Extended Life Flight Results from the GeneSat-1
Biological Microsatellite Mission

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GeneSat-1 Overview

- **Launch Dec. 16, 2006**
  - Secondary payload on Minotaur launch from WFF
  - Developed by NASA Ames Research Center

- **Unique biological experiment**
  - The study of microgravity effects on *E. coli* metabolism
  - GFP and well turbidity were primary measurements

- **Technology validation demonstration**
  - Small satellites can be a valuable asset in conducting tests in orbit
  - Miniaturization of biological support system including fluidics, heating and optics

- **Mission Success – 1 Month of Operations**
  - SCU operations team responsible for ground segment and extended mission after NASA handover
  - At least 5 heritage missions flying GeneSat-1 bus and/or payload elements, motivating long-term performance trend analyses

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GeneSat-1 Biology Results

Growth doubling: pGREEN 51(11) min flight vs. 38(17) min ground

AcGFP 45(6) min flight vs 33(5) min ground
Long Term Performance – Bus

- **Nominal Overall Performance**
  - Telemetry measured at regular intervals over 15 months

- **Power**
  - Solar panel degradation 2.62%/year
  - Voltages nominal

- **Thermal**
  - Thermal profile remains constant
  - Microhard radio warmest component at 35.8 °C

- **CPU**
  - No indicated resets, latch-ups, or SEUs
  - Experiment data successfully downloaded after 15 months of storage
  - Clock drift >24 hrs over 15 months

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Long Term Performance - Payload

- **Mission Success**

- **Heater Anomaly After ~10 Months**
  - Discovered when setpoint was not maintained. Well plate temp fluctuated with orbital period.
  - Current draw dropped from 500-700 mA to 50 mA.
  - Subsequent heater shut off
  - Suspected blown FET on duty-cycled well plate heater
Primary Station

- **18m parabolic antenna**
  - Owned by SRI International, land leased from Stanford University
  - Recently refurbished to support 2.4 GHz

- **Satellite command and telemetry link**
  - Microhard MHX-2400: low cost ISM band 2.4 GHz transceiver
  - COTS radio not originally intended for space flight
  - GeneSat-1 first flight demonstration for unit

- **Long term performance**
  - Link strength measured over time – no noticeable signal degradation.
  - Satellite rotation created signal ‘coning’, which occasionally affected link performance
Deployable Stations

**Two stations developed**
- Support of NASA PreSat and NanoSail-D missions
- Installed in El Salvador and Kwajalein Atoll
- Link analyses showed feasibility of such stations for limited operations (~10 dB loss vs. SRI dish).
- COTS equipment including 3m parabolic antenna
- 0.5° pointing accuracy, 6°/sec azimuth rate
- Use of OSCAR dual Yagi antennas for amateur radio beacon tracking

**Validation**
- Used for GeneSat-1 contacts, 15-70° elevation
- Weather, temperature, noise, and coning effects more noticeable

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MHX 2420

- **Upgrade from 2400 to 2420**
  - Microhard Inc. discontinued MHX-2400 unit used on GeneSat-1 flight unit
  - MHX-2400 spares increasingly difficult to find
  - Enhanced MHX 2420 offered with backwards compatibility after factory installed firmware modification

- **Validation**
  - Bench tests confirmed backwards compatibility
  - MHX-2420 successfully used in GeneSat-1 contact when installed at SRI primary ground station (7/24/08 - 30+ pages downloaded)
Heritage Missions

- **GeneSat-1 Heritage**
  - Mission success spawned a number of follow-on missions adapting key components of GeneSat-1 bus and payload

- **PharmaSat (NASA ARC)**
  - PI driven pharmacological experiment
  - Bus reflight. Larger, more complex biological support payload.
  - Secondary payload on WFF launch (Oct. 2008)

- **PreSat (NASA ARC)**
  - Technology validation and evaluation flight for PharmaSat (SpaceX Falcon-1 Launch, Aug. 08)

- **NanoSail-D (NASA MSFC/ARC)**
  - GeneSat-1 bus with one-of-a-kind deployable solar sail payload. (SpaceX Falcon-1 Launch, Aug. 08)

- **Additional**
  - PI-driven biological laboratory satellites (OOREO Dec. 09)
  - NASA Ames’ COTSAT program (Mar. 09)
  - Future research and industry partners

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Conclusions

● GeneSat-1 Heritage
  – Mission proved that triple CubeSat configurations are effective for *in-situ* biological research
  – Designs intended for a short-lived study can last successfully for extended periods of time
  – New flights carrying a number of heritage components
  – Streamlined ground segment development for heritage mission support

● Educational Contributions
  – Small satellites in the classroom: student operations laboratory, space systems design class, university nanosatellite program, publications, undergraduate and master’s level theses
  – Worldwide amateur HAM radio community involved in beacon packet collection and submission
  – Student involvement in other institutions, i.e. University of Central America, El Salvador
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- **Kwajalein Ground Station**
  - Steve Buckley, SpaceX, RTS, KRS
QUESTIONS?
## Link Budget

### GeneSat-1 ISM Cmd&Tim
#### 2.4GHz DownLink Budget

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