



# Initial Flight Results from the PharmaSat Biological Microsatellite Mission

**Presented by:** Christopher Kitts, Mission Operations Lead

**U. Texas Medical Branch:** D. Niesel, M. McGinnis

**NASA Ames:** J. Hines, E. Agisid, C. Friedericks, M. Piccini, M. Parra, L. Timucin, C. Beasley, M. Henschke, E. Luzzi, N. Mai, M. McIntyre, R. Ricks, A. Ricco, D. Squires, B. Yost, G. Defouw, A. Schooley, D. Ly, M. Diaz-Aguado, E. Stackpole, O. Diaz, T. Doukas

**Santa Clara University:** C. Kitts, K. Ronzano, R. Rasay, I. Mas, J. Acain, M. Neumann, L. Bica, P. Mahacek, G. Minelli, E. Beck, S. Li, B. Gamp, S. Agnew, J. Shepard

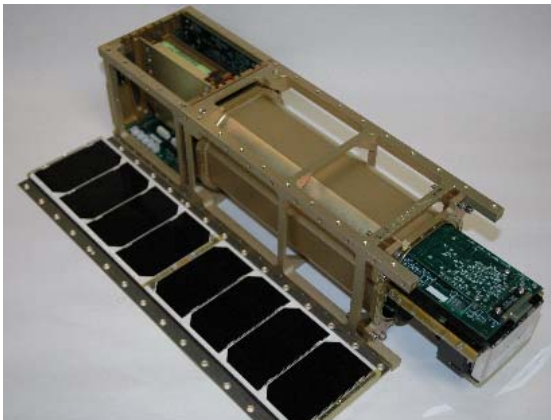




# PharmaSat Experiment Approach

---

- Experiment strategy: Explore the use of a low-cost small spacecraft for supporting such an experiment
- Challenge: Need for a small but complex *in situ* bio-lab: storage, incubation, nutrient delivery, data acquisition....
- Solution: Exploit NASA GeneSat-1 team experience: miniature bio-payload, heritage bus, launch, operations





# PharmaSat Mission Overview

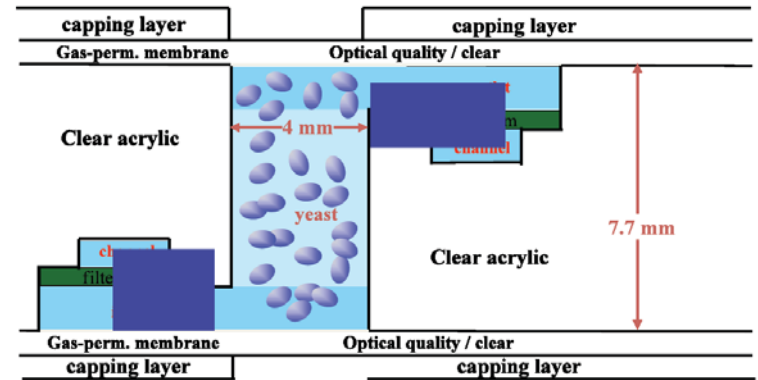
---

- Mission Statement: assess the efficacy of antifungal drugs in a microgravity environment
- 5 Critical Functions:
  - Provide life support for yeast growth in 48 microwells
  - Dose sample subsets with 3 distinct antifungal doses (+ control)
  - Track yeast population via optical density
  - Determine yeast viability using a colorimetric reagent
  - Telemeter resulting science and system status data to ground
- One of the first sub-10 kg small satellite missions to be:
  - Competitively-selected, peer-reviewed, and science-driven
  - Managed via industry-standard systems engineering practices



# Payload - Wellplate

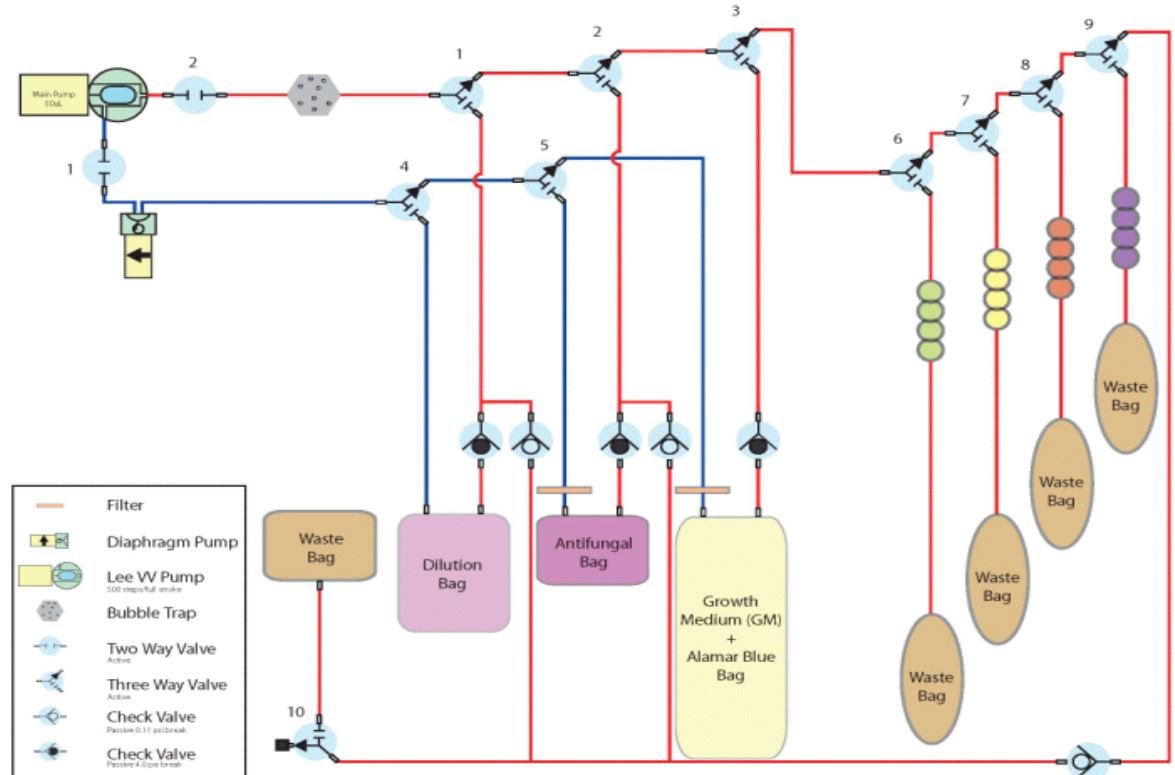
- Biological Wells:
  - 100 $\mu$ l wells
  - Fluidic network connections
  - Filters & permeable membrane
  - Bio: Common lab yeast
    - *Saccharomyces Cerevisiae*
- Wellplate:
  - 60 wells in a 4"x8" plate
  - 5 banks: standard, 0/L/M/H dose
  - Thermally controlled





# Payload - Fluidics

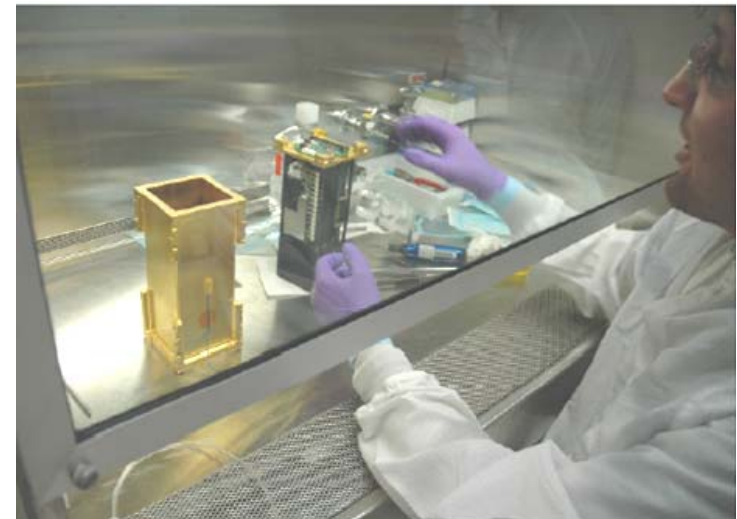
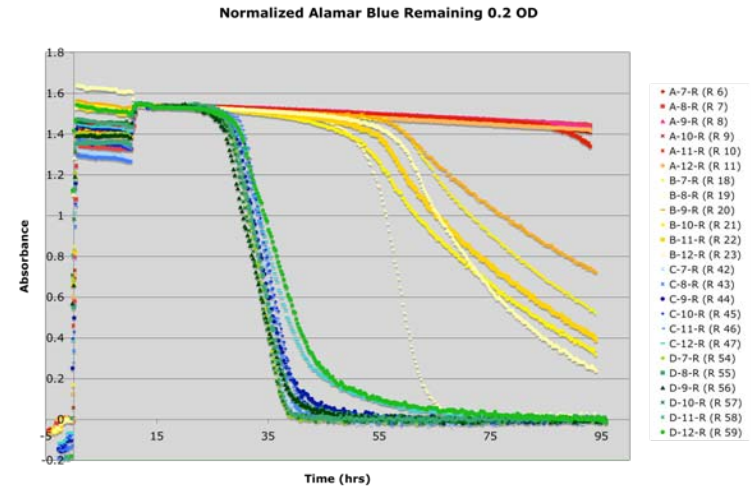
- Fluids
  - Growth media with colorimetric reagent (Alamar Blue)
  - Antifungal (voriconazole)
- Network
  - 4 parallel banks
  - Bags & pumps
  - Tubes & valves
- Processing
  - Circulation
  - Feeding
  - Dosing





# Payload – Sensing & Environment

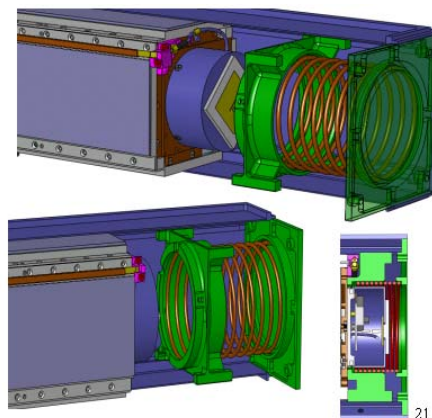
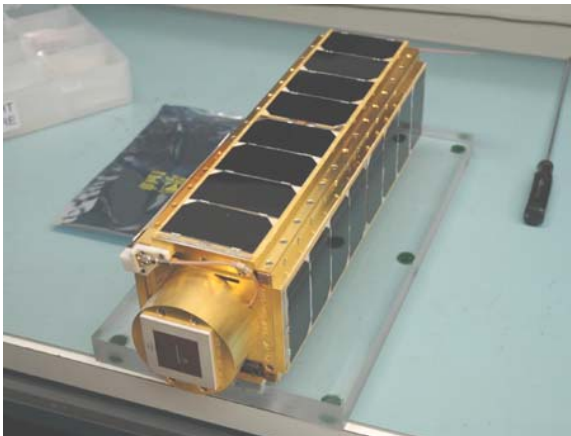
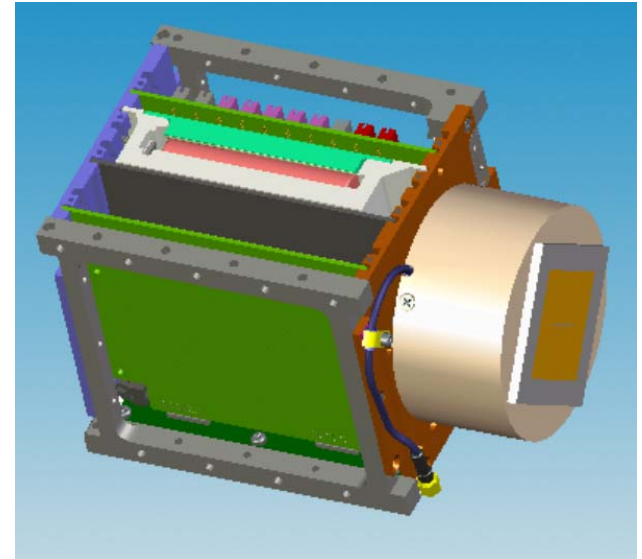
- Optical Sensor System
  - Tri-color LED shines light through well
  - Yeast absorbs light
  - Detector measures RGB absorption
  - Green provides OD (population count)
  - Blue-Red shift indicates metabolism
    - Alamar Blue oxidizes w/growth
- Payload subsystem engineering
  - 2 PIC processors in payload
  - Fluid and plate temperature control
  - Components in sealed container





# Satellite Bus and Launcher

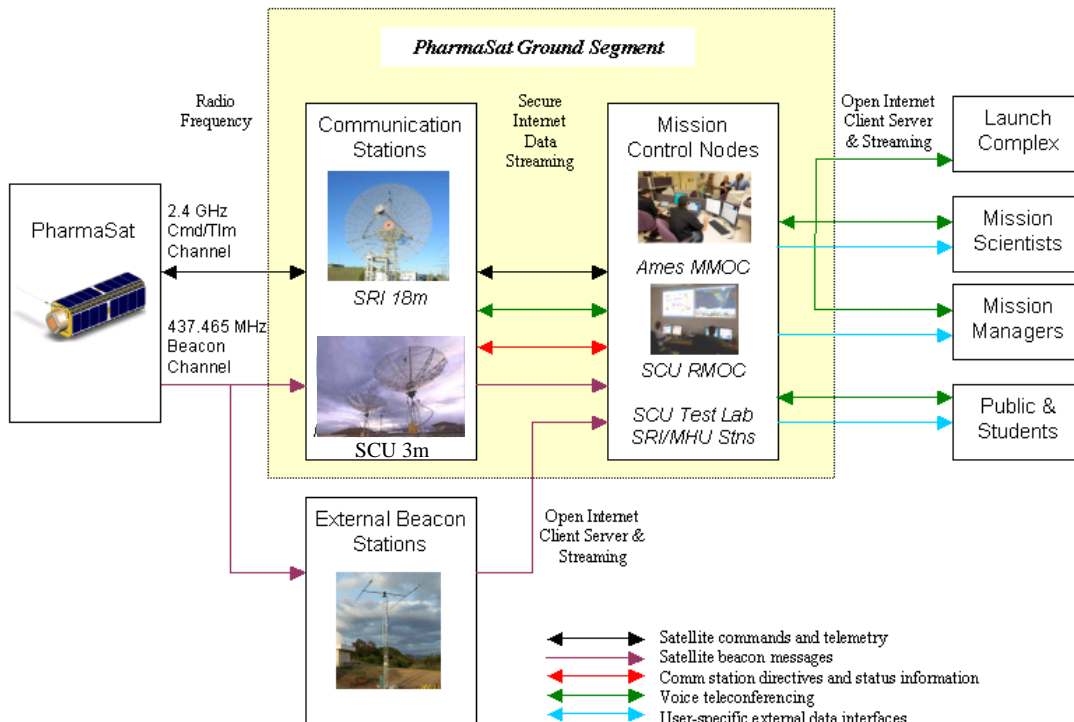
- Configuration: 4.6 kg extended triple CubeSat
- Communications: 2.4 GHz w/437 MHz beacon
- CDH: PIC-based processor with an I<sup>2</sup>C bus
- Power: body mounted arrays, NiCad battery
- ADC: passive magnetic stabilization
- Thermal: active control for payload
- Launcher: Modified CalPoly P-POD





# Mission Operations

- Communication Stns: 18-m SRI, Two 3-m SCU, UHF amateur
- Control Segment: Internet-based distributed control software
- Ops Team: SCU undergraduates and graduate students







# Flight Results Summary

---

## Launch on May 19, 2009

Minotaur 1 secondary from WFF  
410 km 40° circular orbit



5/19: 1655	Launch
5/19: 1717	Ejection from P-POD
5/19: 1822	Beacon received at SRI
5/19: 2010	S-Band comm at SRI
5/21: 1530	Experiment initiated
5/25: 1805	Baseline data collected [Bus s/w lock-up anomaly]
5/26	SRI off-line (encoder failure)
5/27	No S-Band contact, Nominal beacon, Anomaly diagnosed
6/15	Beacon turned off
present	Comm link testing



# Flight Results

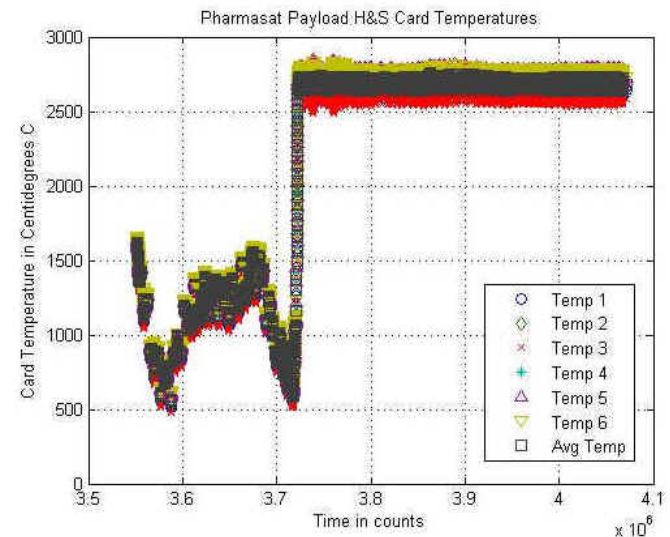
---

- Science Results

- Scientific analysis underway
- Positive evidence of yeast growth in all wells
- Positive evidence of measurable growth difference in banks
- Positive evidence of solid instrumentation performance

- Engineering Results

- Microgravity levels achieved
- Pressure specification maintained
- Humidity specification maintained
- Temperature specification maintained





# Flight Results – Software Anomaly

---

- Symptom: Loss of S-Band channel command capability
  - Beacon channel operational      Beacon telemetry nominal
  - S-Band transceiver responsive      GeneSat-1 contacts successful
- Diagnosis: Serial communication software flag
  - CPU serial comm flag not cleared if transceiver doesn't report back that a telemetry response has been successfully communicated to the ground
  - This can occur for a poor quality comm link - duplicated in ground test
  - Anomalous software identified and a patch has been developed
- Resolution: Awaiting CPU Reset due to low power
  - Unable to reset CPU via ground or to upload new code
  - Over time, power supply/storage degradation may cause CPU reboot
- Program Response:
  - NASA PharmaSat mission complete - Integrating patch into O/OREOS
  - SCU performing comm testing – will use satellite if it reboots



# PharmaSat Mission Summary

---

- Mission: - Microgravity effects on antifungal efficacy
- Results: - Experiment completed and data downloaded
  - Communication testing ongoing
  - Software anomaly diagnosed
- Science Impact: Understanding of space environment effects
- Technology Impact: Contributes to Ames' program to develop advanced *in situ* biological laboratories for very small spacecraft
  - Competed, peer-reviewed, and science-driven
  - Managed via industry-standard practices
- Workforce Impact: Integration of young engineers into mission





# PharmaSat Science Background

---

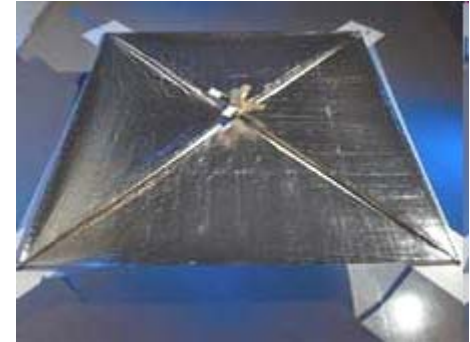
- Science Driver: Obtain a deep understanding of the effect of the space environment on biological systems
- Three early findings:
  - Space flight increases human infection risks
  - Some pathogens are more virulent in microgravity
  - Some pathogens develop drug resistance in microgravity
- PharmaSat Objective: Measure the influence of microgravity on the resistance yeast has to antifungal drugs
- Typical research constraints:
  - Costly space flights      Ground-based tests      Short durations
  - Re-entry effects          Limited samples          Platform vibrations



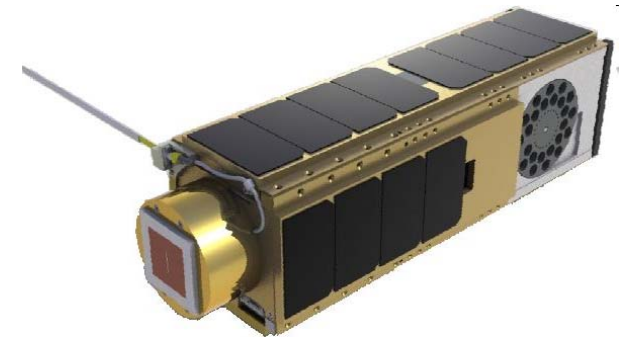
# What Else?

---

- In the past: PreSat & NanoSail-D
  - Summer 2009 launch from Kwajalein
  - SpaceX Falcon 1 Flight 3
  - Failure to reach orbit



- In the future: O/OREOS
  - 2010 launch from Kodiak
  - Minotaur IV secondary
  - Circular, 650 km, 72° orbit



- Education & Training
  - PharmaSat and GeneSat-1 incorporated into education and research program
  - Satellite operations class: 50+ students, multiple undergraduate design projects, multiple graduate thesis/dissertation experiments