Santa Clara University

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

Giovanni Minelli

Research Assistant - Robotic Systems Laboratory - Santa Clara University

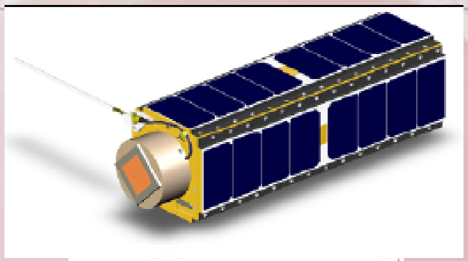
Email: gminelli@scu.edu Web: http://rsl.engr.scu.edu/

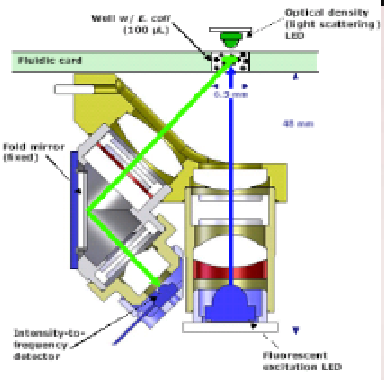
Outline

- Introduction
- GeneSat-1
  - Overview
  - Long-Term Performance
- Ground Segment
  - Primary Station
  - Low-Cost Deployable Stations
  - MHX 2420 Upgrade
- Heritage Missions
- Conclusions

GeneSat-1 Overview

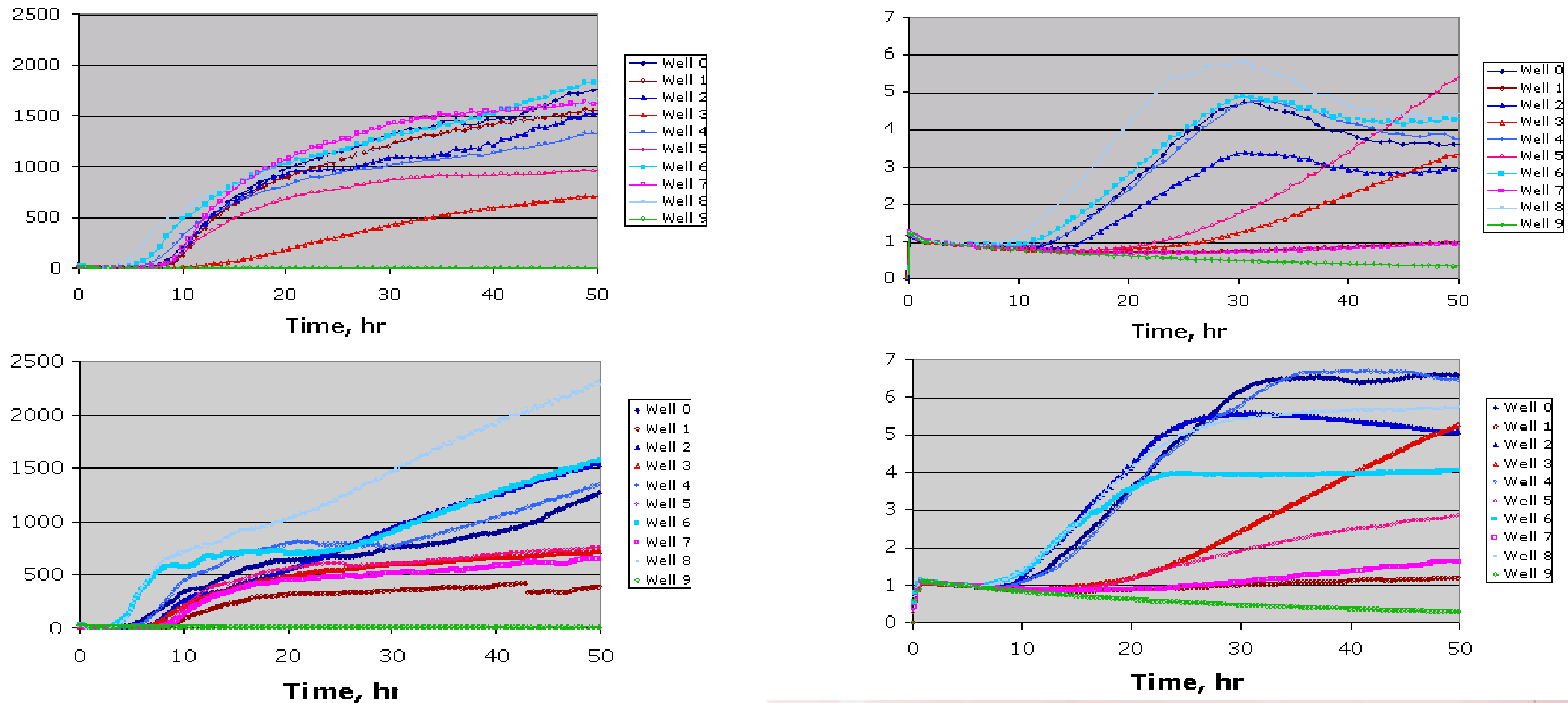
- Launch Dec. 16, 2006
  - Secondary payload on Minotaur launch from WFF
  - Developed by NASA Ames Research Center
- Unique biological experiment
  - The study of microgravity effects on *E. coli* metabolism
  - GFP and well turbidity were primary measurements
- Technology validation demonstration
  - 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





Santa Clara University

GeneSat-1 Biology Results

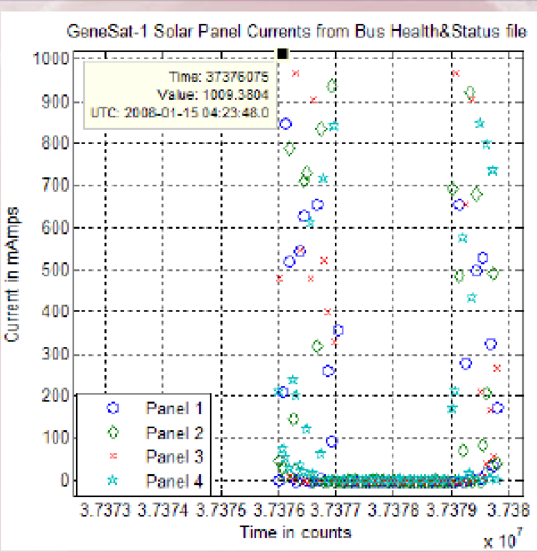


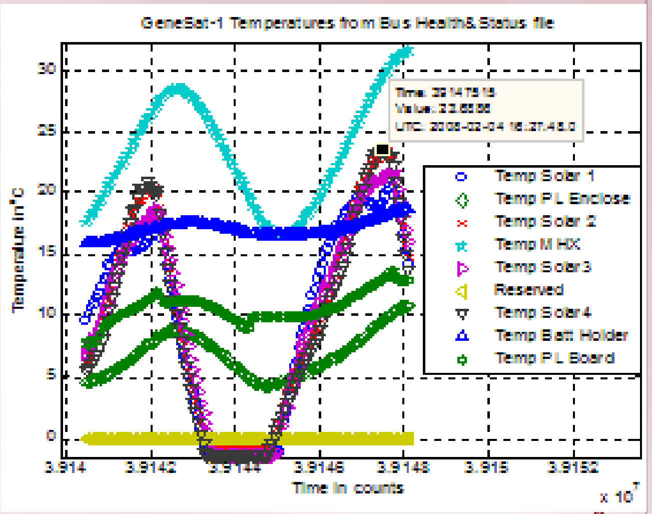
Growth doubling: pGREEN 51(11) min flight vs. 38(17) min ground

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

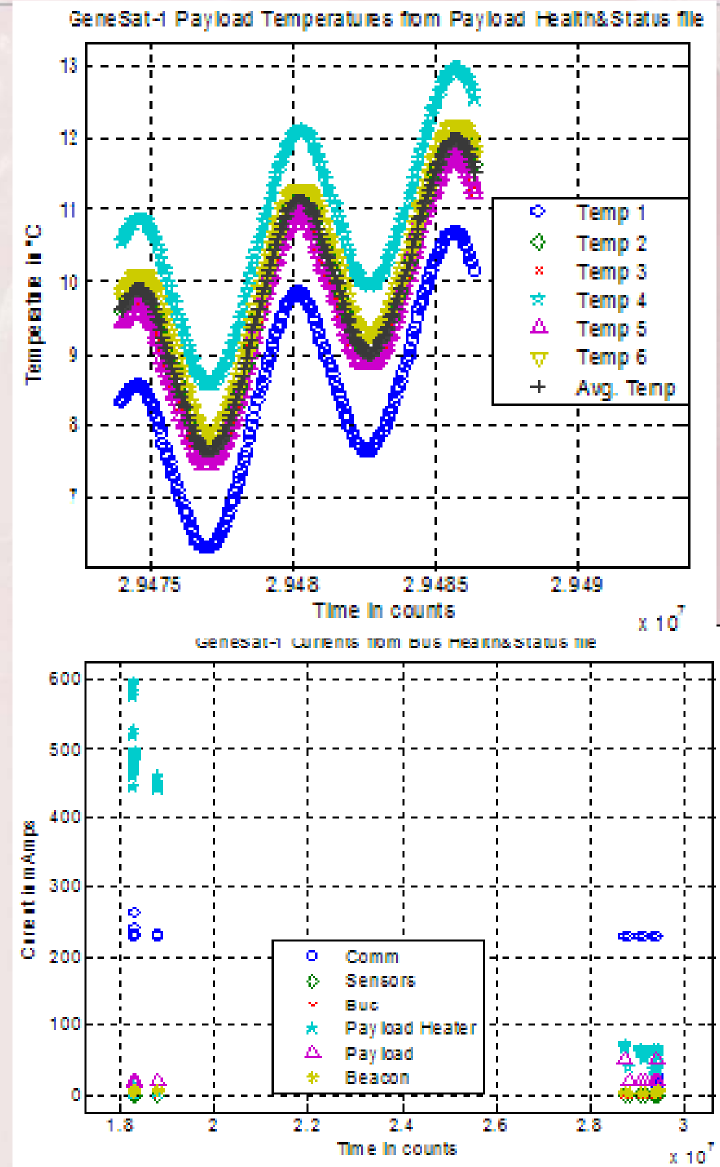




Santa Clara University

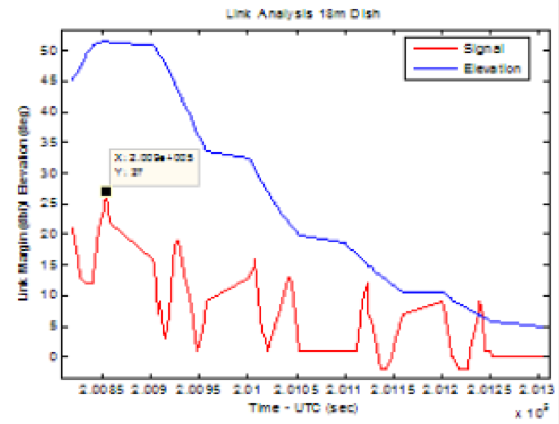
Long Term Performance - Payload

- 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



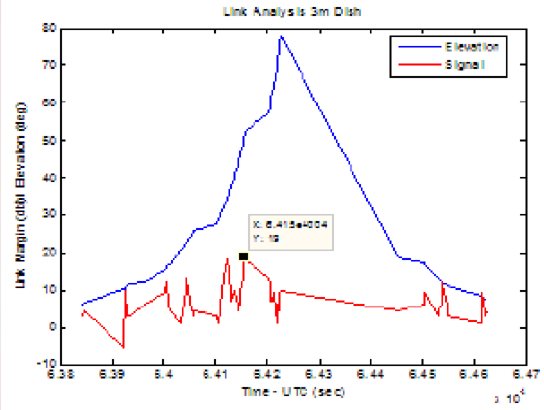
Primary Station

- 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



Santa Clara University

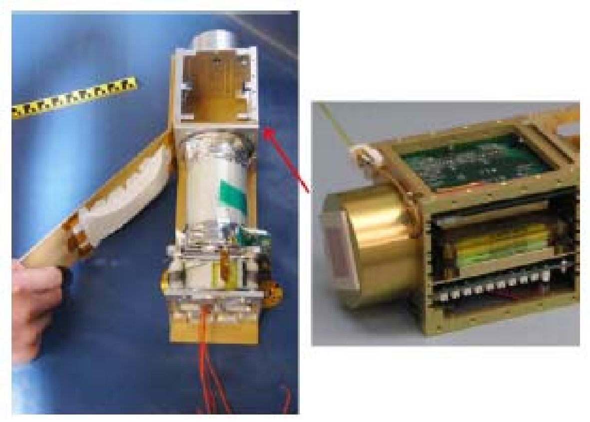
MHX 2420

- 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

PreSat/ PharmaSat



NanoSail-D

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

Acknowledgments

- NASA Ames Research Center
  - John Hines, Elwood Agasid, Charlie Friedricks, Matthew Piccini, Macarena Parra, Linda Timucin, Mike Henschke, Antonio Ricco, Ed Luzzi, Nghia Mai, Mike McIntyre, Robert Ricks, David Squires, Chris Storment, John Tucker, Bruce Yost, Greg Defouw
- Santa Clara University
  - Christopher Kitts, Karolyn Ronzano, Christopher Beasley, Mike Rasay, Ignacio Mas , Phelps Williams, Paul Mahacek, Brian, Gamp, John Shepard, Jose Acain
- SRI International
  - Michael Cousins for primary ground station support
- University of Central America
  - Ismael Sanchez and Oscar Valencia for their help in El Salvador ground station setup
- Kwajalein Ground Station
  - Steve Buckley, SpaceX, RTS, KRS

Santa Clara University

Santa Clara University

QUESTIONS?

The Jesuit university in Silicon Valley

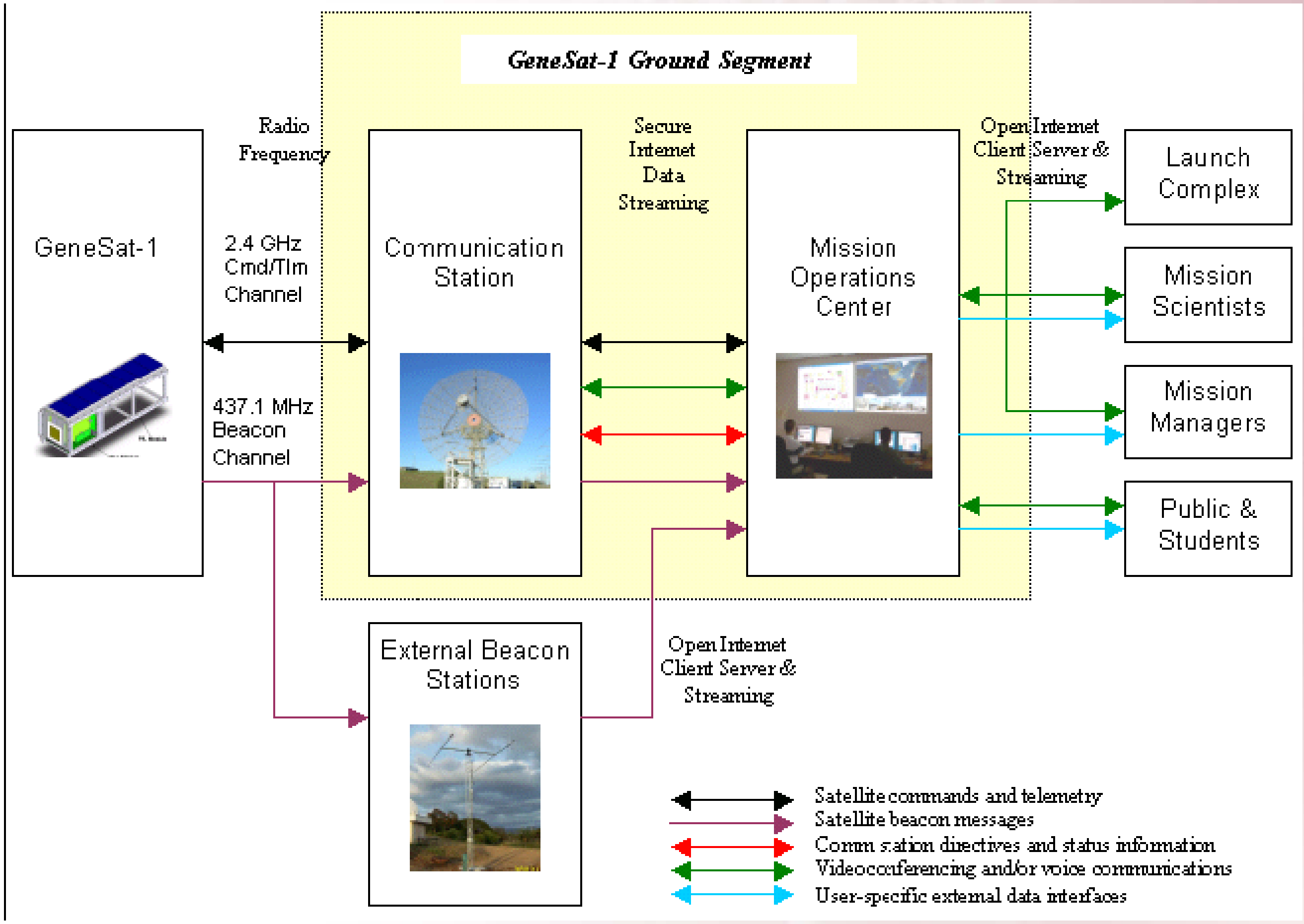
Santa Clara University

Link Budget

GeneSat-1 ISM Cmd&Tlm 2.4GHz DownLink Budget			
Item	**Sym**	**Units**	**DL**
Orbit Altitude (km)		km	450
Elevation Angle		deg	**10**
Frequency	f	GHz	2.4
Transmitter Power	P	Watts	1
Transmitter Power	P	dBW	0
Transmitter Line Loss	Ll	dBW	-1
Avg Transmit Antenna Gain	Gpt	dBi	**3.0**
Transmit Total Gain	Gt	dB	2.0
Eq. Isotropic Radiated Power	EIRP	dBW	2.00
Propagation Path Length	S	km	**1570**
Space Loss	Ls	dB	-164.0
Propagation and Polarization Loss	La	dB	-3
Receive Antenna Diameter	D	M	3
Receive Antenna Eff	Eta		0.55
Peak Receive Antenna Gain	Grp	dBi	34.96
Receive Antenna Line Loss	Lr	dB	-0.5
Receive Antenna Beamwidth*	Theta	deg	2.92
Receive Antenna Pointing Error	E	deg	0.50
RX Antenna Pointing Error Loss	L_θ	dB	-0.35
Receive Antenna Gain with pointing error	Gr	dB	34.1
System Noise Temperature **	Ts	K	585
Data Rate	**R**	bps	**86000**
Eb/No (1)	Eb/No	dB	20.7
Bit Error Rate	BER		10-5
Required Eb/No (2)	Req Eb/No	dB-Hz	13.5
Implementation Loss (3)		dB	-2
Margin		dB	**5.2**

Santa Clara University

Ground Segment



Santa Clara University

Ground Segment Architecture