

# Flight Results from the GeneSat-1 Biological Microsatellite Mission

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### GeneSat-1 Mission Overview

<u>Mission</u>: Validate technologies to provide low-cost, *in situ* life sciences research using automated spaceborne platforms

<u>Biology experiment</u> : chosen for suitability in aiding technology validation	-Study the effects of microgravity on the metabolism of <i>E. coli</i>
<u>Payload system</u> : developed to exploit standard biological test processes	<ul><li>-Use fluorescent imaging (GFP)</li><li>-Support specimen life-support through storage, activation, growth</li></ul>
Bus & ground segment: developed to meet payload demands at low-cost	<ul> <li>Triple CubeSat configuration</li> <li>Simple bus subsystems</li> <li>COTS ISM-band radio</li> <li>Internet-based mission operations</li> <li>Significant university involvement</li> </ul>



### Presentation Overview

- Design Summary
  - Payload
  - Bus and Launcher
  - Ground Segment
- Flight Results
  - Biology
  - Technology
  - Education & Public Outreach
  - Programmatic





## **Biological Payload**

- Fluidics wellplate
  - Microfluidic nutrient delivery
  - Array of 12 100µl wells: 10 samples, 2 standards
- Optics module
  - Fluorescence: blue excitation, GFP response
  - Optical density: green scattering through well
  - Integrated module: common collection optics
- Payload assembly
  - Pressurized and temperature controlled chamber
- Experiment process
  - Initiation pumps nutients into wells
  - Periodic measures of FL and OD for each well
  - ~96 hour growth cycle









### Satellite Bus & Launcher

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











### **Mission Operations**

- Primary Communication: Refurbished 18-m SRI Station, Palo Alto CA
- Control Segment: Internet-based control system developed & operated by students











### Flight Results - Overview

#### Launch on December 16, 2006

TacSat 2 secondary from WFF 410 km 40° circular orbit



#### Table 1: Primary Operational Milestones

	· · ·
Dec 16, 2006	Successful Minotaur launch from WFF
0400 PST	
Dec 16, 2006	Deployment of GeneSat-1 from P-POD
0420 PST	
Dec 16, 2006	Beacon first received
0530 PST	
Dec 17, 2006	2.4 GHz command & telemetry
0400 PST	communications established
Dec 18, 2006	GeneSat biological experiment initiated
0500 PST	
Dec 22, 2006	96-hour biological experiment complete
0535 PST	and baseline data retrieved
Dec 22, 2006	Baseline science data disseminated to
0635 PST	complete mission team
Jan 17, 2007	All primary mission criteria successfully
1700 PST	completed
Feb 21, 2007	Operational control of satellite handed
1430 PST	over to SCU for training and research
Fall 2007	Expected de-orbit



#### Flight Results – Biology (prelim)



Growth doubling: pGREEN 51(11) min flight vs. 38(17) min ground AcGFP 45(6) min flight vs 33(5) min ground



### Flight Results - Engineering

Spec	Target	Actual
Micro-g	< 10 <sup>-3</sup> g	< 70x10 <sup>-6</sup> g
Pressure	14.2-14.95 psi	14.6-14.95 psi: Mean=14.78 psi; Mode=14.67 psi
Humidity	~ 90% RH	77-92% RH; Mean=83.94%; Mode: 89% RH
Temperature	34 +/- 0.5 °C	33.18-34.85 °C; Mean=33.77 °C; Mode=33.85 °C

Satellite Bus Temperatures 30 25 Temp Solar 1 0 20 Temp PL Enclose Temperature in °C Temp Solar 2 Temp MHX 15 Temp Solar3 Reserved Temp Solar4  $\nabla$ 10 Temp Batt Holder Δ \$ Temp PL Board 5 Π 3.672 3.674 3.676 3.678 3.68 3.682 3.684 3.686 3.688 3.69 Time in counts x 10<sup>6</sup>





#### Flight Results - Engineering

#### Solar Panel Current



Satellite Load Currents



#### Multi-Contact Link Margin vs Azimuth



#### Contact Link Margin as Elevation Varies





### **Programmatic Highlights**

- **Programmatic Operation** •
  - Streamlined NASA 7120.5C Class D **Project Management**
  - Near-realtime Data Dissemination
- University Education:  ${\color{black}\bullet}$ 
  - 50+ university students on team
  - Several grad/undergrad theses
  - Stanford: bus prototyping
  - Cal Poly: baseline PPOD
  - Santa Clara: design, test, mission ops
- Outreach
  - Amateur participation: 50+ operators, 40,000+ packets, 12+ countries
  - Middle/high school projects/exercises
  - 1,500+ via exhibits, class visits, etc.

#### GeneSat1 Mission Dashboard Happy 2 Month Birthday to GeneSat-1 Mission Counter Satellite Status Ground Segment Status S808236 203 Seconds Bus Health Control Nodes Power Nominal: Bus voltages all as emected; Primary MOC - ACTIVE Nominal **Mission Phase** Ext. Temp Nominal: Solar Panels ~ 11.8-13.1 deg C (entering eclipse) Backp MOC Nominal Pre-Launc ominal: Payload Canister ~ 18.85 deg C SRI Node Nominal Int. Ter CPII Nominal: # processor resets = 0 SCII Node Nominal Laund Nominal: 2.4 GHz functional: beacon no Deployme Com Communication Statio Stabilization Payload SPL - trinod light installed Nominal Temp Nominal: mean Temp 25.27 deg C (for set-point 25 deg C) SCU - handheld working! Nomina Monipal: 14 22 Pressur 36 000+ heacon nackets from HAMs 96-hr Optical Densi Event Summary 12/16 0400 Launet 12/16 0420 Deployment 2/16 0530 Beacon Acquisitio 12/17 0400 2 4 GHz A consisitio 2/18 0500 Experiment Start













nta Clara University Robotics Systems Laborate



### What's Next

- GeneSat-1 Ops & Analysis
  - Final Bio results: ASGSB
  - Student experiments and training

#### • PharmaSat Mission

- Microgravity effects of yeast susceptibility to antifungal drugs
- Expected launch: May 2008, TacSat3 secondary, 460 km 40° circular
- 6 month primary mission
- 59 wells, enhanced microfluidic network
- Tri-color absorbance monitoring, luminescence to colorimetric





### GeneSat-1 Summary

- Technology demonstration mission for advanced *in situ* spaceborne biological studies
- Integrated capability to store, grow, and analyze biological specimens
- Miniaturization requirements and environmental control demands given small satellite constraints
- Innovative teaming of NASAindustry-academia partners
- Successful flight results supporting follow-on PharmaSat science mission

