNL/NASA: Provides time availability within the MSG facility aboard ISS to operate the experiment. Per a Payload Integration Agreement, manifesting and transport services to/from the ISS will be provided by ISSNL/NASA.	See below
Ground GFE & Services needed from ISSNL and/or NASA	ISSNL/NASA: Provides EMI/EMC testing & power supplies, assumes testing services source provides power supplies & breakout boxes as required,	N/A
	ISSNL/NASA: Provides offgassing testing services, if required	N/A
	ISSNL/NASA: Provides transitory disturbance and vibration loads testing services, if required.	N/A
	ISSNL/NASA: Provides acoustics testing services, if required.	N/A
	MSFC: Provides availability in MSG EU for IVT testing.	N/A
	JSC: Provides flight Labels, Stowage Foam & Flight Ziplocks	N/A
	Crew Time: Installation (2.5 hours x 1)	2.5

Ground and ISS Services		
Description	**Notes**	**Crew Time Required**
Flight FSE, ISS Services & Crew interaction of 8.5 hours	Crew Time: Reactants loading into synthesis vessel (1.0 hour each, with up to 4 exchanges)	4.0
	Crew Time: Removal/Stow (2 hours x 1)	2.0
ISS Services Needed over a 10-day operations period	See Table 1.2-1 for on-orbit items list with masses, power, and size	N/A
	ISS Service: KUIP Forwarding for Communications with MaRVIn-MCU via MSG ethernet bridge to JSL	N/A
	Data transfer: 10 mbps communications link via KU-IP Forward Services	N/A
	Standard stowage provisions: Soft transport in foam/bubble wrap	N/A

The investigation does not require special stowage or transport requirements for any hardware including the STA apparatus. Therefore, standard soft stowage provisions will be acceptable for launch/return transport and stowage aboard the ISS either before or after processing. There are no limited life aspects of the samples identified at this time that might require late-load provisions, assuming they are maintained near ambient conditions. Therefore, standard launch integration timelines are anticipated, and thus no special handling needs such as cold stowage are anticipated for launch or return.

1.3 Safety Considerations and Preliminary Risks Identified

The toxicity levels of possible released effluents such as liquid reactants and/or vapors that might be released by the synthesis process must be assessed and, if needed, their control would be provided by a combination of the reactor vessel apparatus as the first containment level with two additional levels provided by the MSG facility.

The NASA Payload Safety Review Panel may indicate more robust containment is needed per the phased review process, which may dictate that the reactor vessel should incorporate additional level(s). The temperatures of the synthesis process are not yet determined, but they may pose injury risks to the crew by elevated touch temperatures as well as possible floating heated droplets should they be inadvertently released. TMI's experience with safe NASA mission containment systems offers a high success probability, especially when combined with the MSG facility's two levels of containment provisions for liquids.

1.4 Ground Facilities and Equipment

Secured TMI laboratory and development facilities with remote ops support telescience center and machine shop in Huntsville, AL will be utilized to develop, test, and verify components, subsystems, and systems. External service providers will be engaged for EMI/EMC, vibration, acoustics, and offgas testing as needed. TMI's Ground and Flight Hardware storage areas will securely maintain integrity and traceability of all Government Furnished Equipment (GFE) if any are supplied and project hardware items per TMI's certified quality system policies. The TMI lab has miscellaneous and cleaning supplies to support fabrication tasks, as well as a ventilated fume hood with water cooled coldplate, which can emulate the MSG work volume. This will support development and verification efforts by providing a safe test containment area.

TMI's lab also has a vacuum box oven and high temperature bakeout furnace for preconditioning components for off-gassed effluents reduction, moisture bakeouts, and accelerated curing of adhesives. TMI support capabilities also include miscellaneous lab wetware stock, an 18-megOhm deionized water system integrated with a laboratory sink, chemicals storage cabinets and containers, inspection microscopes and lighting, precision scales, hot plates, a degassing bell jar with vacuum pump, and magnetic stirrers with pH measurement system. This facility has been used for years to develop and verify ISS and suborbital flight payloads such as the SUBSA furnace and science samples.

By leveraging TMI's MaRVIn architecture and proven flight payload development as commercial projects, it is estimated to provide a significant savings in risk reduction, time, and budget. Project and technical risks will be significantly reduced by leveraging the flight proven MaRVIn architecture hardware and software libraries.

1.5 Budgetary Resources RoM Estimate

TMI proposes support for one (1) flight synthesis reactor apparatus with ancillary MaRVIn hardware necessary to operate a synthesis processing system aboard the ISS for a period of up to 10 operational days within the MSG host facility.

All flight reactants are to be provided by the PI Team to TMI for integration for launch. TMI will coordinate the logistics of flight qualifying and certifying of PI provided items, which will include labelling, obtaining Electrostatic Discharge (ESD) protection stowage bags, flight shipment tags for the CMC turnover, Launch/Return/On-Orbit Data Set (eLRODS) tracking, and coordination of the crew procedures and training products.

The PI will prepare and package the reactants and any flight support components for the containing vessel(s) in ready-for-launch condition. The PI team shall arrange shipment to TMI, who will inspect, clean to ISS standards, and bag them for transport to the CMC site. The PI will perform all science analysis of possible released chemicals in case of loss of containment for the reactants. This includes oxidation, decomposition, or chemical reactions over the possible temperature range. Table 1 provides a cost estimate for the aforementioned payload equipment and labor activities. Note that no travel has been assumed for implementation of this activity.

Table 1. ROM Cost Estimate

Item	Total
Labor	$160,142
Materials	$93,124
ODCs	$90,737
Travel	0
TOTAL	**$344,003**