OBJECTIVES
Current spaceflight foods were evaluated to determine if their nutrient profile supports positioning as a functional food and if the stability of the bioactive compounds in the food matrix over an extended shelf-life correlated with the expected storage duration during the mission. Specifically, the research aims were:

Aim A. To determine the amount of each nutrient in representative spaceflight foods immediately after processing and at predetermined storage time to establish the current nutritional state.

Aim B. To identify and develop foods that stabilize these nutrients such that required concentrations are maintained in the space food system throughout long duration missions (up to five years).

Aim C. To coordinate collaborations with health and performance groups that may require functional foods as a countermeasure.

KEY CONCEPTS
Functional foods, according to the American Dietetic Association, include whole foods and fortified, enriched, or enhanced foods that have a potentially beneficial effect on health when consumed as part of a varied diet on a regular basis, at effective levels.


The unavailability of fresh foods, fruits, and vegetables in the spaceflight food system makes it critical to understand the stability and capability to deliver bioactive compounds (carotenoids, flavonoids, phenolic acids, and sterols) in a shelf-stable food system over time.

Irina and Mohamed (2012) showed that thermal processing degrades most flavonoids and that freeze-drying was less aggressive than hot air drying but still resulted in flavonoid losses.


METHODS
FOOD SYSTEM ANALYSES
A prospective list of spaceflight foods, thermo-stabilized and freeze-dried, was generated. The foods were pulled just after production, taken from inventory if the items were less than 3 months old, or specially produced in a smaller batch and freeze-dried to spaceflight specifications in the Space Food Systems Lab. The tested food items are listed in Table 1.

Food samples were sent to the Food Composition Laboratory of the Linus Pauling Institute at Oregon State University (Corvallis, OR) for bioactive compound analysis. The following tests were conducted:

- Vitamin K (HPLC)
- Vitamin E (HPLC)
- Vitamin C (HPLC)
- Carotenoids (HPLC)
- Steroids (HPLC)
- Phenols, anthocyanins and antioxidants (Spectrophotometric, HPLC)
- Mineral analysis (ICP)

SHELF LIFE STUDIES
Duplicate samples of the food were placed in 4°C, 21°C, and 35°C environmental chambers within the Space Food Laboratory for storage. After 3 months of storage, samples were pulled from each chamber and submitted for repeat analysis.

The stability assessment of the bioactive compounds will proceed over the course of two years. At the one-year storage time point, the food will be pulled from the 4°C, 21°C and 35°C chamber and undergo repeat analysis. Food stored at 4°C and 21°C will be analyzed again at the two-year time point.

RESULTS
Antioxidant Capability
The twelve foods of the study varied significantly in their FRAP antioxidant measurements at the initial time point with Strawberries having the highest antioxidant value of the next highest food. The comparison benchmark, cultivated strawberries FRAP value, is taken from Carlson and others (2010).

The phenolic content of the foods, an indirect measure of antioxidant capability, was assessed for eight of the foods with the highest expected antioxidant capability. Strawberries and the Dark Mint Chocolate Oatmega Bar had a significant concentration of phenolics, especially when compared to the average phenolic consumption by Americans on a daily basis (Figure 2). Initial shelf-life analysis indicates phenolics may be stable in several foods.

CONCLUSIONS
The ability to provision high-phenolics, high-carotenoids, or high-omega-3 foods within the spaceflight food system was demonstrated by the identification of the target foods and their initial chemical analysis during the first months of storage. Samples continue under controlled storage and nutrient content will be assessed after one and two years of shelf-life.

The initial results showed that the flavonoid quantities are contributed as follows: Strawberries > Granola with Blueberries > Cherry Blueberry Cobbler > Sweet and Savory Kale

The sterols content of spaceflight food do not approach the required levels of cardiovascular benefit but initial concentrations are with the range of published values of sterol content in food (Almond 138.4 mg – Spinach 10.2 mg/100 g)

Fatty acids
Salmon in the pouch had the greatest concentration of omega-3 in the spaceflight foods, followed by the Oatmega bar. High concentrations of ALA omega-3 were found in some spaceflight foods, but conversion of ALA to EPA and DHA is very low. There was degradation of EPA and DHA during storage as shown in Figures 4 and 5.