BioNutrients-1

On-Demand Production of Nutrients in Space.

Aditya Hindupur, Natalie Ball, Hiromi Kagawa, Aphrodite Kostakis, Julie Levri, Kevin Sims, Sean Sharif, Alyssa Villanueva, Alan Noblitt, Emanuel Barros, and John Hogan.

NASA Ames Research Center

Current Nutrient Management Approaches

- Nutrients in supplied foods
  - Coordinated food selection
  - Meal planning
- Supplements – vitamin/mineral pills
  - Crew takes Vitamin D, others based on personal medical needs
  - Multi-vitamins, individual nutrients, anti-oxidants, etc.

A Thanksgiving day meal fit for an astronaut: NASA-packaged smoked turkey, cornbread dressing, strawberries, tea w/sugar and as-flown cranberry sauce spread.

Problems with Supplying Nutrients

- What are long-duration, space-based nutritional needs?
  - Extended microgravity and increased radiation may require specific enhancements – *"unknowns"*

- Some nutrients degrade substantially with time
  - Deficiency of even one nutrient could be catastrophic
- Food-based nutrient supply –
  - Must match food types/quantities to provide complete set of required nutrients
  - Astronauts may not follow diet regimen

- Supplements –
  - Lack of potency or adsorption, degradation, crew does not take them correctly
- Human microbiome alterations – can affect nutrient production and interactions

OBJECTIVE: To enable rapid, safe and reliable *in situ* production of needed dietary nutrients using minimal mass, power and volume.

DESCRIPTION: We are developing a platform technology that employs hydratable, single-use packets that contain an edible growth medium, and a food microbe that has been engineered to produce target nutrient(s) for human consumption. The packet is allowed to grow for a short period, deactivated and the contents consumed.

Overall Concept Requirements

- Consistently generate needed compounds in appropriate quantities and quality.
- Effective long-duration storage (must exceed food or supplement stability) >5 years.
- No undesirable products or microbial contamination.
- Easy to use – "fool-proof", no cleaning.
- Very small mass, volume and power requirements.

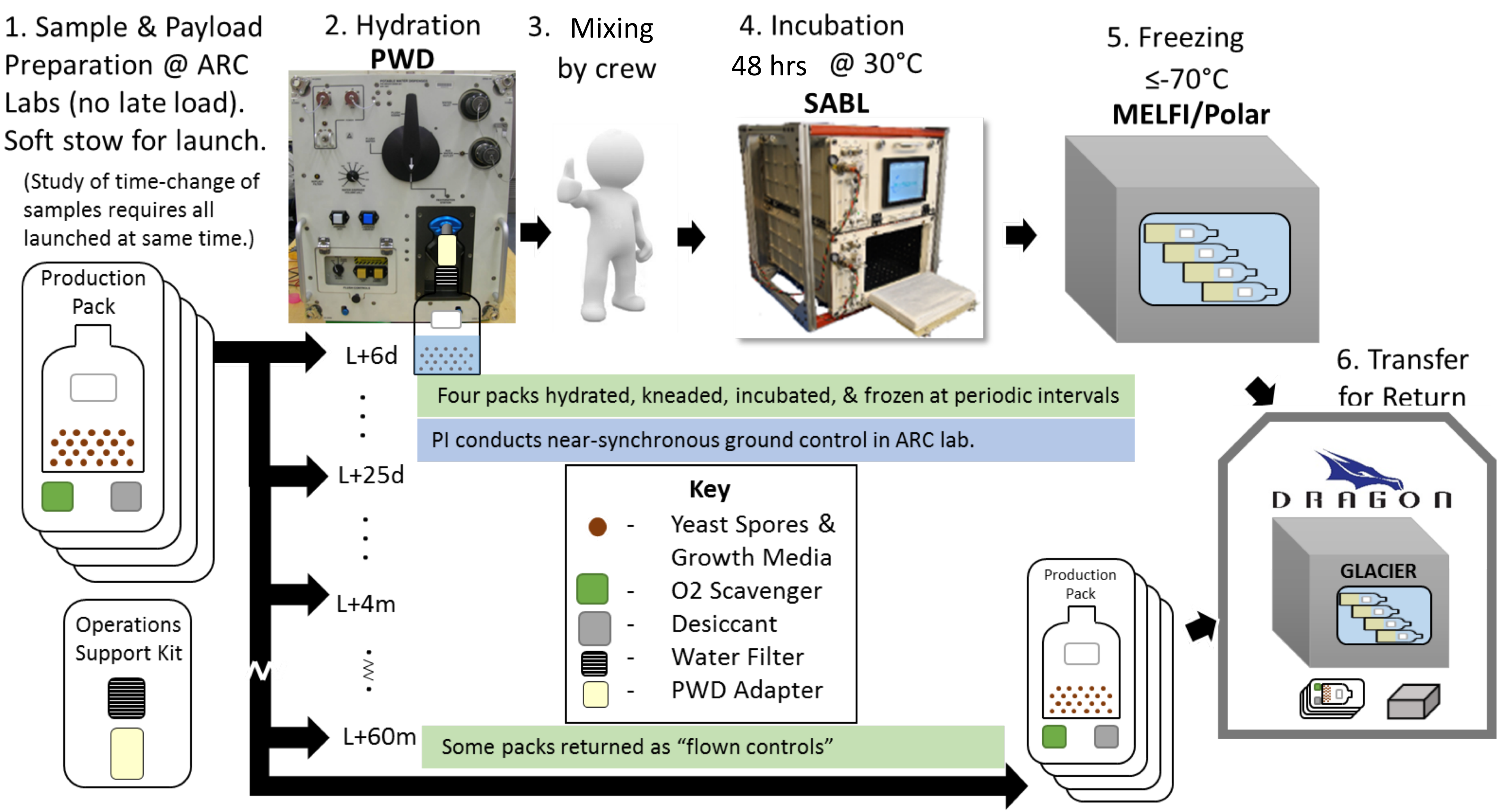
Biomanufacturing Requirements

- Safe for human consumption (GRAS – Generally Recognized as Safe).
- Can store for very long periods of time.
- Rapid revival, growth and nutrient production.
- Readily engineered (genome and tools available).
- Must be acceptable to crew – odor, perception.

Issues that needed to be understood

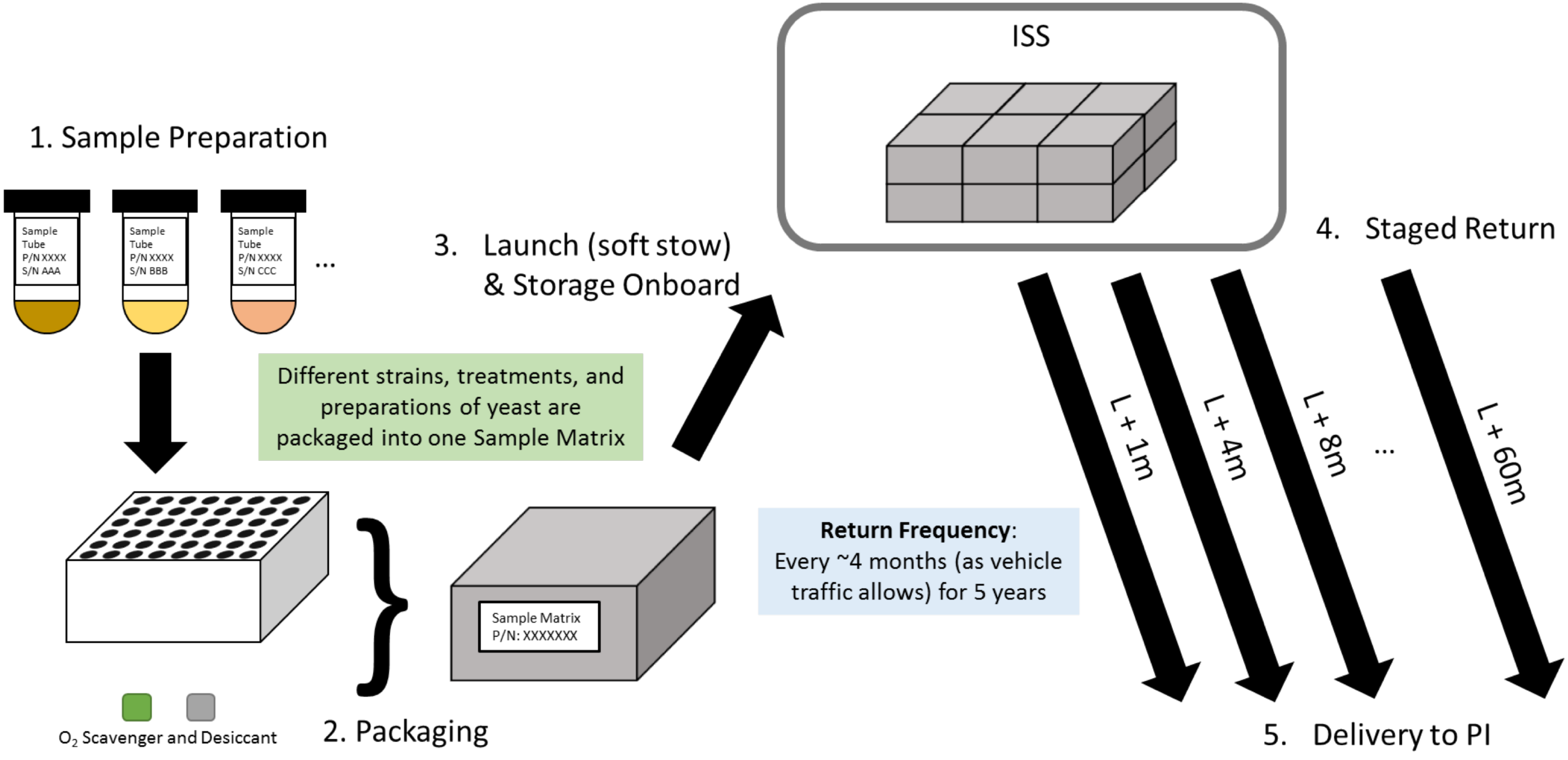
- Long term storage at room temperature > 5 years.
- Development of a media that is edible, easily miscible.
- Development of packaging systems that allows for long term storage of microbial seed and substrates.
- The effect of microgravity on growth.
- Management of secondary products of cultivation.
- Gas Management- Optimizing aeration for aerobes.

Production Pack Assy & Ops Support Kit Lifecycle



Experiment Duration – **5 years**

Stasis Pack Lifecycle



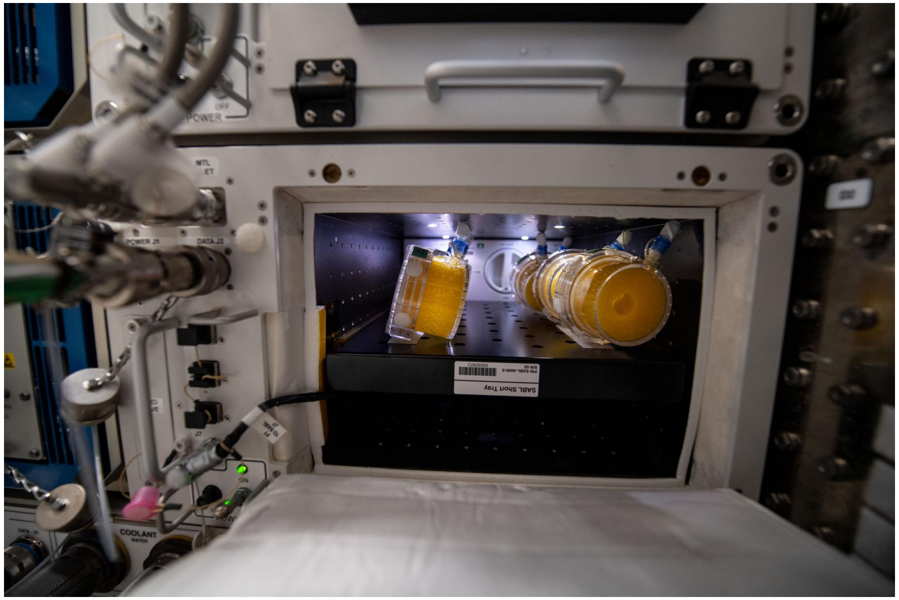
The stasis packs carry 10 different species both yeast and bacteria in different treatment regimes.

Current Status

- BioNutrients-1 launched on NG-11.
- Successfully conducted 1st On-Orbit hydration and growth of the ISS production packs.
- Successfully returned and tested Flight returned Earth production packs.
- Successfully retrieved T1 (SpX-17), T2(SpX-18) stasis packs and completed viability studies on the samples. Expecting retrieval of T3 samples SpX-19.
- Currently prepping DNA/ RNA samples for Omics analysis- expression/survival analysis .
- Next on-orbit hydration and growth experiment is scheduled on Jan 2020.
- Developing Food Safety protocols, multiple target compounds in one pack, etc. for implementation.

Production Pack

Stasis Packs



First On-Orbit operation on the ISS production packs, conducted by David Saint Jacques.