Space Life Sciences Hardware and Expertise

ISS Research Academy and
Pre-application Meeting
3-5 August 2010

BioServe Space Technologies

Speaker: Stefanie Countryman

August 3-5, 2010

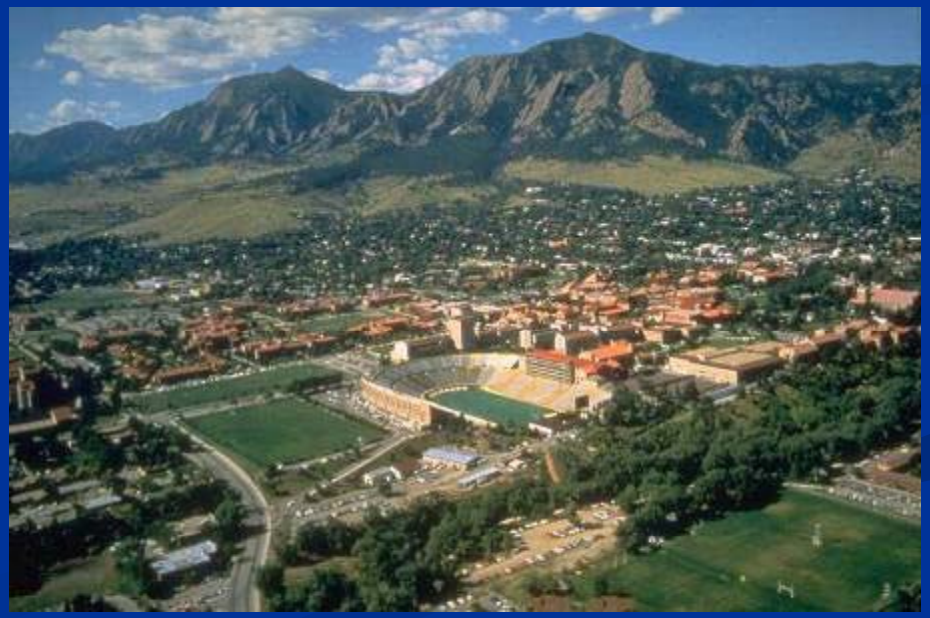
Our Mission:

Work with partners to conduct space life sciences research to advance fundamental science, applied research and commercial interests.

More Information:

www.colorado.edu/engineering/BioServe/

- Based at Univ. of Colorado – Aerospace Engineering Sciences
- Operating since 1987
- Faculty, staff and students with extensive space life sciences and payload engineering expertise



BioServe's Expertise

- Research partnerships
- In-house research expertise
  - Musculoskeletal disuse
  - Bacterial responses to low gravity
- Flight hardware and software development
- Space flight research
  - Planning and execution
  - Integration, safety, mission operations
- Education and public outreach

BioServe Team = Experience

Louis Stodieck
23 years

Dave Klaus
20 years

Mark Rupert
15 years

Dr. Kevin Gifford
17 years

Don Geering
14 years

Jake Freeman
14 years

Emily Pilinsky
2 years

Stefanie Countryman
10 years

Stu Naegele
9 years

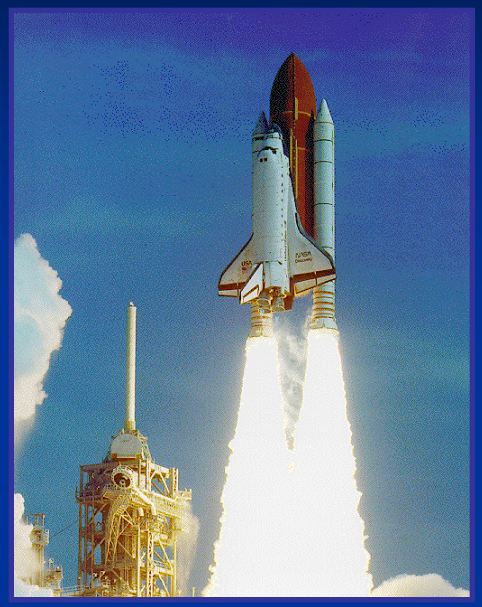
Shea Williams
10 years

Seb Kuzminsky
8 years

Paul Koenig
8 years

Center students
Multi-years

BioServe Flight History



- BioServe payloads on 40 missions
  - 32 Shuttle sortie
  - 2 Russian Mir Space Station
  - 8 International Space Station
  - 2 Soyuz / Progress
- Dozens of individual investigations
  - 70 payloads
  - Molecular, cellular, small organism, plant and animal studies

BioServe Space Flight Services

- Payload Manifest Negotiations
- Payload Mission Management
- PI Team Science Support, Technical Guidance
- Feasibility / Trade Study Assistance
- Science Team Hardware Training
- Engineering Integration – Understand and Satisfy All NASA Documentation Requirements
- Ground Test Facilities/support
- Mission Simulations and Experiment Verification Testing
- Software / Firmware Development
- Real Time Operations
- Dedicated 24/7 Remote Payload Operations Control Center
- Extensive, Off-the-shelf Flight Hardware Solutions
- Flight and Ground Safety Processing
- In-house Manufacturing, Assembly and Test
- Flight Qualification Services
- Launch and Landing site support
- Physical Payload Integration and De-integration – Flight Readiness
- Crew Procedure Writing and Crew training
- Operations Planning
- Closely allied with Industry and Government, especially NASA
- International Experience
- Real-time Problem Solving

Center Faculty can Advise on 0-G Biophysics

$$\text{Gravitational Force} = F = \frac{G \cdot M \cdot m}{R^2}$$

$$\text{Force} = F = m \cdot a = m \cdot g$$

$$\text{Acceleration} = g = \frac{F}{m}$$ ⇒ No movement

$$\text{Stress} = \sigma = \frac{F}{A}$$ ⇒ No stress / strain

$$\text{Pressure} = P = \rho \cdot g \cdot h$$ ⇒ No hydro pressure

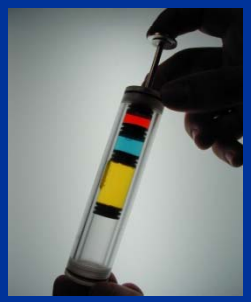
$$\text{Velocity} = V_t = \frac{g \cdot d^2 \cdot (\rho_p - \rho_m)}{18 \cdot \mu}$$ ⇒ No sedimentation

CGBA Multi-Purpose Hardware

Version 2
(STS-95, -93)

Version 3
(STS-93, -106)

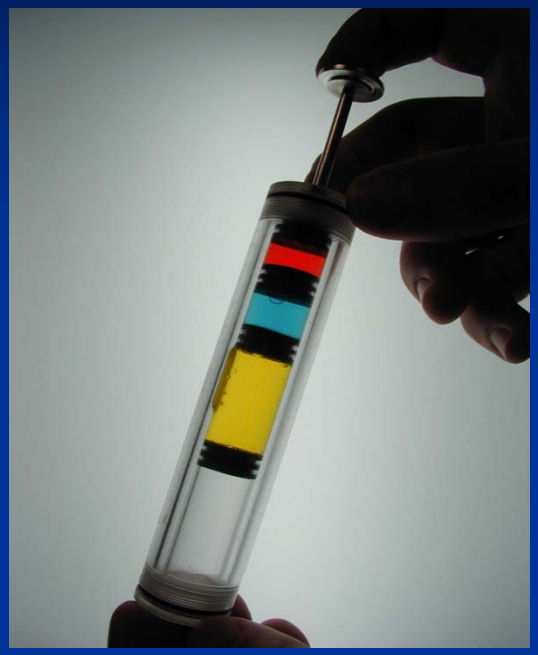
CGBA
(ISS-6A, 8A, 9A, 12A.1, 13A.1)



CGBA Current Configurations

- Standard interface to shuttle or ISS or other transport spacecraft
- Temperature control system
  - Inc-freezer -15ºC to 40ºC
  - Inc-fridge 4ºC to 40ºC
- Large experiment volume
  - Inc-freezer 12.7” x 11.3” x 5.7” = 13.2 liters
  - Inc-fridge 12.2” x 12” x 7.25” = 17.4 liters
- Standard external interfaces (power, ethernet, video, USB)
- Standard internal interfaces to experiments (power, video, RS-485)
- Software permits automated experiment control and data communication

Fluids Processing Apparatus



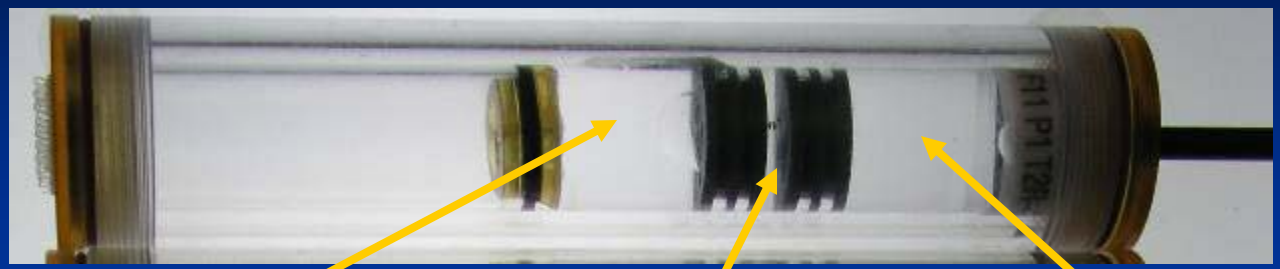
- Space flight "test-tube"
- Mixes 2, 3 or 4 fluids in space
- Wide variety of configurations
- Thousands have been flown

- Group Activation Pack (GAP) works 8 FPAs at once
- Supports large sample sizes
- Robust containment allows use of hazardous materials

Automated FPAs (Group Activation Pack – GAP)

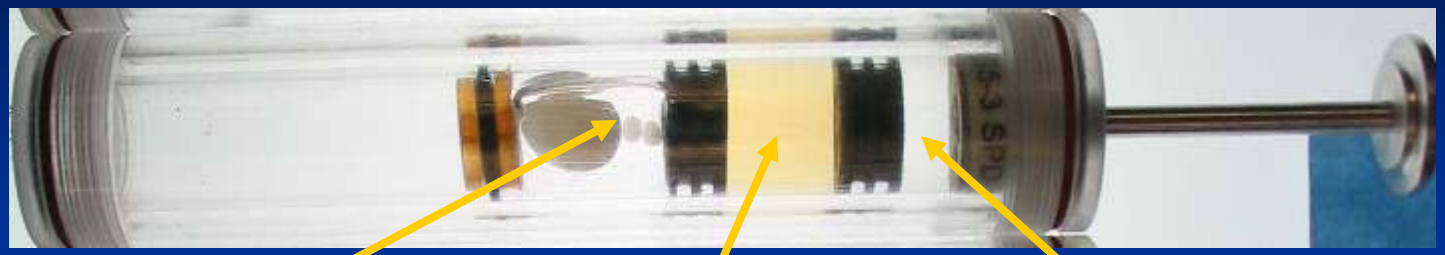
- Motorized GAP with standard FPAs
- Fully automated – can be timed to orbit insertion
- GAP can be charged with desired gas makeup
- Plug and play insert into CGBA
- Transported to ISS, processed inside CGBA, removed, returned to Earth

Example FPA Experiment



- A Chamber
  - Growth media (liquid or agar-based)
  - Gas exchange insert
- B Chamber
  - Microbial inoculum
- C Chamber
  - RNA Later
    or
  - Paraformaldehyde
    or
  - Additional growth media

Example FPA Experiment

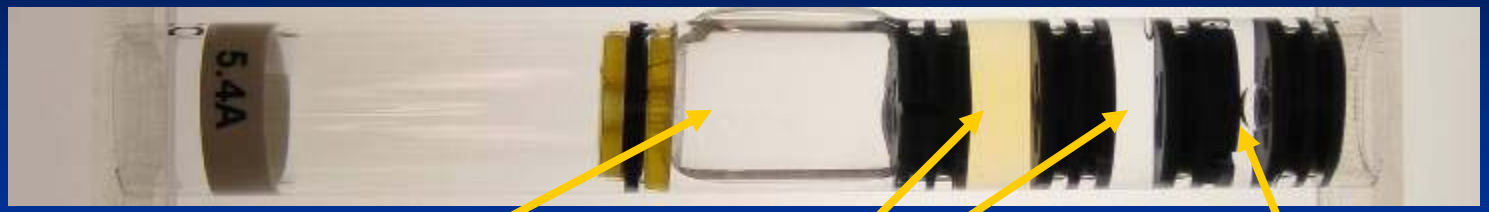


- A Chamber
  - Yeast dried down on filter disk
  - Gas exchange insert
  - Teflon balls to promote mixing
  - Air space displace by media injection
- B Chamber
  - YPD growth media
- C Chamber
  - RNA Later

    or
  - Glutaraldehyde

    or
  - Additional growth media

Example FPA Experiment



- A Chamber
  - Cells of interest in growth media
  - Gas exchange insert
- B and C Chambers
  - Inoculum plus growth media

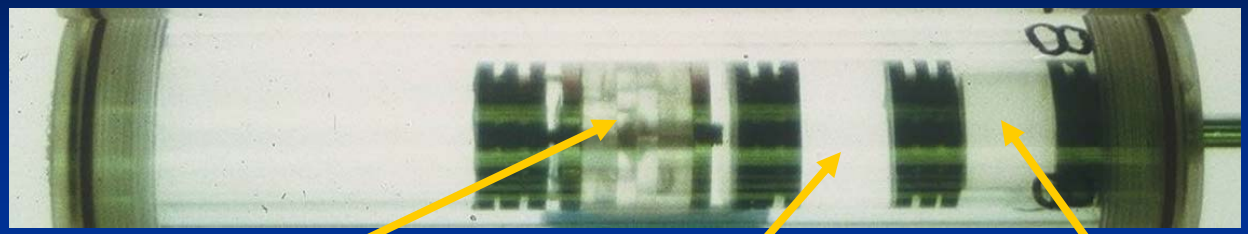
    or
  - Inoculum plus inducing agent
- D Chamber
  - Paraformaldehyde

    or
  - Glutaraldehyde

    or
  - Additional growth media

Infection Study Configuration

Example FPA Experiment



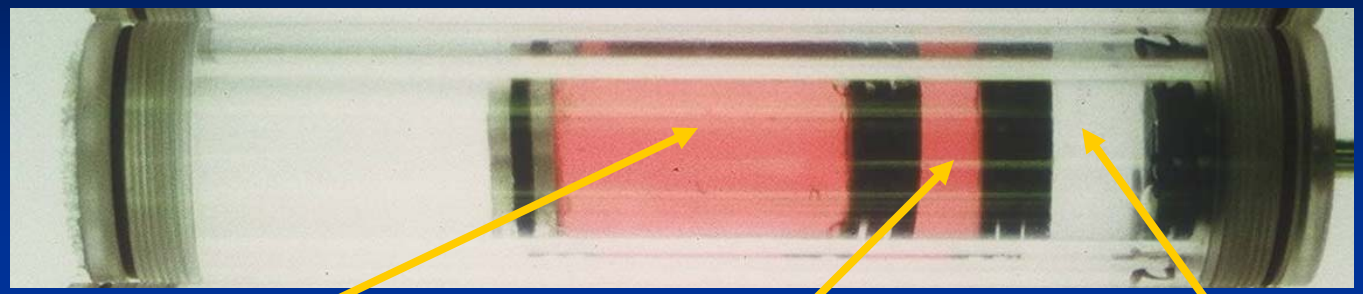
- A Chamber
  - Specialized insert (8 small chambers with protein solution separated from chamber by dialysis membrane)
  - Main chamber with equilibrium solution
- B Chamber
  - High salt solution

    or
  - Osmotic dewatering solution
- C Chamber
  - No chamber

    or
  - Solid plug (method to synchcronize with other FPAs in GAP)

Protein Crystal Growth

Example FPA Experiment



- A Chamber
  - Cells suspended in growth media (free or on beads)
  - Gas exchange insert
  - Immune system cells or cells that work on beads
- B Chamber
  - Nutrient rich media

    or
  - Media with inducing agent
- C Chamber
  - Paraformaldehyde

    or
  - Glutaraldehyde

    or
  - Additional growth media

    or
  - RNA Later

Suspension Mammalian Cell Culture

Example FPA Experiment

- A Chamber
  - Cells grown on surface (cover slip or MilliCell insert)
  - Gas exchange insert
  - Any attachment dependent cell type
- B Chamber
  - Nutrient rich media

    or
  - Media with inducing agent
- C Chamber
  - Paraformaldehyde

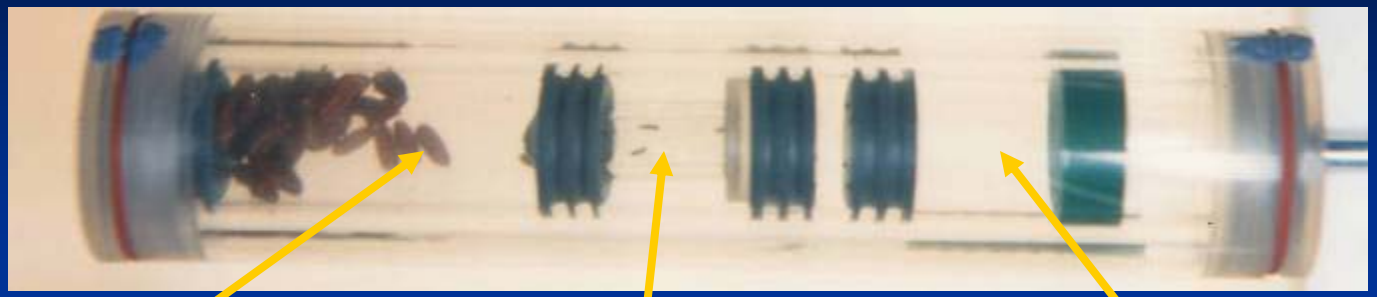
    or
  - Glutaraldehyde

    or
  - Additional growth media

    or
  - RNA Later

Attached Mammalian Cell or Tissue Culture

Example FPA Experiment



- A Chamber
  - Insect pupa

    or
  - Fruit fly larva media

    or
  - Other media
- B Chamber
  - Insect predator

    or
  - Adult fruit flies

    or
  - Other adult insects / organisms
- C Chamber
  - No chamber

    or
  - Solid plug (method to sync with other FPAs in GAP)

    or
  - Fixative

Insect development and behavior in 0-G

Cells, Tissues and Organisms Flown in FPAs

- Microbes
  - E. coli
  - S. cerevisiae
  - S. plicatus
  - S. pneumoniae
  - B. subtilis
  - P. aeruginosa
  - H. fuscoatra
  - S. aureus
  - S. typhimurium
  - And more
- Cells / Tissues
  - Lymphocytes
  - Macrophages
  - Cardiomyocytes
  - Explant metatarsals
  - Hepatocytes
  - Fibroblast cells
  - Bone marrow cells
  - Spleen cells
  - Kidney cells
  - And more
- Organisms
  - Nematodes
  - Seedlings
  - Fruit flies
  - Planaria
  - Brine shrimp
  - And more
- Other
  - Virus capsids
  - Liposomes
  - Protein crystals
  - And more

Alternate GAP Configuration

OptiGAP

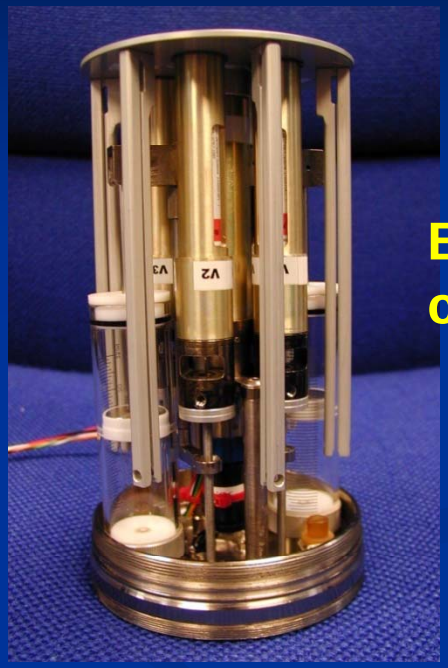
- Culture in 2 modes
  - Passive with no activation or termination
  - Active and terminate with hand crank peristaltic pump
- Can charge GAP with desired gas makeup
- Large volume, surface area, minimal gas diffusion
- Up to six OptiCells per GAP

Alternate GAP Configuration

- Agar based culture
- Use low temperature to arrest growth/ development
- Elevate temperature on orbit to initiate experiment
- Can charge GAP with desired gas or use gas exchange version
- Up to 10 standard 100mm petri dishes per GAP

BioServe Culture Apparatus

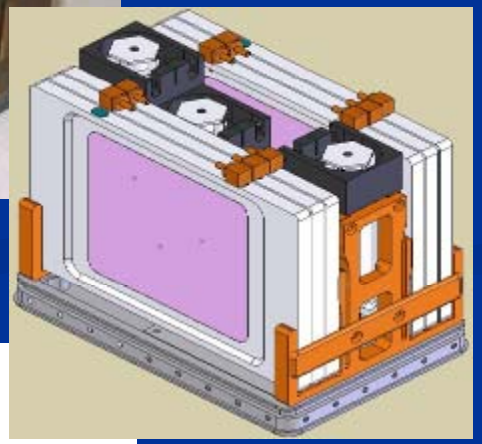
- Uses FEP Teflon culture bags
  - 4 at 30 mls each
- Utilizes 2 – 25 ml syringes for media or fixative addition
- Utilizes 4 – 5 ml vacutainers for sample collection from each culture
- Can charge sealed GAP with desired gas or allow passive exchange with cabin air
- System is fully automated
- Up to 8 can be housed inside each CGBA unit

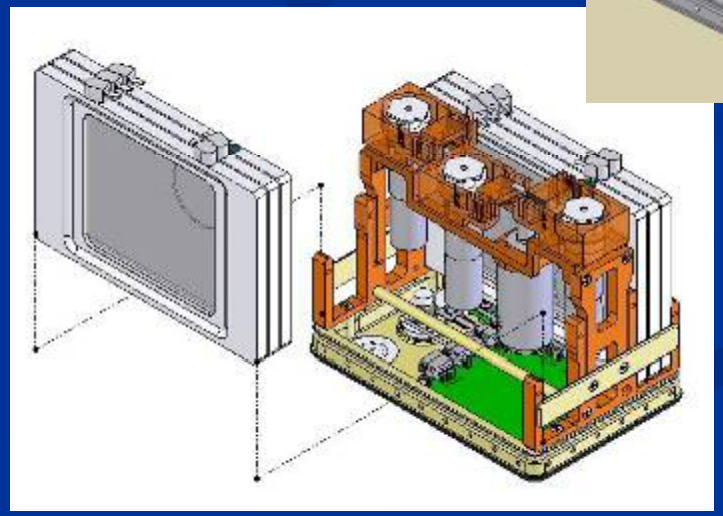


BCA with and w/o culture bags

Cell Culture Habitat (CHab)

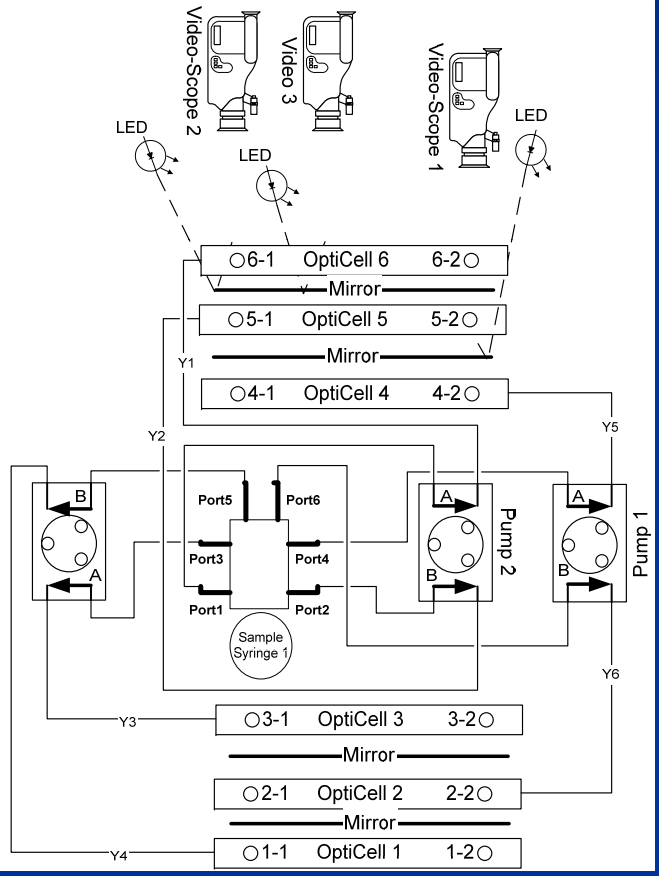
- Based on off-the-shelf Opticells for cell culture
- Employs 3 – double-headed peristaltic pumps
- Has an additional syringe for sampling or inoculation
- Can be plumbed together in myriad ways
- Observation window permits direct on orbit observations



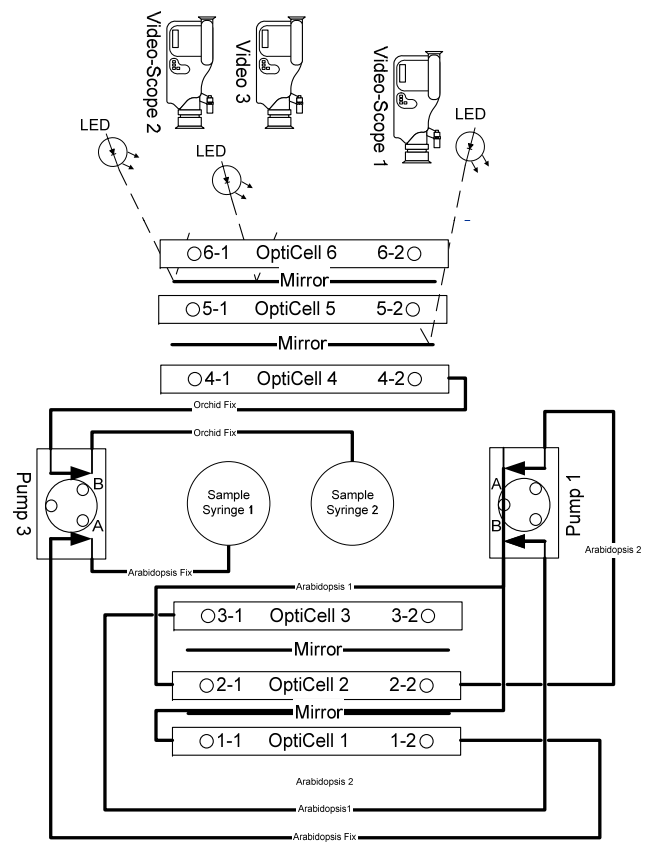


CHab Configuration Examples

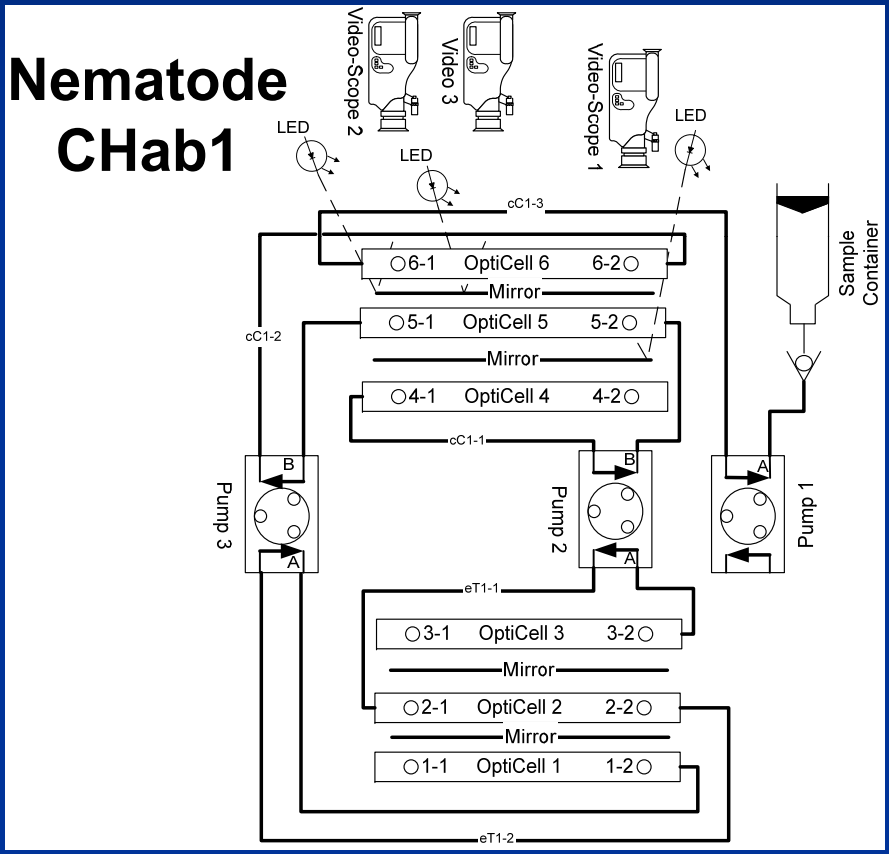
Yeast CHab

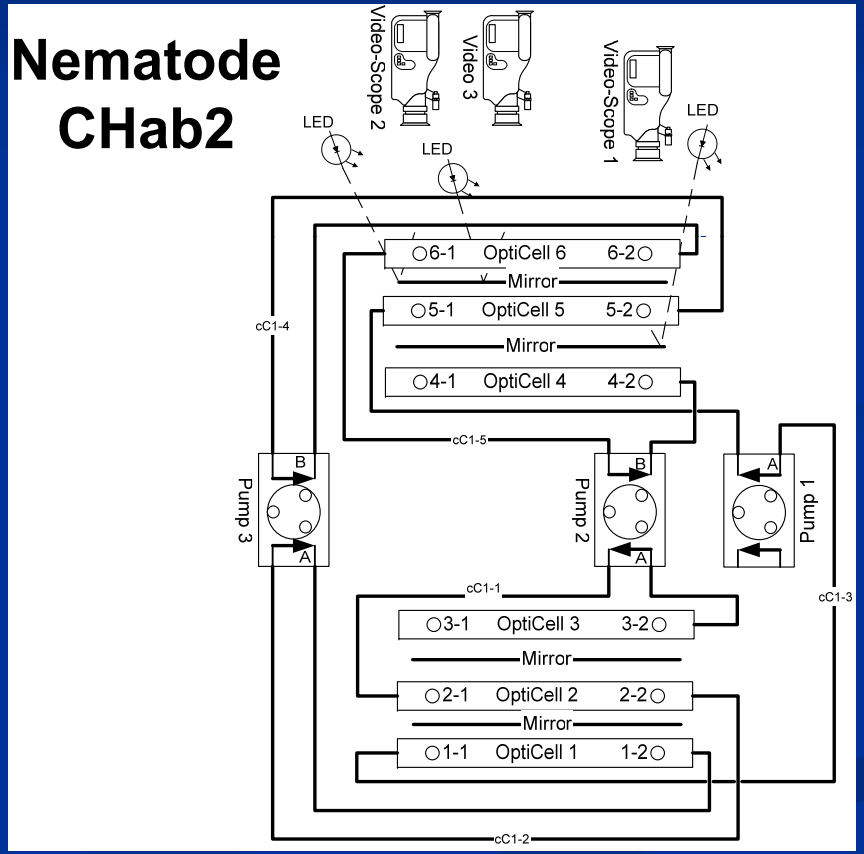


Cell Culture CHab



CHab Configuration Examples





Biomedical Testing with Rodents

- Animal Enclosure Module
  - Special food bars
  - Redundant lixit water supply
  - Waste management system
- Work in collaboration with NASA Ames Research Center
- Can fly mice for up to 18 days
- Utilize female C57BL/6J
- Can support wide variety of studies on physiological responses to space flight

Biomedical Testing with Rodents

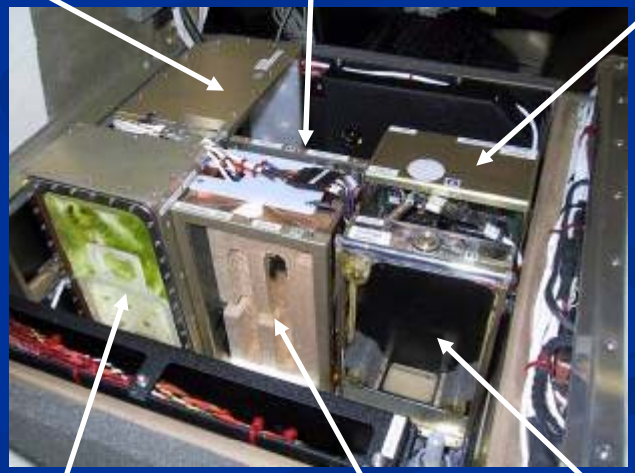
- In collaboration with NASA-ARC, have conducted 5 flights
  - 3 utilizing rats (Immune 1, 2, 3)
  - 2 utilizing mice (CBTM 1, 2)
- CBTM flight configuration
  - 3 AEMs each with 8 mice per AEM
  - Evaluated musculoskeletal issues for Amgen, Inc.
  - Half of mice treated with novel therapeutic, half with placebo
- BioServe assembled extensive science team to maximize use of high value tissues

STS-118 - Example Amgen Investigation

Hardware from K-12 Education Program

Started with experiments flown on STS-93 in 1999

Second suite of habitats flown on STS-107 in 2003



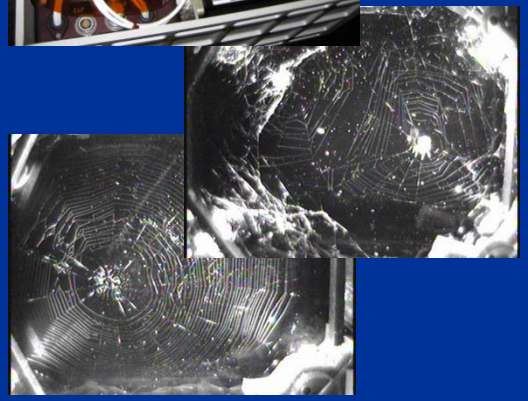
K-12 education Program cont.

Third suite of hardware flown on STS-126 (CSI-03)

Butterfly habitat

Camera module

Spider habitat

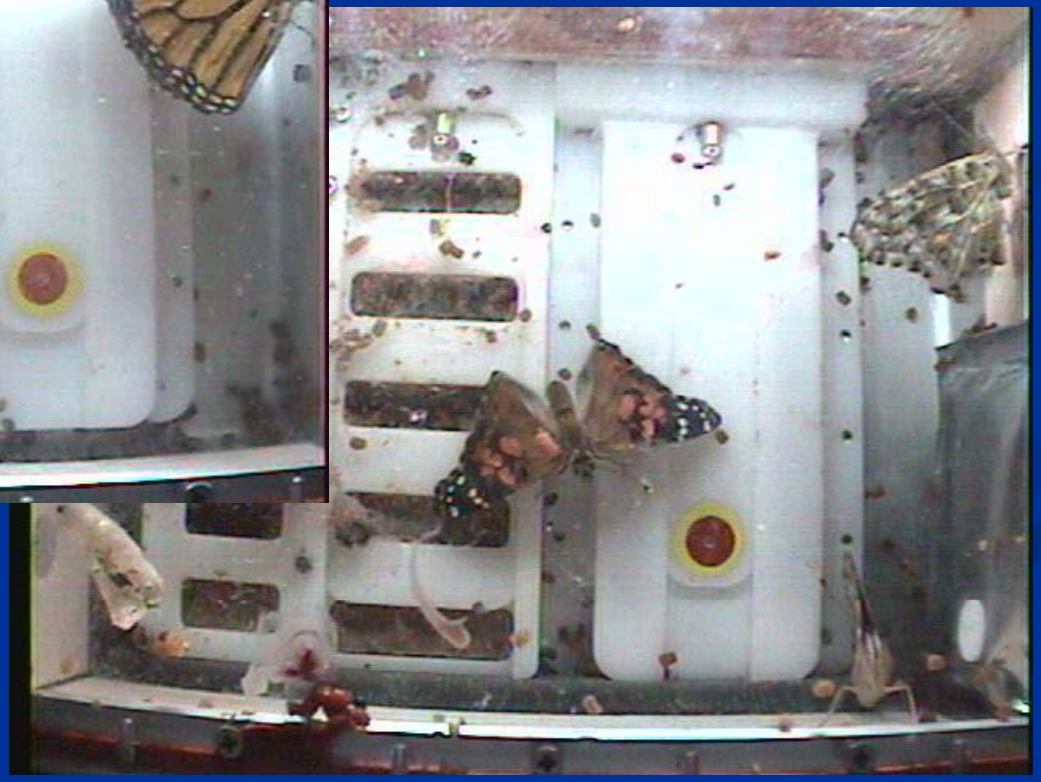


Fourth suite of hardware flown on STS-129 (CSI-03re)

Butterfly habitat on board ISS

CGBA

Recent Butterfly Experiment for Education reached over 180,000 students nationally and Internationally



Small Habitats Available

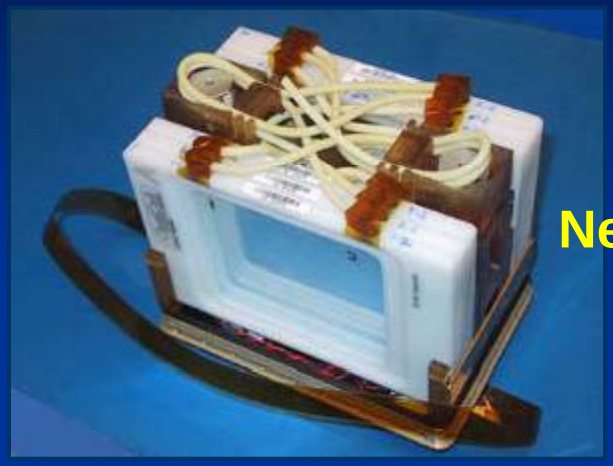
Spider / Fruit flies

Butterflies w/ larval food and nectar

Ants with gel substrate

Wheat / Aphids / Ladybugs

Small Habitats Available



Nematodes

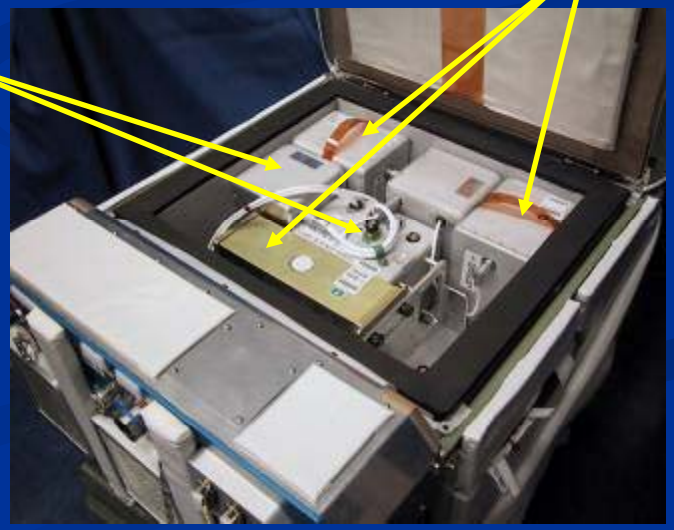
Silicate Garden

Aquatic Ecosystem

Plant Development

CGBA Science Inserts on ISS

- Habitats plus camera systems plus sensors plus CGBA = Excellent on orbit capability
- Can observe, analyze and collect relevant data from wide variety of organisms
- Data delivered from payload directly to PI and students via the Internet in near real-time



Habitats

Camera Systems

BioServe as Turnkey Solution

- Highly experienced team
- Large inventory of available flight hardware
- Already operating on the ISS National Lab
- Can modify or design new hardware, as needed
- Full knowledge of all details required to successfully fly in space
- Long-standing, solid relationship with NASA
- Allow PI team to focus on science, not on flight process requirements
- BioServe team is dedicated to success in space!

Additional Information Slides

BioServe's Vision

To be recognized worldwide as a major leader in expanding the space frontier by developing breakthrough life science technologies using the unique environment of space that benefit humanity…

and enable humans to safely explore the solar system.

BioServe Partnership Building Success

- Dozens of partnerships with wide variety of organizations

P&G

SOPHERION THERAPEUTICS

Bristol-Myers Squibb Company

WRIGHT MEDICAL TECHNOLOGY
A Wright Medical Group Company

FOREST SERVICE U.S. DEPARTMENT OF AGRICULTURE

AMGEN

LIGOCYTE PHARMACEUTICALS, INC.

SPACEHAB
WE MEAN BUSINESS IN SPACE

LVRE

Weyerhaeuser

PentaPure INCORPORATED

STELSYS

CHIRON

Plum Creek
Growing Value from Exceptional Resources

NASA

AFFYMETRIX

Payload Systems Inc

CALBIOCHEM

USDA
United States Department of Agriculture

Coca-Cola

UPM

AgriHouse

NATIONAL INSTITUTES OF HEALTH

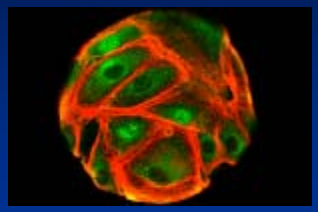
BioServe Already Supporting ISS National Laboratory

- Space Act Agreement to promote commercial utilization of the ISS National Lab research
  - Conduct pathfinder research on remaining shuttle flights
  - NASA provides transportation and on orbit resources
  - BioServe partners with commercial and education users. Provides hardware, integration, ops services.
  - Expected to transition and expand after assembly of the ISS is complete and the shuttle is retired
- Currently supporting vaccine development and stem cell research

Recent and Current BioServe Projects

Agricultural

- Lignan regulation
- Secondary metabolites
- Space flight food production



Biomedical

- Bone loss countermeasure
- Muscle atrophy countermeasure
- BioNet – wireless network
- Microbial virulence and antibiotic effectiveness
- Cell and tissue culture

Payload Hardware

- Cells / tissues / small organisms
- Rodent models
- Higher plants

Education

- CU Bioastronautics curriculum
- CSI – K-12 Program

Payload Space Flight History

May 2009

Mission	Launch	Mission	Launch
1. STS-37	Apr 1991	18. STS-106	Sep 2000
2. STS-43	Aug 1991	19. STS-100 (*ISS*)	Apr 2001
3. STS-50	Jun 1992	20. STS-108	Dec 2001
4. STS-54	Jan 1993	21. STS-110 (*ISS*)	Apr 2002
5. STS-57	Jun 1993	22. STS-112 (*ISS*)	Oct 2002
6. STS-60	Feb 1994	23. STS-107 (*Columbia*)	Jan 2003
7. STS-62	Mar 1994	24. 13-P (*Progress / ISS*)	Jan 2004
8. STS-63	Feb 1995	25. STS-115	Sep 2006
9. STS-69	Sep 1995	26. STS-116 (*ISS*)	Dec 2006
10. STS-73	Oct 1995	27. STS-118 (*ISS*)	Aug 2007
11. STS-77	May 1996	28. 15-S (*Soyuz / ISS*)	Oct 2007
12. STS-79 (*NASA / Mir 3*)	Sep 1996	29. STS-123 (*ISS*)	Mar 2008
13. STS-83	Apr 1997	30. STS-124 (*ISS*)	May 2008
14. STS-94	Jul 1997	31. STS-126 (*ISS*)	Nov 2008
15. STS-86 (*NASA / Mir 6*)	Sep 1997	32. STS-119 (*ISS*)	Mar 2009
16. STS-95	Oct 1998	33. STS-125 (*HST*)	May 2009
17. STS-93	Jul 1999		

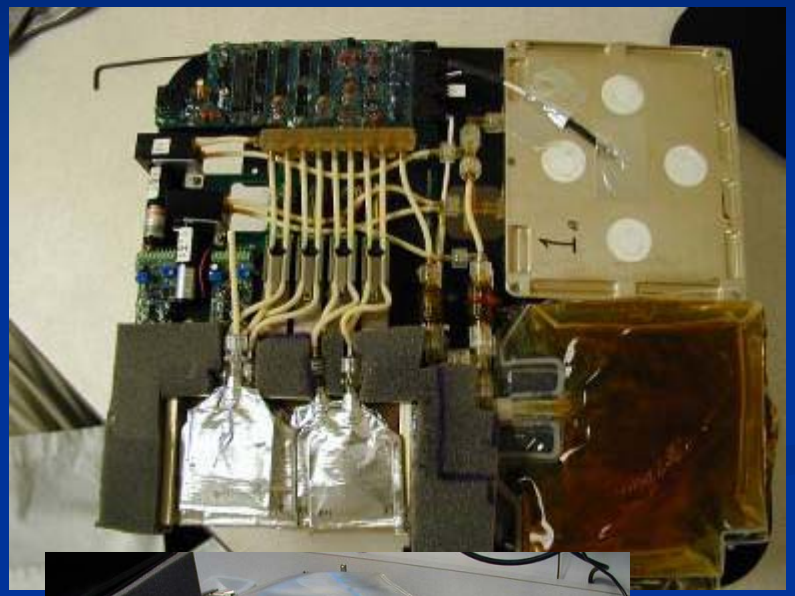
Fixation Tube

- Plant or animal tissue harvest and preservation
- 2 levels of containment
  - Tested to -4ºC

- Insert drops into ICM
- Tubes compatible with other cold storage systems

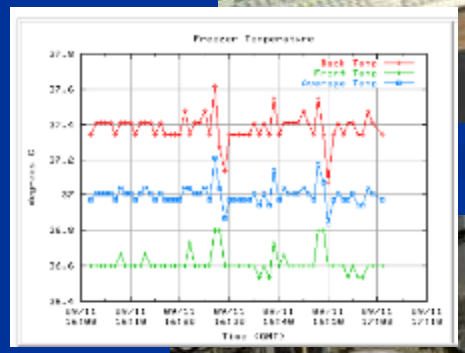
Bioreactor Configuration

- Sophisticated system for cell culture research
  - 6 trays per CGBA
  - 50 ml culture chamber
  - 8 samples per culture
  - Independent temperature control of culture and samples
- Previously flown on ISS (ISS 6A and ISS 8A) to study antibiotic production



Real Time Mission Support

- **Monitor on-orbit crew activities**
  - Voice loops
  - Ground monitoring
- **Address real-time issues**
  - Daily Science Tag-ups
  - Payload Information Management System
- **Dissemination to investigator**
  - Email, Web-based
  - Near real time



Plant Generic Bioprocessing Apparatus (PGBA)

- 25 cm x 30 cm x 25 cm aerial tissue volume
- 280 umol/m^2/s of light
- Temperature, humidity and CO_2 control
- Atmosphere treatment
- Uplink commanding, downlink monitoring
- Synchronized, identical ground control system