Understanding the impact of long duration space radiation on biology and nutrients in food. C. D. Quincy[1], B.M. Link[2], [1]NASA (UB-I NASA Kennedy Space Center, FL 32899 Charles.D.Quincy@NASA.gov), [2]Southeastern Universities Research Assoc. (SSPF M6-0360, LASSO-001, NASA, Kennedy Space Center, FL 32899 Bruce.M.Link@NASA.gov.

Introduction: No food or bioregenerative life support system (BLSS) is likely to be deployed on Mars prior to being fully vetted on lunar long duration missions. BLSS systems developed for lunar missions will trade well in terms of up mass and volume with prepackaged food for Mars missions, but only if they are reliable. There are significant differences in the gravitational and radiation environments between the moon and Mars, and one key challenging aspect for a BLSS on Mars missions is the extremely long durations. This results in the exposure of seeds, spores, or other dormant stages of organisms to both natural and radiation induced degradation over time frames of two or more years before they might be needed for growth. This can result in poor or no germination and sickly crops. A poorly functioning BLSS represents a threat to crew health. To ensure that a BLSS food production system will function well, we need to understand, at an early stage, the impact of these long missions on the biology. This is important to meet the Mars Exploration Program Analysis Group (MEPAG) goals.

MEPAG Goal IV, Sub-Objective B1: Assess risks to crew health and performance by: (1) characterizing in detail the ionizing radiation environment at the Martian surface. There is a known risk that key vitamins degrade in stored food items over time [1] [2] representing a threat to mission success. Radiation is likely to increase the rate of degradation. One way to address this problem is to produce (grow) fresh nutrients during the mission. Another way is to oversupply or stabilize critical nutrients so that degradation isn't a problem. There is an urgent need to understand how long duration flights to Mars impact both biological and nutrient stability. Simply flying and returning sample packets to Mars and back will aid in understanding the radiation and environmental impacts on food and biological risks.

Objectives and Scenarios: The primary science objectives mapped to mission scenarios is: **Objective 1)** Measure the impact of a Mars mission on revival from dormancy for yeast, bacteria, and plant seeds. Measurement of food and nutrient degradation on long duration missions. (Scenario robotic only, I, II, III, IV). **Objective 2)** Measurement of revival rates for yeast, bacteria, and seeds on Mars. Test food and nutrient degradation over longer time periods, or the impact of stabilizing technologies on slowing the degradation. (scenario I, II, III, IV). **Objective 3)** Measurement of DNA damage rate on Mars (IV).

Concept of Operations: For objective 1) packets of dormant biology (yeast, bacillus, plant seeds) and of food test samples are attached to the inside of return vehicles traveling out to Mars and back. Ideally, some samples would reside on Mars for some time prior to return while some would remain in orbit before return. Samples could be placed on a variety of missions, and should be present on multiple early missions, including the upcoming sample return mission. Germination or revival rates would be measured on return to earth as well as DNA mutation rates. Nutrient levels will be measured in returned food samples and compared to Earth stored controls. No crew or power is required for this type of experiment, and base line experiments should be performed well in advance of any crewed missions. Return masses of less than 50 g are possible. Packets should be prepositioned on Mars during robotic landing missions and retrieved by crews during their missions, increasing the exposure times (Scenario I, II, III, IV). No special equipment of any kind is needed.

Objective 2) "Measuring dormancy break on Mars", would require small culturing vessels that could be pre-loaded with nutrients requiring only the addition of a 1-5 mL of potable water. For bacteria or fungi, the growth curve could be measured using the same techniques as on BioSentinel [3]. Plants would be germinated on specialized plates, and germination rates determined by counting seedlings, or sending a picture back to Earth. In principle, this could be performed using a robotic lander or by a crew. Time estimates for crew are 1 to 2 hours total time. Nutrients in food would have to be measured using a colorimetric assay or returned to Earth for full analysis and characterization. If returning to Earth, they could remain in their packets and up masses of less than 50 g are possible with no special storage requirements. Total down mass could be restricted to 5 – 10 kg or less.

Objective 3) "Measurement of DNA damage rate on Mars," could be estimated by looking at mutation rates that result in the loss of function in the ability to use a specific nutrient source (classic Ames test). This could be measured by examining growth curves in nutrient solutions, an analogous approach to the Biosentinel. A second approach that would be most appropriate for scenario IV where there is a permanent habitation,

would be to use a sequencing system on Mars. This system will be valuable for monitoring the microbiome in vehicles and the habitat, as well as for detecting Earth life carried into the local environment. If Mars life has 16S ribosomal RNA (panspermia) then the same system would be useful in detecting it. A sequencing system would require specialized reagents brought from Earth (a 10 kg down mass of supplies) and would allow for thousands of runs. Only the data would be returned to Earth. In a sequencing approach, DNA would be isolated from biology packets and then sequenced. Cross comparisons of thousands of reads would determine the mutation rate.

Recommended Special Tools: No specialize tools are require for objective 1. Objective 2 requires a plate reader, specialized plates with the organisms prepositioned, a pipet for conducting a dilution series, a camera (as part of crew equipment) for photographing seedling counts. For nutrient tests, special solutions would be needed for measuring the nutrients colorimetrically on the same plate reader as used for growth curves. The down mass is given in the concept of operations.

Objective 3 could be performed using only a plate reader, however a sequencer that is likely to be present on a scenario IV mission for reasons given above could do the job more directly. Recommended resources are: a sequencing system (Minion or equivalent), metagenomics reagents, and computational power similar to a PlayStation 4 loaded with a 50 Gb or larger sequencing data base. This would allow for metagenomics work to be conducted on Mars with no sample return (estimated down mass of 10 kg). The computational resource can service multiple payloads or be used to meet other needs.

It is likely that there will be a mass spectrometer (MS) landed within a scenario IV mission. If it could be made “multi-purpose” then more chemistry analysis can be performed on Mars without the need for returning the samples to earth. It would be beneficial to a crewed mission to have liquid and gas chromatography available using the MS as a detector. This allows for the identification of multiple chemistries including food nutrients as well as enabling the search for amino and nucleic acids on Mars (search for Mars or Earth life MEPAG goal I and IV, D.) The mass allocation could be divided between different science packages and is approximately 20 kg down mass.

Refferences: [1] M. Cooper, M. Perchonok and G. L. Douglas, "Initial assessment of the nutritional quality of the space food," npj Microgravity , vol. 3, no. 17, 2017. [2] G. L. Douglas, R. M. Wheeler and R. F. Fritsche, "Sustaining Astronauts: Resource Limitations, Technology Needs, and Parallels between Spaceflight Food Systems and those on Earth," Sustainability, vol. 13, no. 16, p. 9424, 2021. [3] NASA, "BioSentinel," NASA, 4 January 2022. https://www.nasa.gov/centers/ames/engineering/projects/biosentinel.html. [Accessed 22 February 2022].