

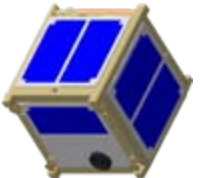


# İTÜ NXG – Scaling Up for Low-Cost Science

Can Kurtuluş, Ilke Akbulut

Asst. Prof. Gökhan İnalhan

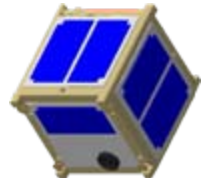
Prof. A. Rüstem Aslan





# Scaling Up

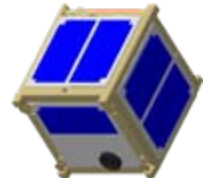
- Payload/s might require something bigger (in terms of volume, power etc.)





# What Carries On?

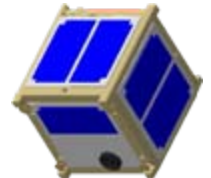
- With Little Modification
  - OBDH, Power, Comms
- With Some Modification
  - ADCS
- Experience





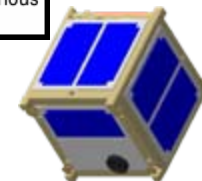
# Issues

- Launch
  - Standardized Adapters
- Time-frame might be >2 years

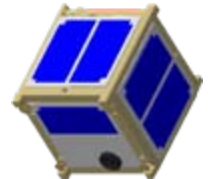
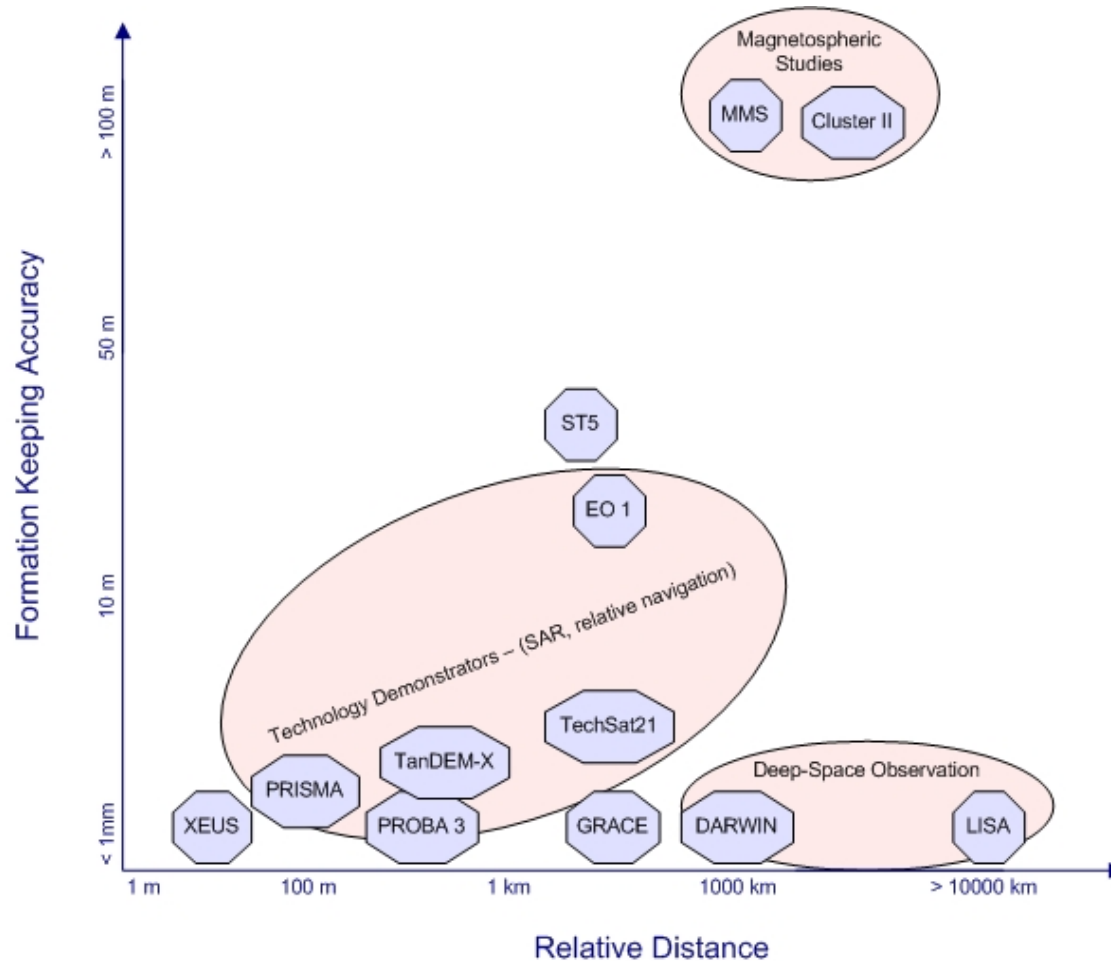


# Example Missions

Mission	Timeline	No of S/C	Mission	Orbit	Constellation / Formation	Constellation/Formation Size	Relative Positioning Accuracy
EO 1	2000	2 (1 is the target to be followed - already in orbit)	FF Testing by following a known s/c	Follows Landsat 7 - 700km	Formation	450km (60 seconds between s/c)	20m
Cluster	2000	4	Mapping the Magnetosphere	19000 - 119000 km	Constellation	200-18000 km	?
GRACE	2002	2	Mapping the Gravity Field of Earth	500km polar	Constellation	220km	0.01mm (GPS and microwave ranging)
ST5	2006	3	Mapping the Magnetosphere	300x4500km Sun-Synchronous	Constellation	40-200km	5m in Leo, 100m RMS in GEO
PRISMA	2008	2	FF & Rendezvous Demo (uses GPS for FF, VBS + GPS for rendezvous, tests RF metrology)	700 km	Formation	5km -> 0m	5m(initial)/GPS
TanDEM-X	2009	2 (Will fly in formation with TerraSAR - X)	Bi-Static and ATI SAR	514 km polar	Formation	200 - 2000m	2-4 mm
MMS	2013	4	Studying the Magnetosphere	4 phases, varies between $1.2 R_E$ - $12 R_E$ , $10R_E$ - $40 R_E$	Tetrahedron Formation	Phase 1,2 - 1000 - 2000km, Phase 3,4 - on the same orbit (string of pearls) a few $R_E$ 's	100m(using GPS and xlink ranging(probably RF)) - also uses GS doppler in phase 1
DARWIN	2015	4	Deep Space Optical/Infrared Interferometry	L2	Formation	1200m	Sub millimeter(Laser metrology)
LISA	2018	3	Gravitational Wave Detection	1 AU, 20 deg phase behind Earth	Formation	Triangle, 5 000 000km	TBD
PROBA 3	TBD	2	Validate GPS + RF metrology, test coarse & fine optical metrology	600-36000km (GTO)	Formation	200-400m	cm range (0.1mm in optical metrology test)
XEUS	TBD	2	X-Ray Spectroscopy	L2	Formation	35m	0.1mm (laser metrology)
TechSat21	Cancelled	3	SAR demo	550km	Formation	500m	10cm(DGPS)(1 cm before data collection by various techniques)

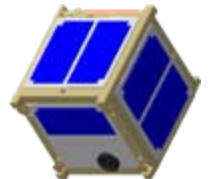


# Formation Keeping Accuracy vs. Formation Size



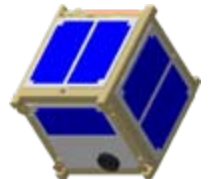
# Technology Drivers

- Relative navigation and attitude sensing
- Relative motion dynamic modeling
- Fleet level control and coordination
- Inter-s/c comm. for interoperation and time synch
- On-board intelligence and fault-tolerance



# Example Requirements for high-resolution InSAR

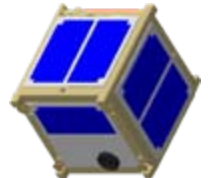
- Meter level height resolution → cm level Baseline accuracy
- $0.01^\circ$  attitude control
- $2.5 \times 10^{-12}$  s clock stability
- $10^{12}$  flops on-board for 1m resolution





# What will the mission do?

- Demonstrate and space mature technologies necessary for tightly controlled FF
- Examine flexible s/c structures

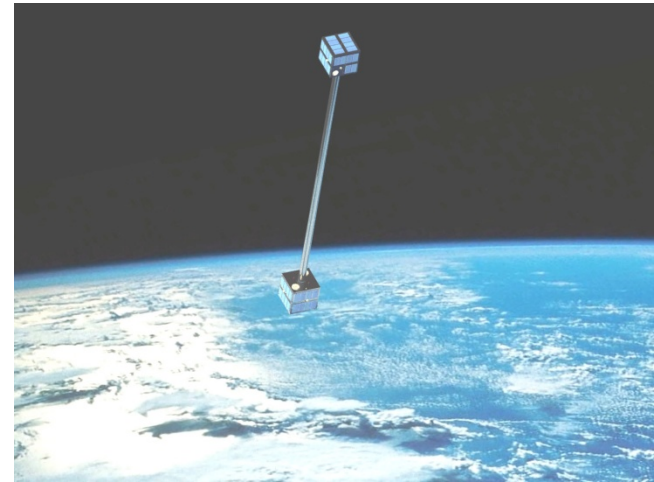


# Mission Modes

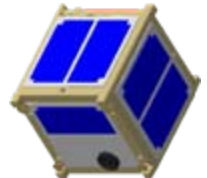
Modes	Experiments	Precision
A: Launch Configuration	Orbit Checkout & System Verification	
B: Flexible Monolithic Structure	Coordinated Attitude Control of Flexible Structures High Precision Relative Positioning & Attitude Metrology Test Cross - Navigation Verification	<0.1° control 10 μm relative distance knowledge 5 - 0.05 mm relative distance knowledge
C: Free Formation Flight	Precision Formation Planning and Control	< 10 cm relative distance control



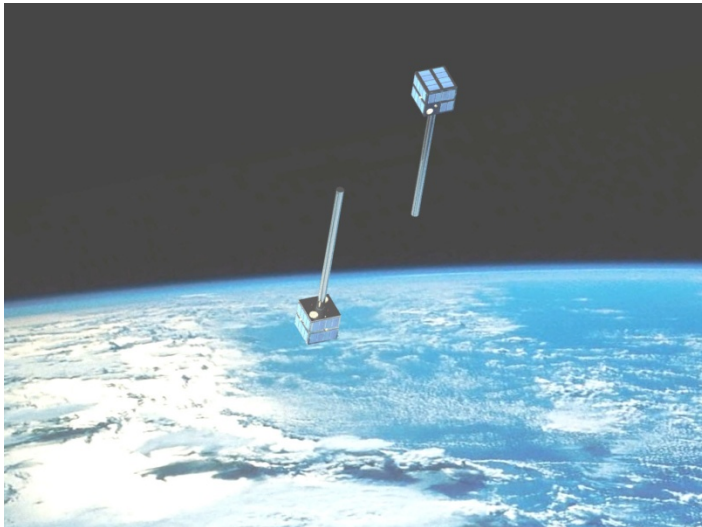
**Mode A**



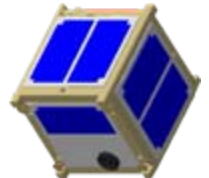
**Mode B**



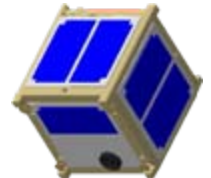
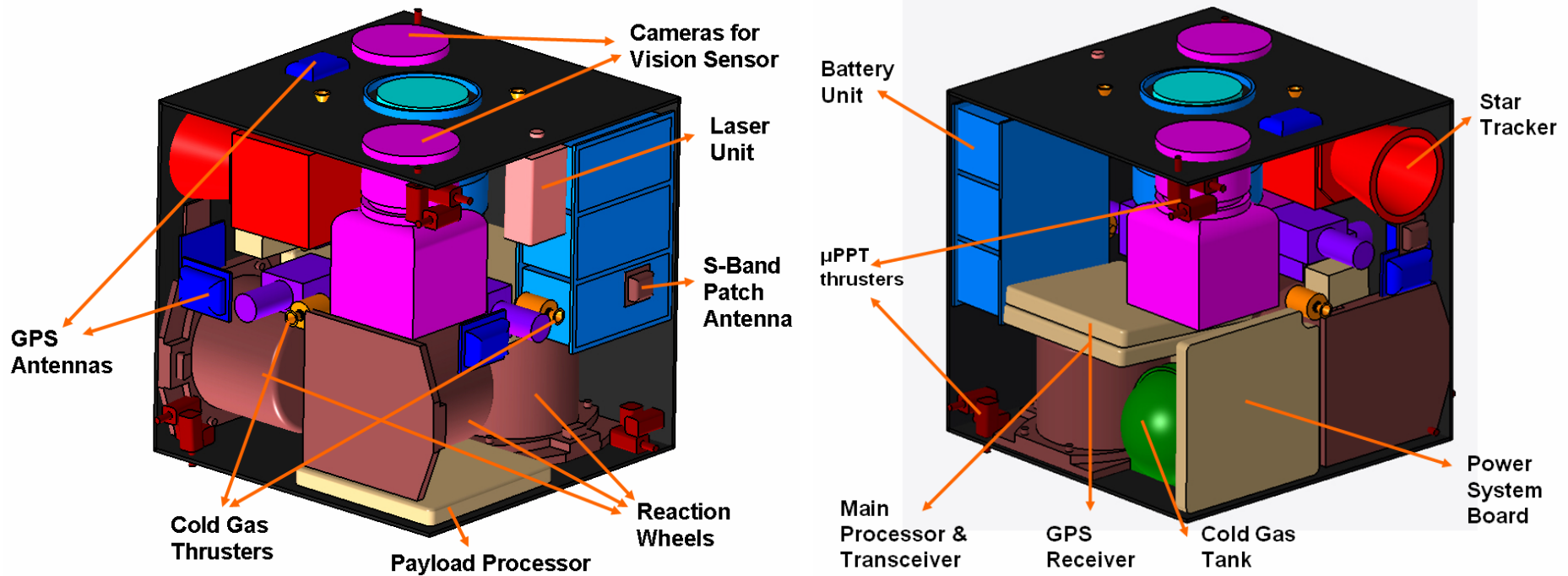
# Mission Modes - 2



**Mode C**

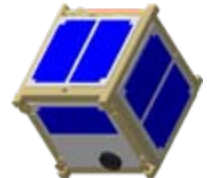


# System Overview

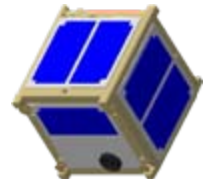
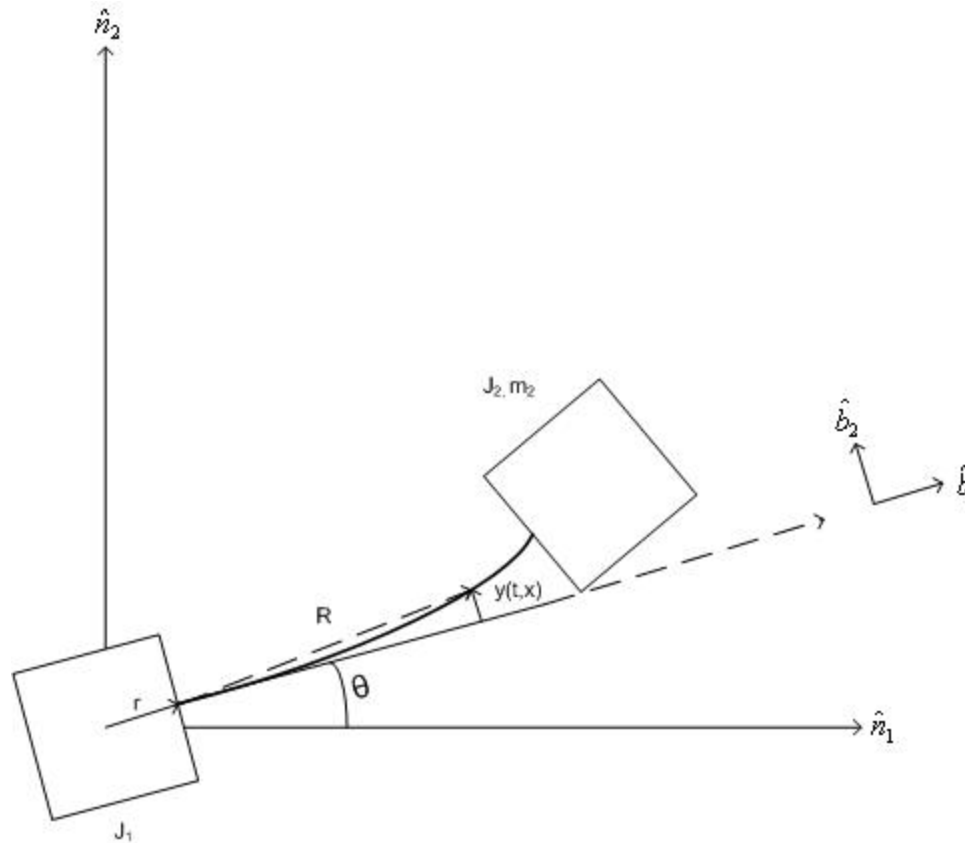


# System Overview - 2

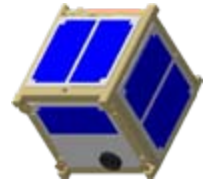
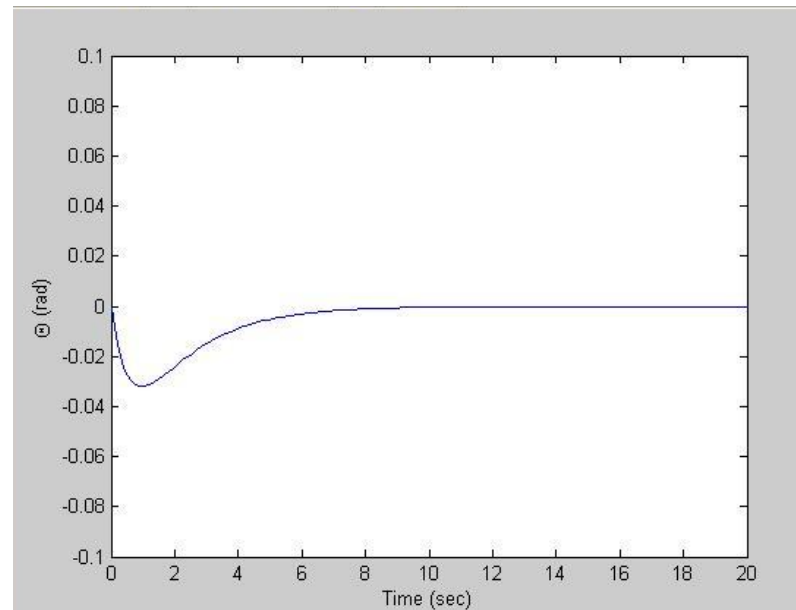
System Overview				
<b>Spacecraft</b>		<b>ADCS</b>		
Power	8.5 W on average	<u>Sensors</u>		
Mass	9.5kg	Magnetometer		
Volume	20*20*20cm <sup>3</sup>	IMU		
<b>OBDH</b>		GPS		
Storage	1Gbit	Star Tracker		
<b>Comm</b>		<u>Actuators</u>		
Cross-Link	Wireless Ethernet	3 reaction wheels		
<b>Power</b>		<u>Thrusters</u>		
GaAs Cells	0.1 m <sup>2</sup>		$\Delta V$	Thrust Levels
Li-Ion battery	10Ah	12 $\mu$ PPT	60 m/s	20 $\mu$ N
		7 cold gas thrusters	30 m/s	50mN



# Model

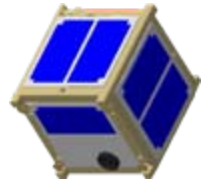


# Initial Analyses – Disturbance Rejection via LQR



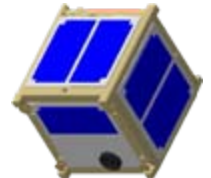


# İTÜ pSAT I Brief Update

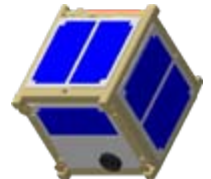
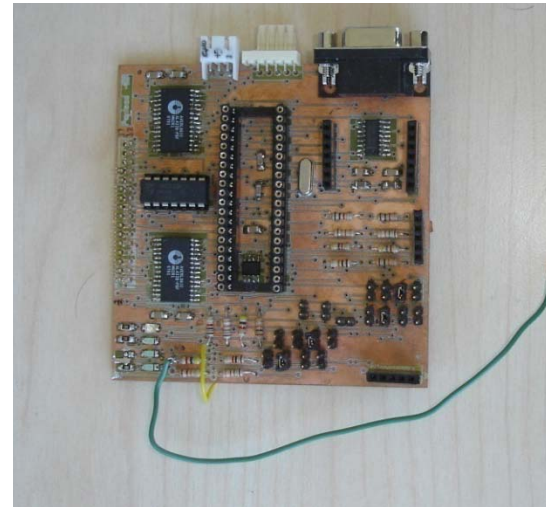
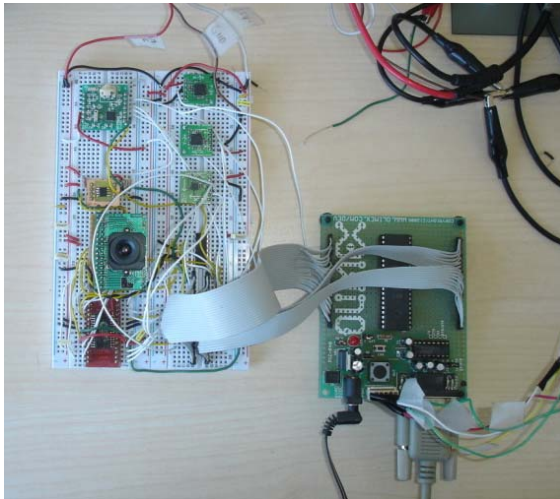




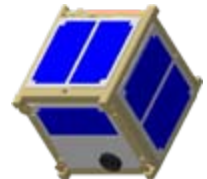
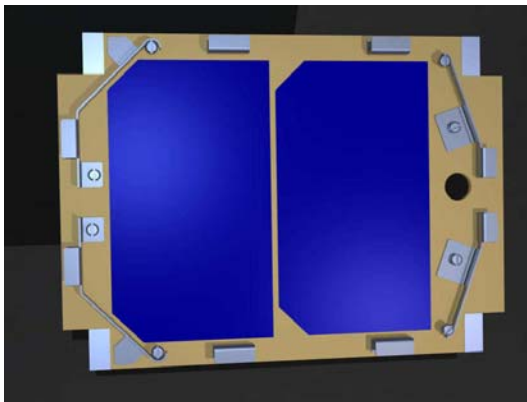
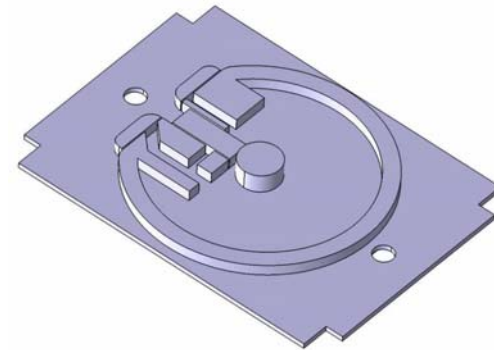
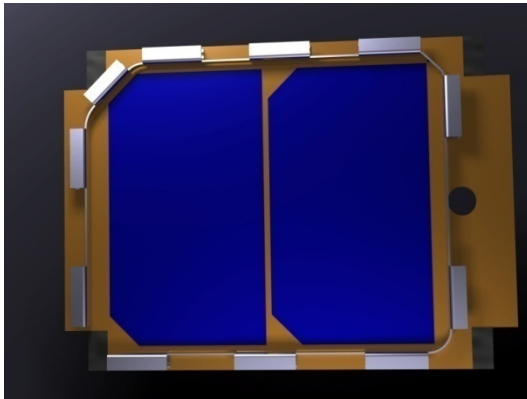
# Example Pictures



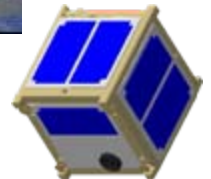
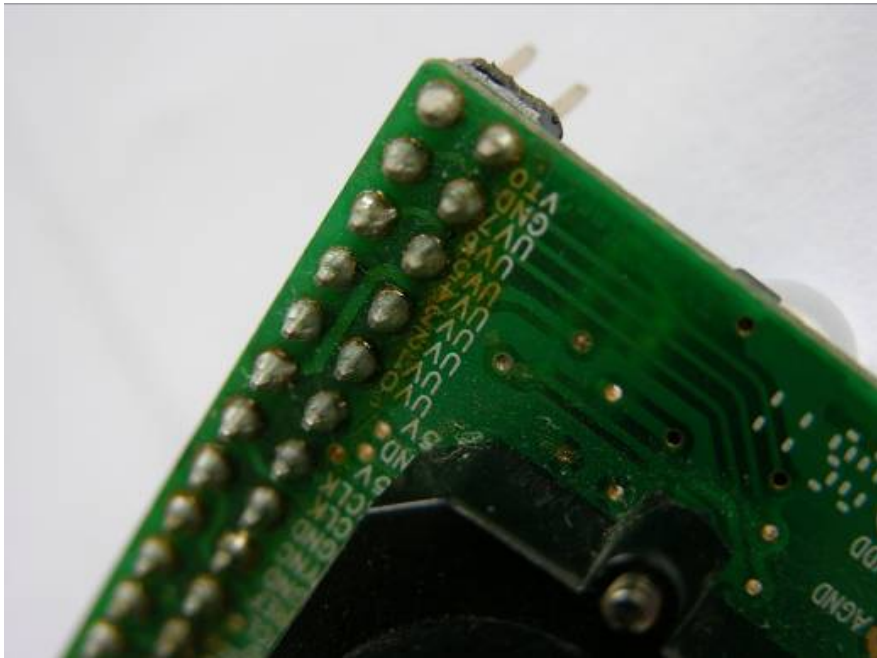
# Payload Prototypes



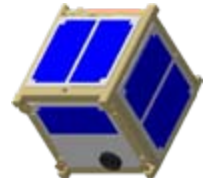
# Antenna Opening



# After Thermal & TV Tests



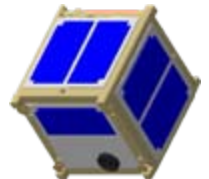
# Ground Station





# Remaining Work

- Shake & TV tests of complete satellite
- Finish operational software
- RF Tests
- Ground station test during a real launch!



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