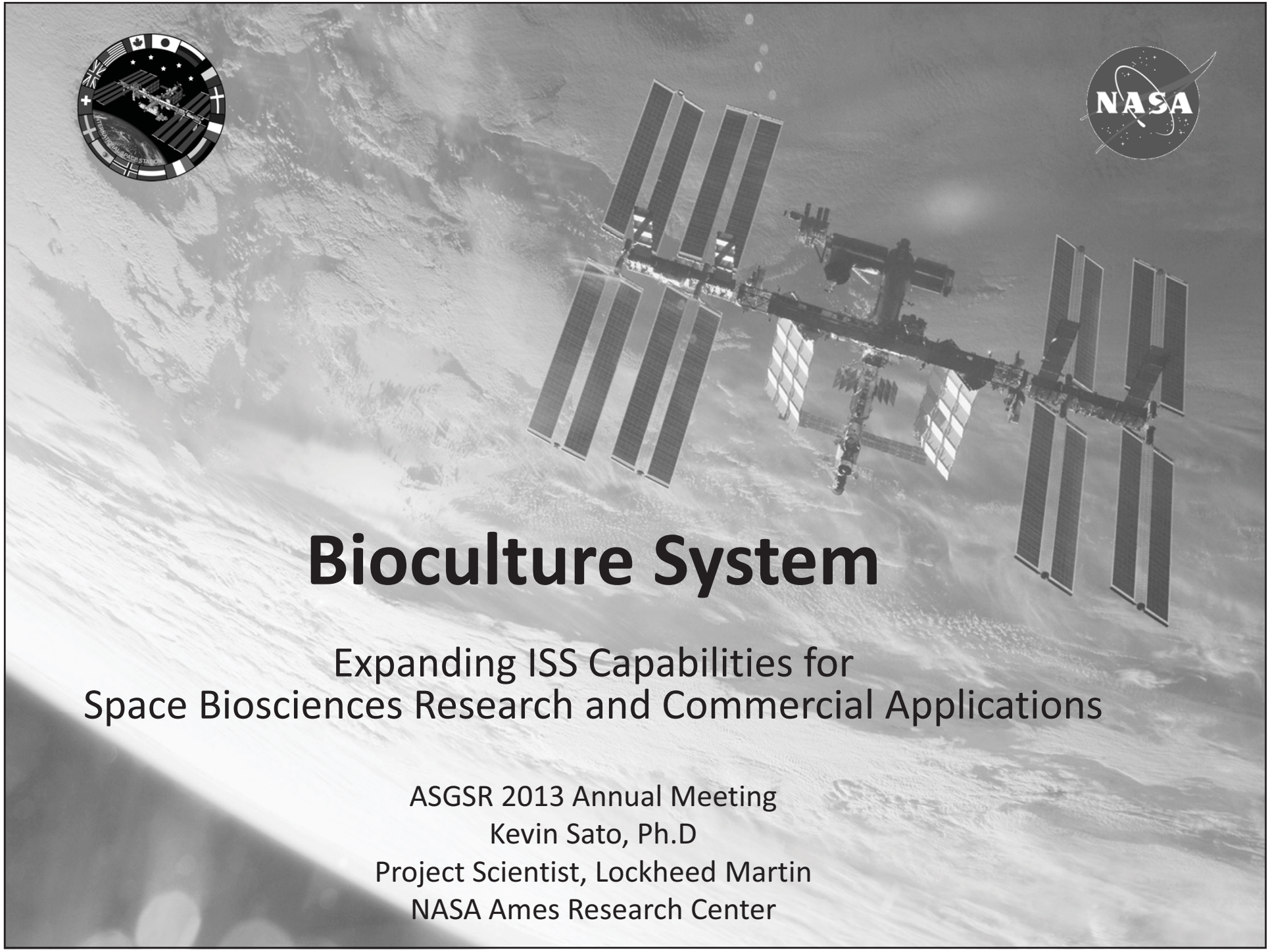


Bioculture System

Expanding ISS Capabilities for Space Biosciences Research and Commercial Applications

ASGSR 2013 Annual Meeting
Kevin Sato, Ph.D
Project Scientist, Lockheed Martin
NASA Ames Research Center

Bioculture System Objectives

1. Provide academia and industry with an incubator system on ISS that provides automated stable and selectable environment conditions to conduct a diversity of space flight experiment for cellular and microbiological research

2. Provide an incubator that carries independent biospecimen cultures that are individually housed and accessible to the Crew for manual operations, and hardware refurbishment

3. Provide a system compatible with numerous types of cell cultures and microbiological specimens up to a BSL-2 safety level and Toxicity level 2

1. Support variable duration experiments and time course driven experiments

2. Provides the capability to maintain a sterile environment for culturing biospecimens under automated and manual operations

3. Provide experiment flexibility for experiment design and configuration for delivery to and implementation on ISS, culture initiation, specimen propagation, and sample processing

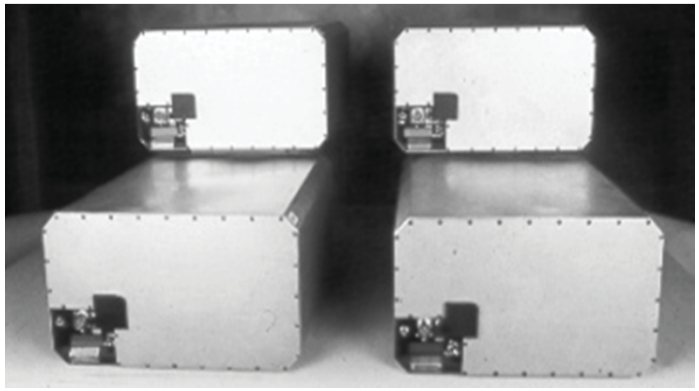
Biological Specimens Supported

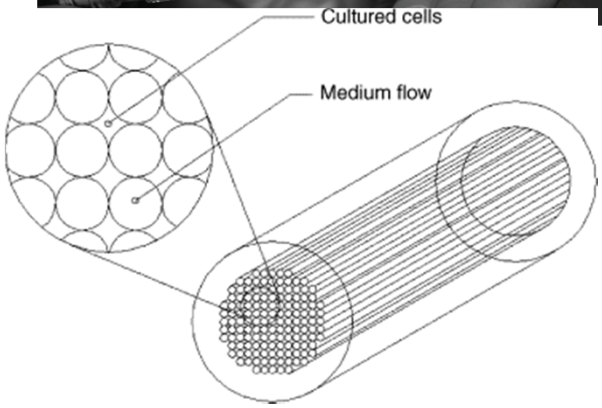
Single cell type cultures, co-culture, infection, beads

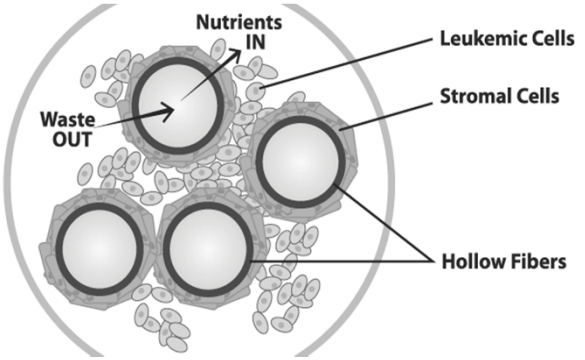
- Mammalian and non-mammalian Cell Cultures
  - Primary, Immortal, Tumorigenic, Explant
  - Stem Cells
  - 3-D Tissue Cultures
- Microbes
  - Bacteria
  - Yeast
- Miscellaneous small eukaryotic organisms

Bioculture System Technology Heritage: Cell Culture Module (CCM)

(Walter Reed Army Institute of Research, Tissue Genesis, Inc [HI])

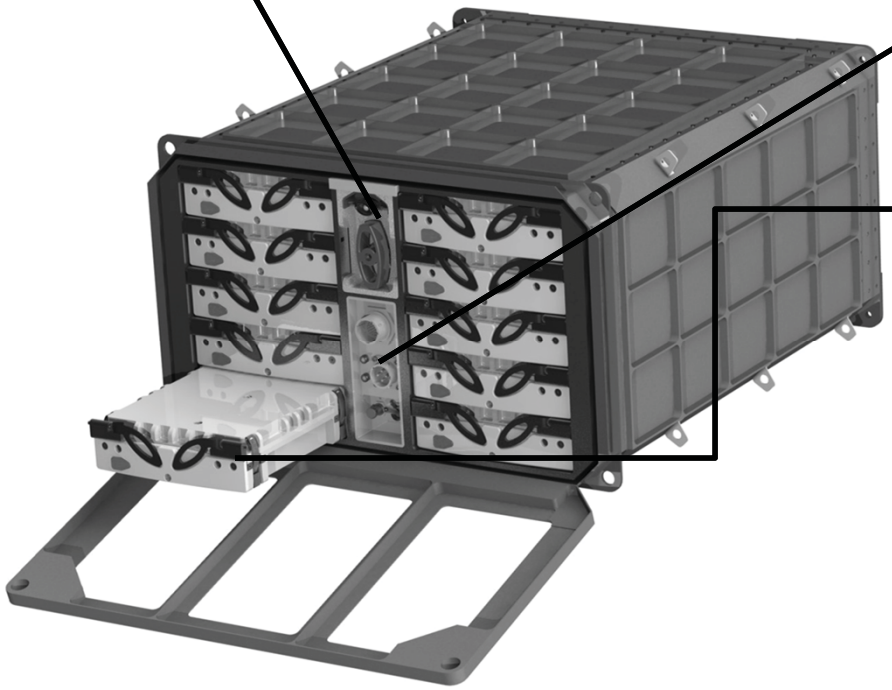






Bioculture System

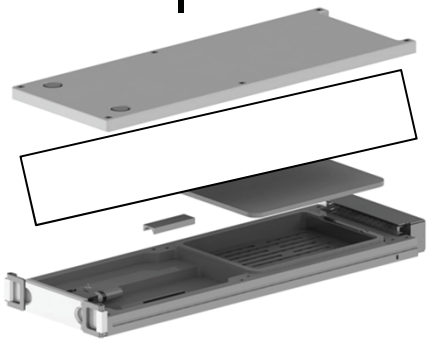
(NASA, Tissue Genesis Inc, Lockheed Martin)

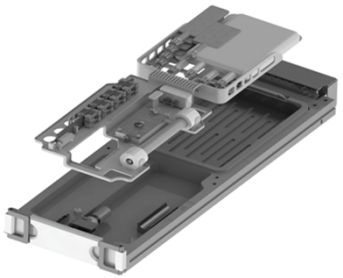


CASSETTE ASSEMBLY

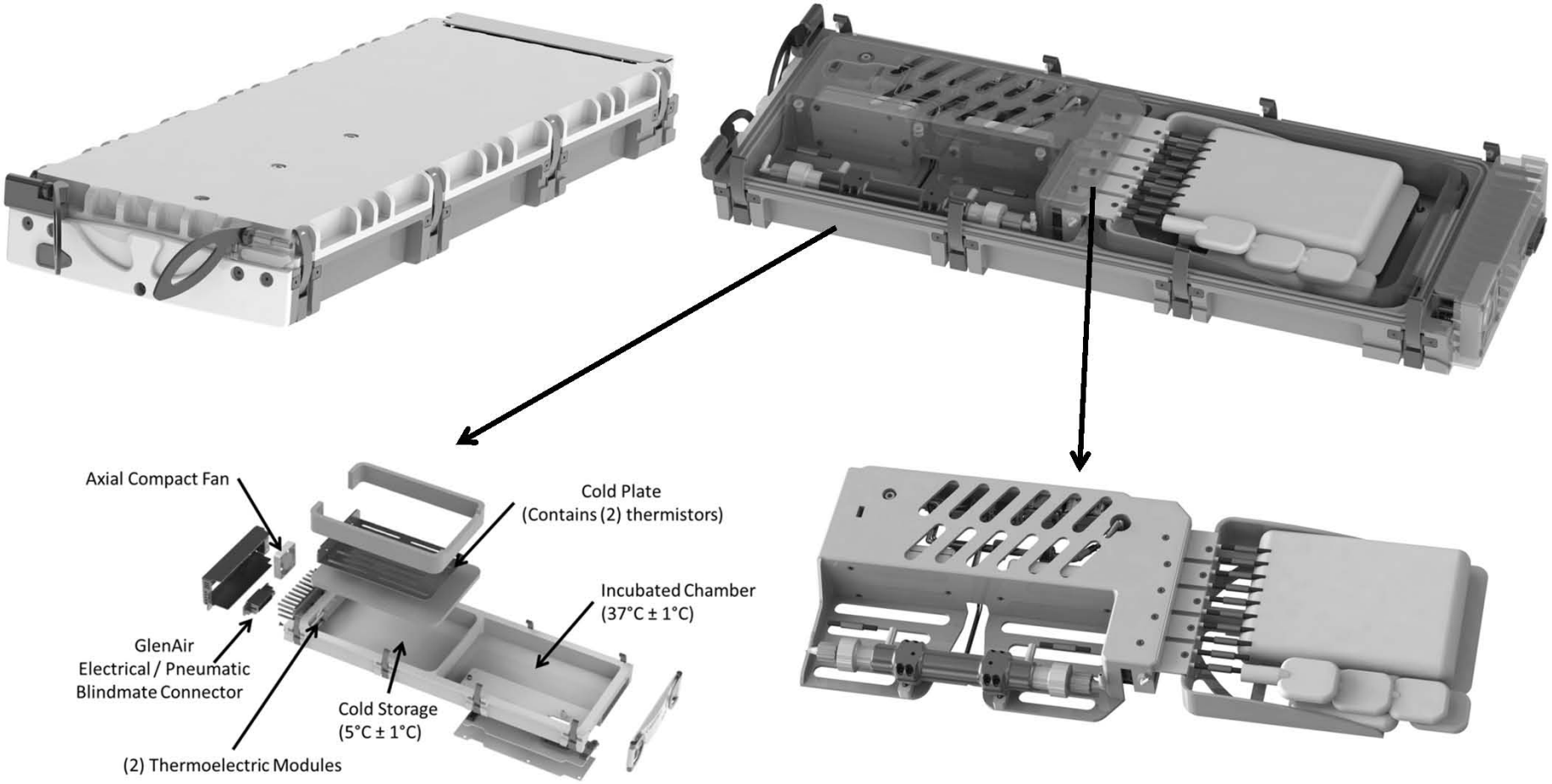
CASSETTE DURABLE ASSEMBLY

DISPOSABLE FLOWPATH ASSEMBLY





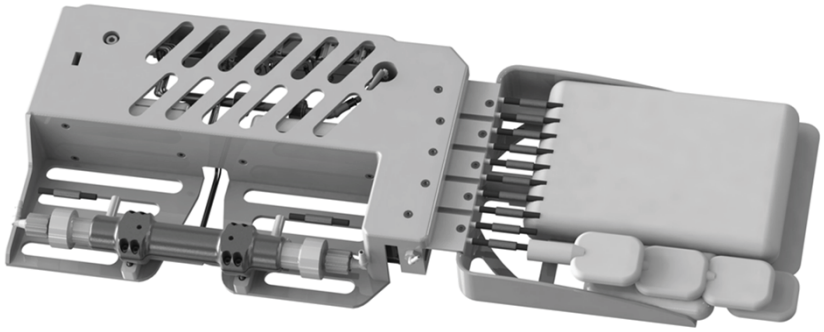
Cassette

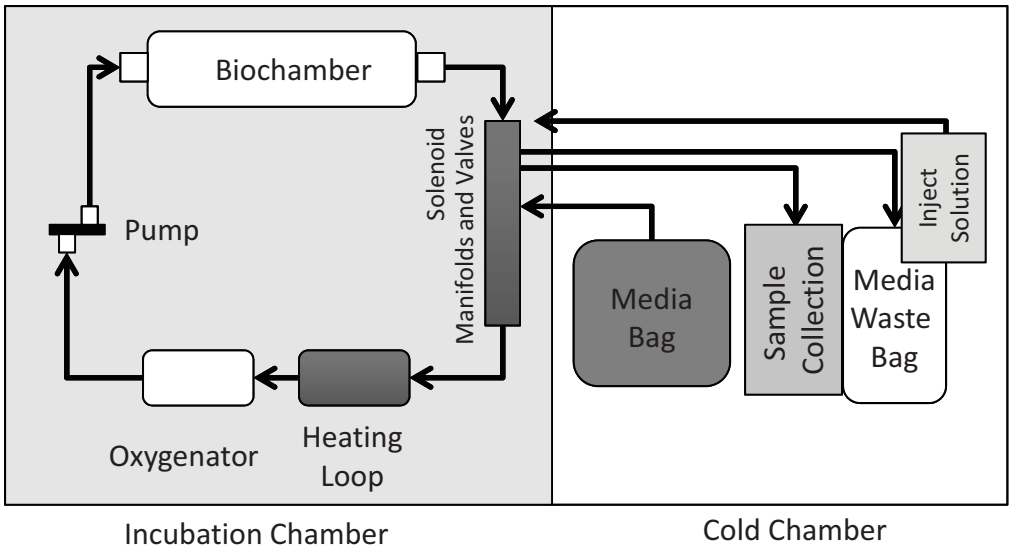


Durable Base

Disposable Flow Path Array

Flow Path Schematic





- Perfusion-based medium delivery
- Pre-programmed temperature set points
- Pre-programmed fluid flow rate
- Pre-programmed fluid replacement modes
- Medium oxygenation system
- Medium warming loop
- Automated sampling
- Automated solution injection
- Cold chamber for stowage
  - Peltier system
- Incubation chamber
- Crew accessible
- Replaceable on-orbit
- All bags are replaceable on-orbit

Can multiplex to add a Second Biochamber

Up to a total of 10 sample and/or injection bags

Bioculture System Specifications Overview

- Ten Cassettes each with a fluid flow path with biochamber
  - Independent programming for each cassette
    - Independent temperature control
    - Independent fluid flow rates and modes
    - Automated sampling and solution injection
  - Shared gas supply
- User selectable incubation temperature – ambient to +42 ^{o}C (+/- 0.2 ^{o}C accuracy)
- User selectable cold chamber temperature – ambient to +5^{o}C
- User selectable fluid flow/pump rate – 0 to 15 ml/min
- User selected medium delivery mode and volume – continuous or periodic
- Continuous medium recirculation
- Shared gas supply – 5% CO_2 or user defined, may shut off gas supply for anaerobic cultures
- Programmable specimen sampling – single or time course, volume collected
- Programmable solution injection – single or multiple, including time course, volume injected
- Compatible with most standard fixation and preservation chemicals (aldehydes, RNALater, etc)
- Three levels of containment for particulates and liquids
- Data storage, data telemetry, and commanding from the ground
- Temperature, humidity, gas, and pump operational sensors
- Gas Supply Assembly change out

Science Operational Scenarios

1. Automated or manual injection of compounds (e.g. growth factors, activators, cell staining/tagged antibody compounds, etc)
2. Automated or manual injection of fixatives and preservatives
3. Automated or manual injection of microbe, virus, DNA
   - Virus and DNA for introduction of expression vectors or inhibitors
4. Automated sampling
5. Sampling by Crew – single or multiple
   - From biochamber or media bag (e.g. check on glucose, lactate, etc)
6. Initiation of cultures on-orbit by injection into a biochamber
7. Change out of biochambers, flow paths, and/or bags
8. Subculture

Con Ops Context Overview

- Launched to ISS on SpaceX Falcon in the Dragon Capsule
  - Powered Bioculture System to support proliferating cultures
  - Manifest of entire unit or cassettes only if power is not required
  - Option for pre-packaging flow paths, solution bags, and specimens in stasis for initiation on-orbit for single runs and multiple run iterations

- Experiment run on ISS for days, weeks, or months (up to 60 days)
  - Longer durations are possible with change out of flow path components and gas supply
  - Transfer to ISS, specimen processing, consumable change-out, experiment initiation
  - Asynchronous ground control run on ARC (nominal due to S. Cal return of live specimens) or KSC

- Return payload in Dragon
  - Live specimens
  - Processed specimens/cold stow
- Payload handed over at the Southern California turnover location

Ames Research Center

NASA

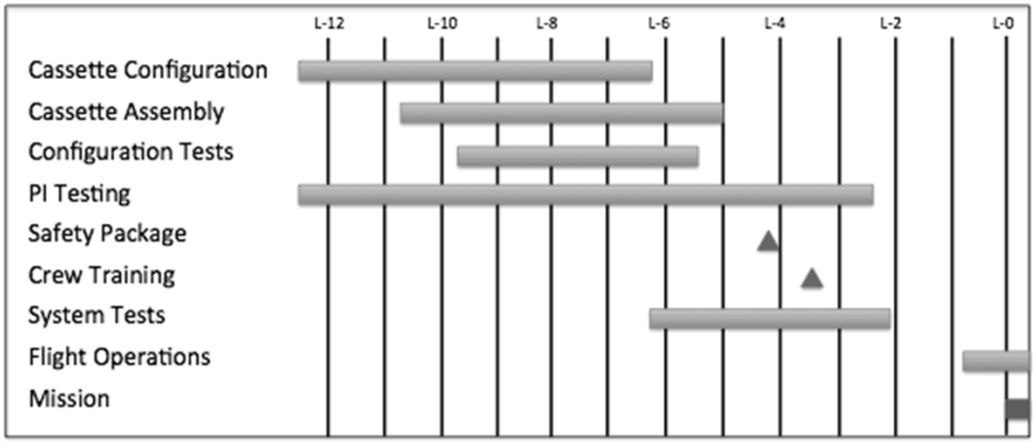
Experiment Definition, Ground Testing and Baseline Data Collection

Phase 1: Biocompatibility testing

- CellMax commercial system for testing cells in a Bioculture System simulated flow path system and biochamber
  - Culture biocompability and growth/proliferation characterization
- Initial definition of fluid circulation rate and injection mode
- Automated and manual operations definition

Phase 2: Cassette biocompatibility,, experiment set point verification, experiment automated and manual testing with biology, specimen characterization and baseline data collection

Phase 3: Mission duration experiment verification test in the fully configured flight Bioculture System



Example payload and science Preparation timeline

Bioculture System Flight Plan

1) Bioculture System Validation flight - Inc. 39/40; SpX-5
NET 9/12/14

- Biology-based hardware testing
- Engineering-based hardware testing

2) First science experiment(s) flight – Inc. 43/44; SpX-7 NET 4/2015

3) Current planning for one flight per year or on each odd numbered SpaceX ISS mission

How You Can Use This Hardware

- NASA Space Biology NRAs
  - Current announcement already released for 2013, plans for 2014, 2015 annual solicitations
  - Unsolicited proposal submittal
  - http://nspires.nasaprs.com/external/

- CASIS
  - Commercial, NIH, DoD, Academic
  - Life science solicitations in near future
    - There may be restrictions to PIs at NASA Centers - Contact CASIS for information
  - Unsolicited proposal submittal
  - http://www.iss-casis.org/Opportunities/Solicitations.aspx

Bioculture System Contacts: Utilization, Project, and Proposals

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