Life Sciences Payload
Hardware and Expertise

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NIH BioMed-ISS
Presolicitation Meeting

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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  
22 years

Dave Klaus  
19 years

Mark Rupert  
14 years

Dr. Kevin Gifford  
16 years

Don Geering  
13 years

Jake Freeman  
13 years

Emily Pilinsky  
1 year

Stefanie Countryman  
9 years

Stu Naegle  
8 years

Shea Williams  
9 years

Seb Kuzminsky  
7 years

Paul Koenig  
7 years

Center students  
Multi-years
BioServe Flight History

- BioServe payloads on 35 missions
  - 24 Shuttle sortie
  - 2 Russian Mir Space Station
  - 7 International Space Station
  - 2 Soyuz / Progress

- Dozens of individual investigations
  - 52 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
- 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

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

Force = $$F = m \cdot a = m \cdot g$$

Acceleration = $$g = \frac{F}{m}$$  \(\Rightarrow\) No movement

Stress = $$\sigma = \frac{F}{A}$$  \(\Rightarrow\) No stress / strain

Pressure = $$P = \rho \cdot g \cdot h$$  \(\Rightarrow\) No hydro pressure

Velocity = $$V_t = \frac{g \cdot d^2 \cdot (\rho_p - \rho_m)}{18 \cdot \mu}$$  \(\Rightarrow\) 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  -15°C to 40°C
  - Inc-fridge  4°C to 40°C
- 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
- Paraformaldehyde
- Additional growth media

Microbial Growth and Spaceflight Response
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

Yeast Growth and Spaceflight Response
Example FPA Experiment

4-Chamber Infection Study Configuration

- **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
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 synchronize 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
- Media with inducing agent

C Chamber
- Paraformaldehyde
- Glutaraldehyde
- Additional growth media
- 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
- 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
- Fruit fly larva
- Other media

B Chamber
- Insect predator
- Adult fruit flies
- Other adult insects / organisms

C Chamber
- No chamber
- Solid plug (method to sync with other FPAs in GAP)
- 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

- 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

Nematode CHab1

Nematode CHab2
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
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

Ladybugs/Aphids
Butterflies
Sweet Potatoes

Silk Worms
Ants
Chemical Garden
Medaka Fish
Carpenter Bees
Spider
Small Habitats Available

- Spider / Fruit flies
- Ants with gel substrate
- Butterflies w/ larval food and nectar
- Wheat / Aphids / Ladybugs
Small Habitats Available

- Nematodes
- Aquatic Ecosystem
- Silicate Garden
- 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
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
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

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**Shuttle**  
**International Space Station**  
**Soyuz**  
**Mir**  
**Progress**
Fixation Tube

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

- 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/m²/s of light
- Temperature, humidity and CO₂ control
- Atmosphere treatment
- Uplink commanding, downlink monitoring
- Synchronized, identical ground control system