Attitude Determination and Control for PACE

-Platform for Attitude Control Experiment

Jung-Kuo Tu[1] Brian Shi-Hua Wu[2]

Jason Chen-Chi Chu[1] Ken Tsung-Hsin Tsou[1]

Department of Aeronautics and Astronautics [1]

Department of Electrical Engineering [2]

National Cheng Kung University, Taiwan, ROC

Mission

The mission of the PACE project is to offer students opportunities to experience the whole development process of satellite design, analysis, assembly, integration, test, launch and operation.

- **Primary experiment**

  Perform three-axis stabilization of a pico-class satellite.

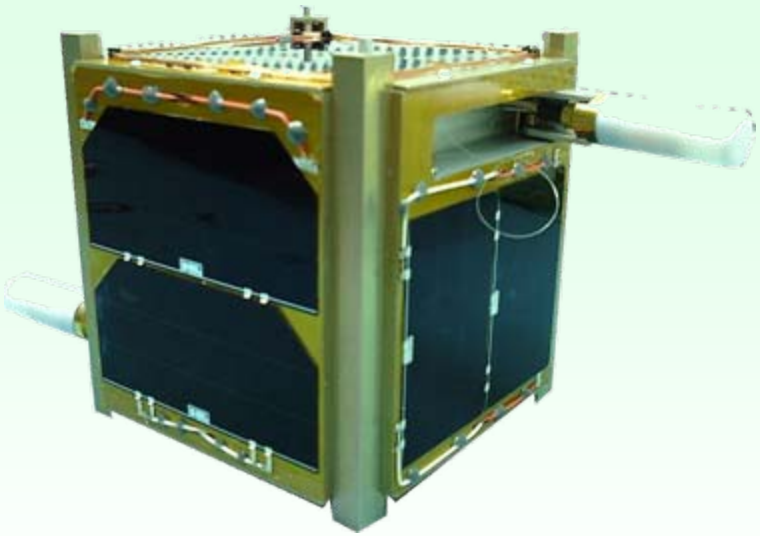
- **Secondary experiment**

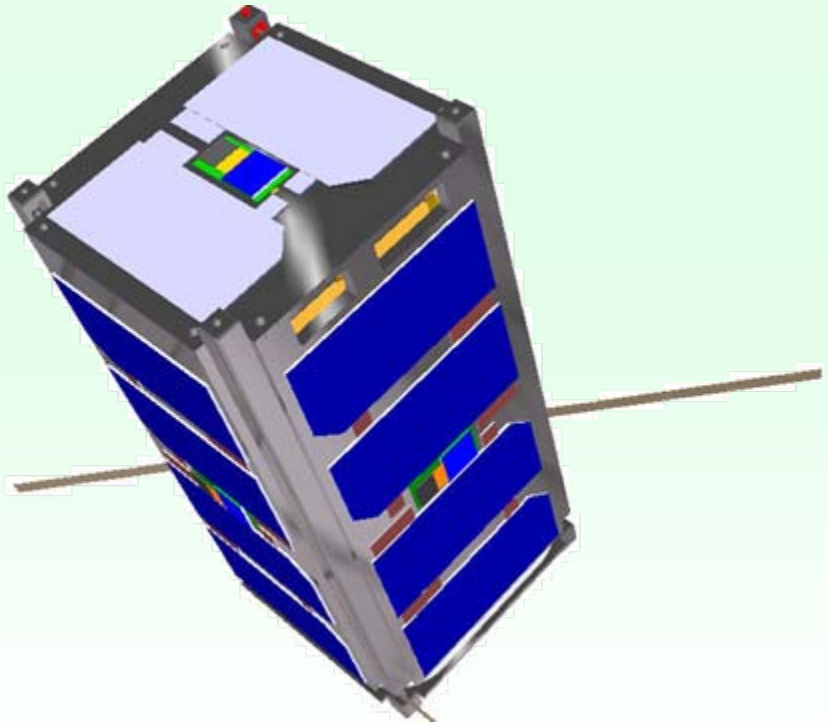
  Verify self-made MEMS sensors for space applications.

CubeSat Research in Taiwan

NSPO : YAMSAT (2001-2002)

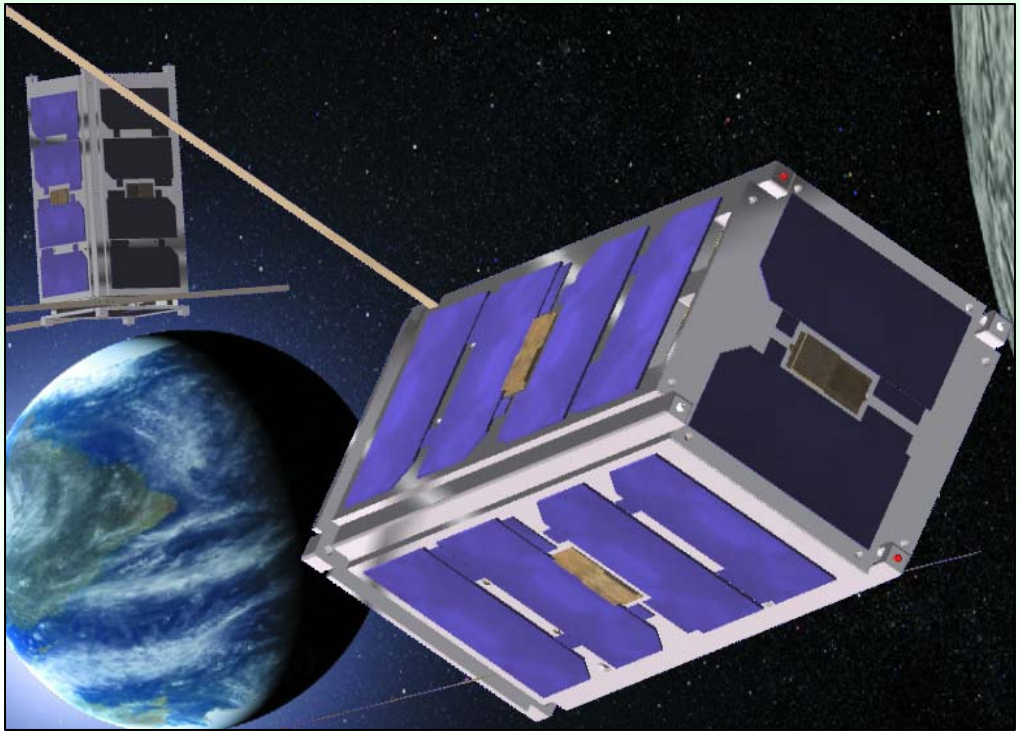
NCKU : PACE (2003-)



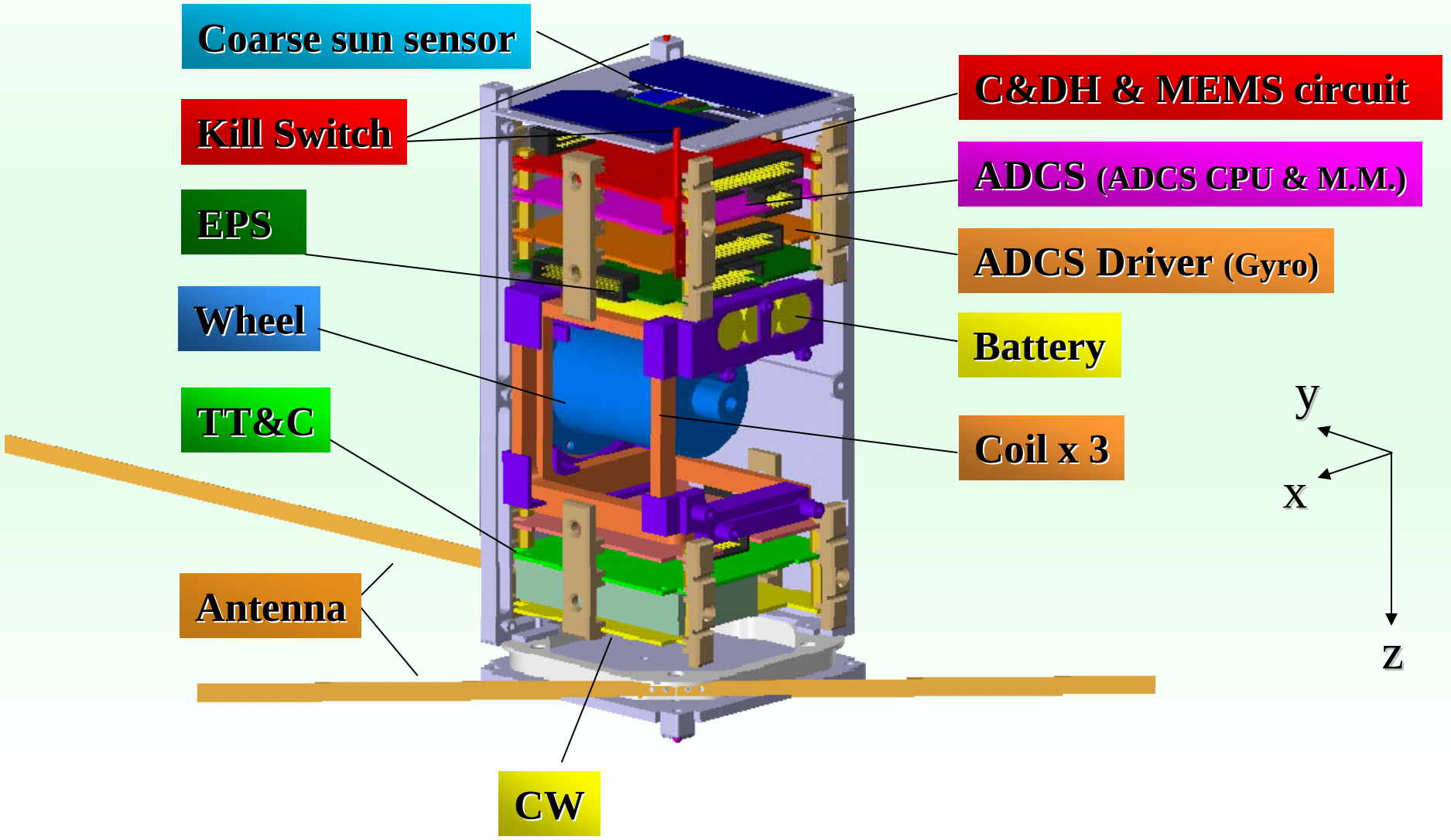


PACE Overview

- A double cube design
- Three-axis stabilization requirement
  --Pointing accuracy 5º
- Two CPU design
  -- 8051-based: C&DH and ADCS
- MEMS sensor demonstration
  -- Coarse sun sensor
  -- Temperature sensor



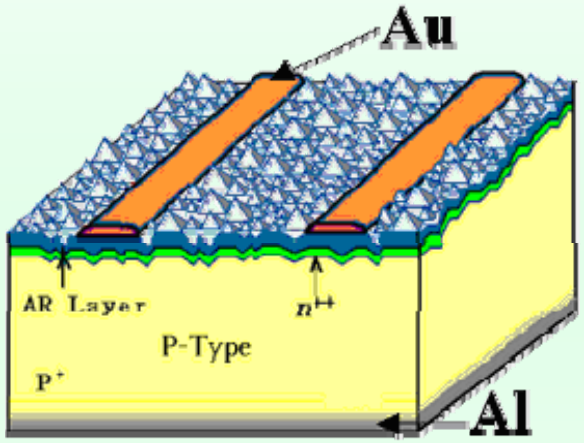
PACE Configuration

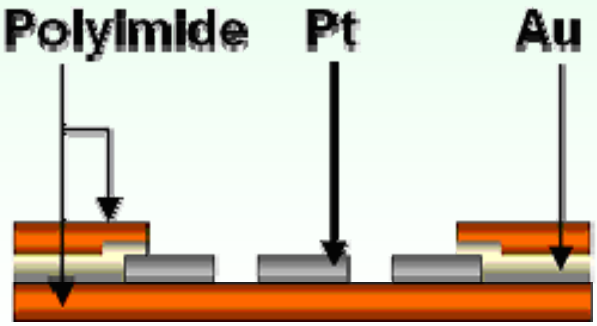


MEMS Payload

To test and verify self-made MEMS sensors in space environment.

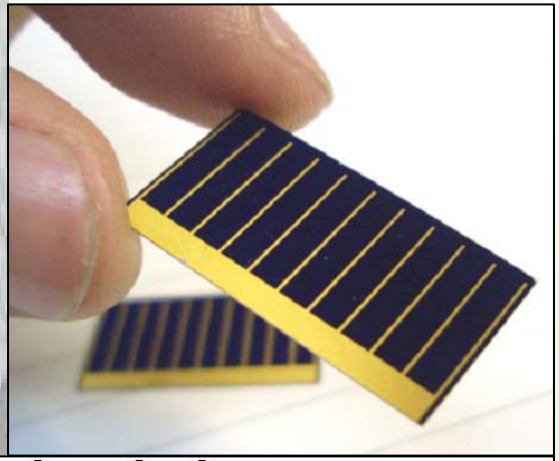
- **MEMS coarse sun sensors**
  - **Assist attitude determination**
- **Flexible skin temperature sensors**
  - **Validation of passive thermal control**
  - **Monitoring of PACE SOH**





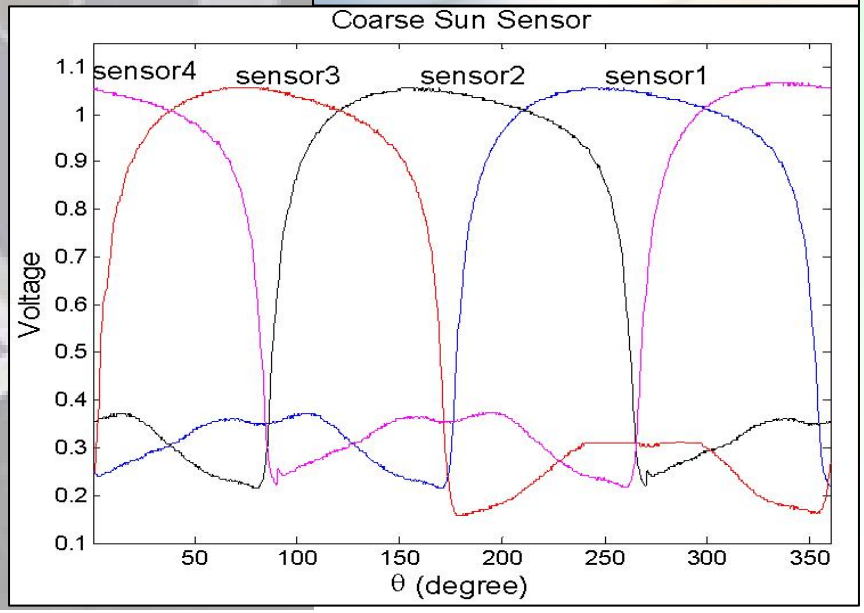
MEMS Coarse Sun Sensor

The present sensor was developed from single–crystalline silicon solar cells.



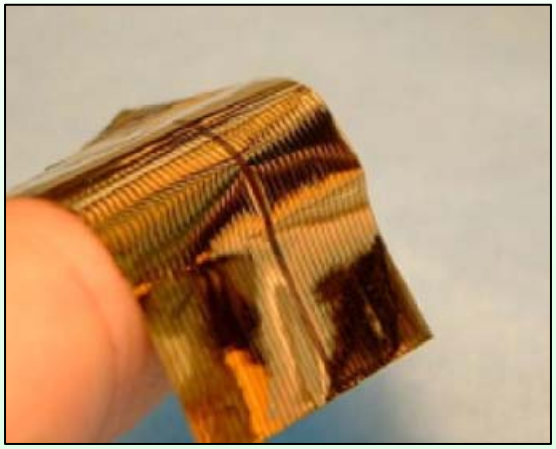
Finished products.

•The sensors are place on the out surfaces of four outside-walls and top-wall. Attitude information can be deduced from the signal of the sensor.



Angle performance.

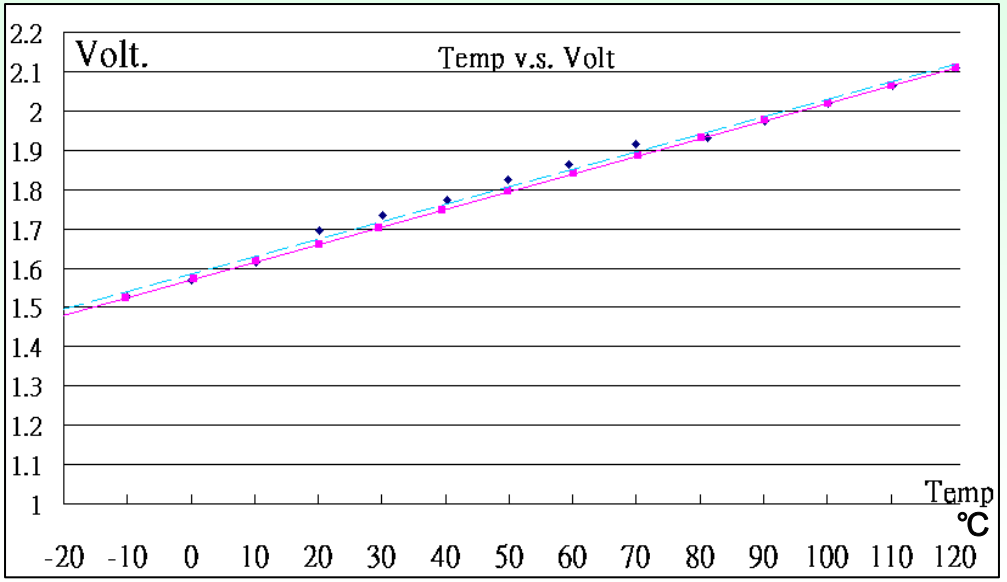
MEMS Temperature Sensor



Platinum resistors as sensing materials are sandwiched between two polyimide layers.

Flex. skin sensor finished products.

MEMS platinum resistor temperature sensor has **linear output** and a **sensitivity of 4.5 mV/°C**



The performance of temperature sensor.

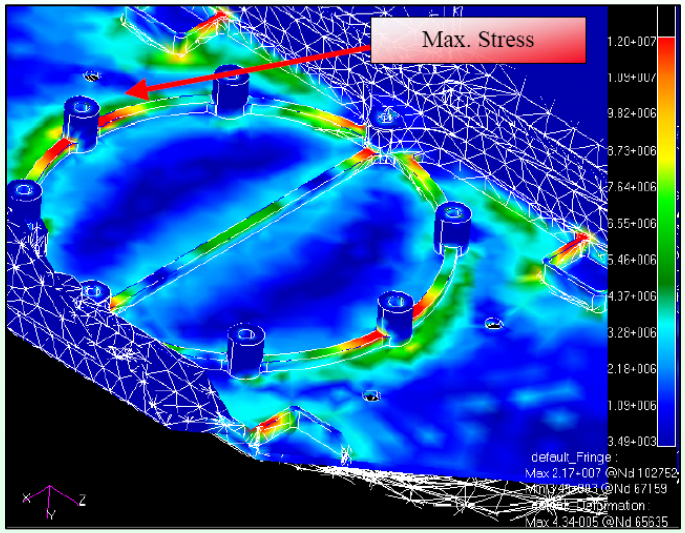
Structure and Thermal Analysis

➢ Stress & Dynamic Analysis

Lateral mode : 652 Hz >> 25Hz

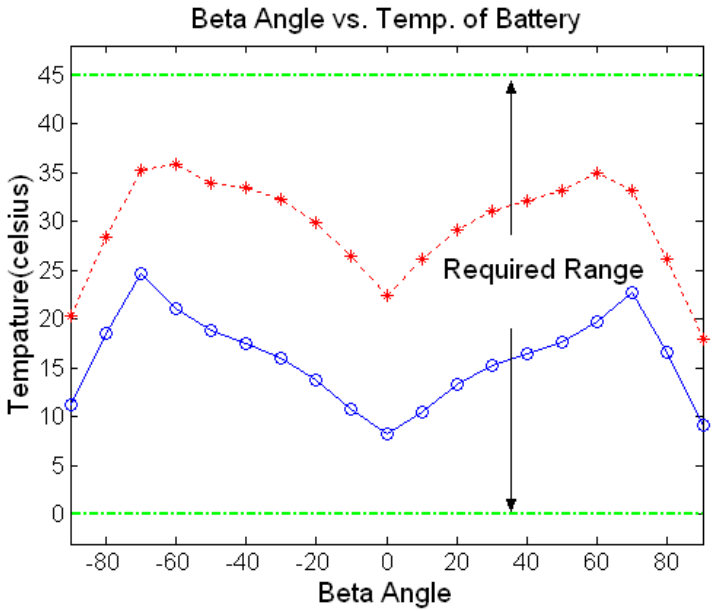
Longitudinal mode : 1079Hz >> 40Hz

Yielding stress : 440MPa >> 30~40MPa



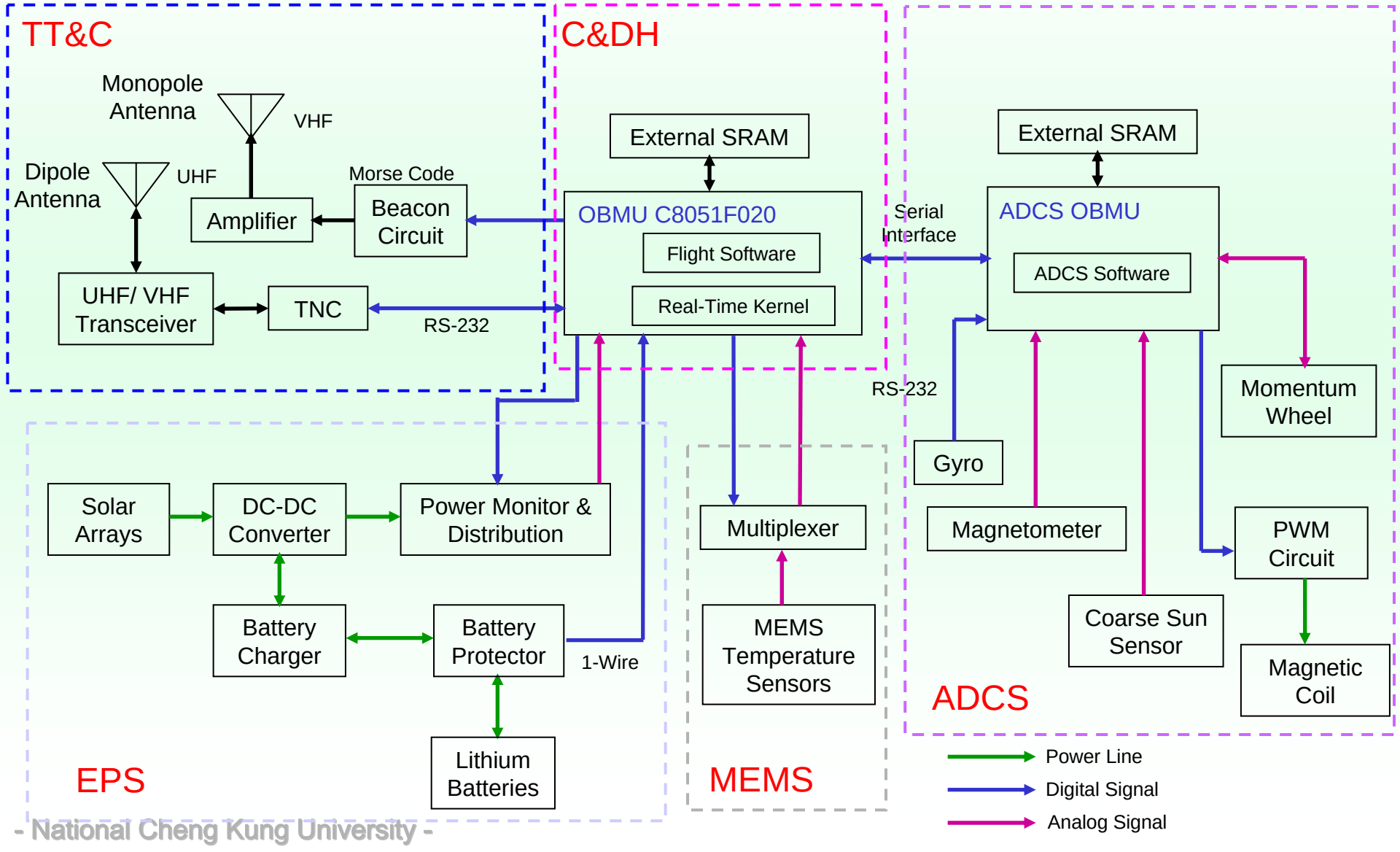
➢ Thermal Analysis

Worst hot and cold analysis with ADCS 3-axis stabilization requirement

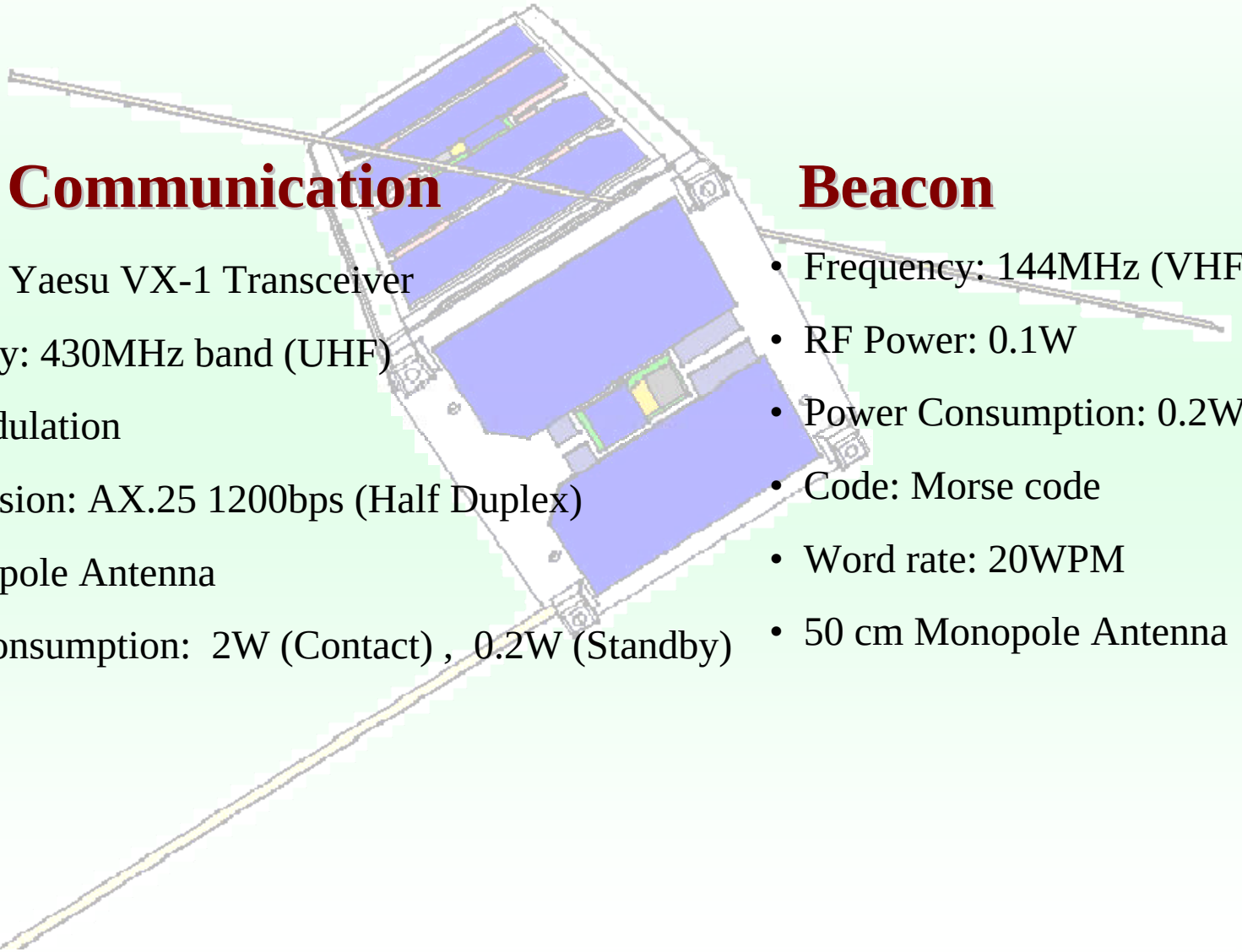


The results are acceptable.

Electrical Block Diagram



Telemetry Tracking & Command



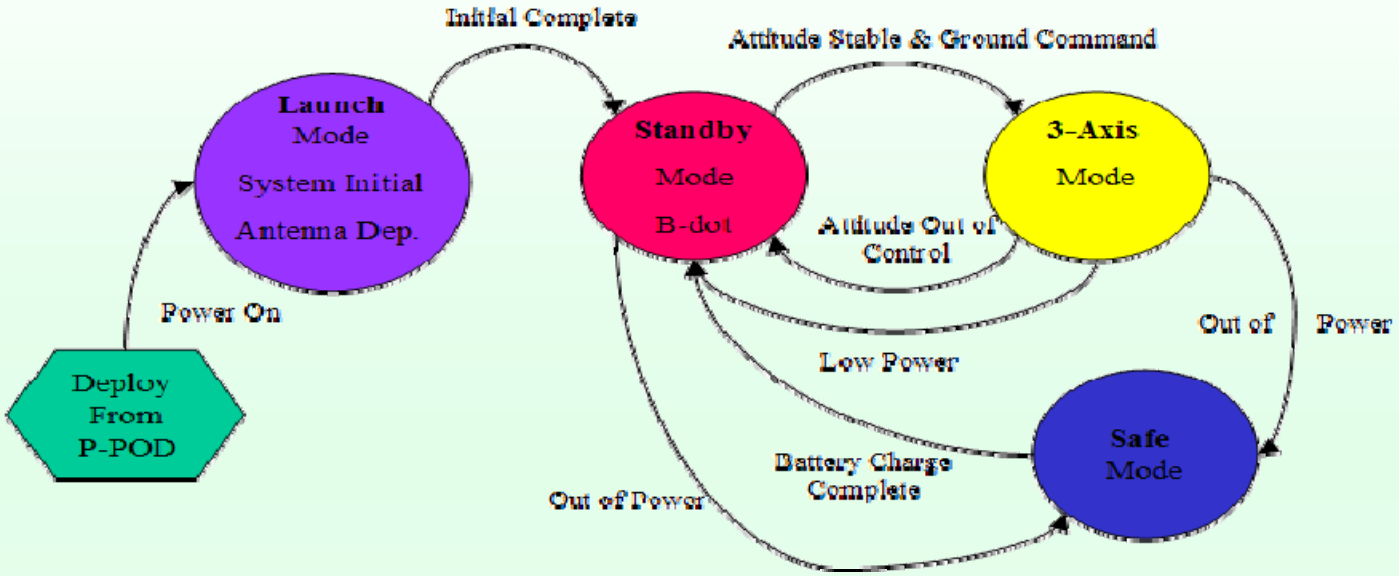
UHF Communication

- Modified Yaesu VX-1 Transceiver
- Frequency: 430MHz band (UHF)
- FSK Modulation
- Transmission: AX.25 1200bps (Half Duplex)
- 17 cm Dipole Antenna
- Power Consumption: 2W (Contact) , 0.2W (Standby)

Beacon

- Frequency: 144MHz (VHF)
- RF Power: 0.1W
- Power Consumption: 0.2W
- Code: Morse code
- Word rate: 20WPM
- 50 cm Monopole Antenna

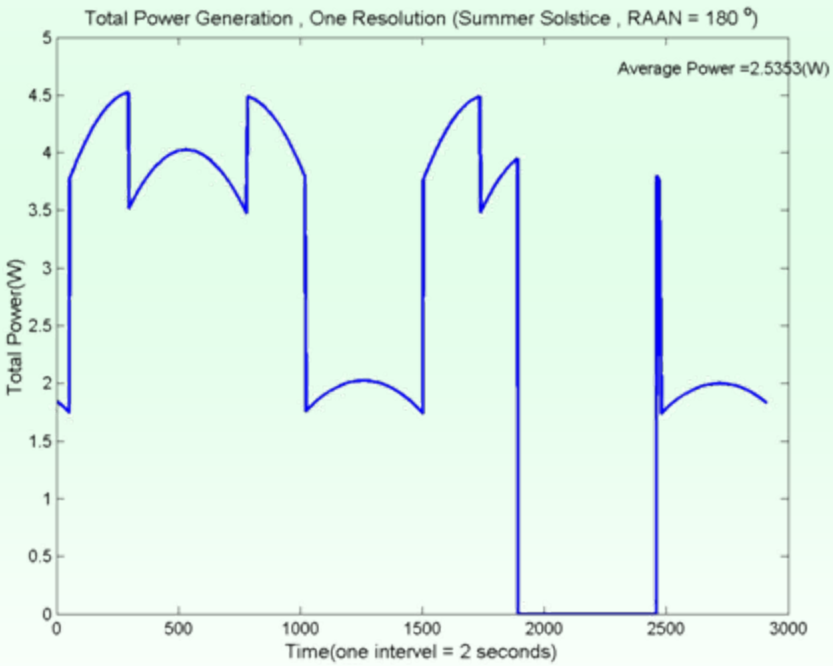
Operation Mode Transition



Subsystem / Mode	C&DH	ADCS CPU	Magnetic Coil			Magneto meter	Gyro	Coarse Sun Sensor	Momentum Wheel	DRU	CW	TT&C RX/TX	Ant. Deploy	Remark
			X	Y	Z									
Launch	ON	-	-	-	-	-	-	-	-	-	-	-	After t sec ON	Release from P-POD
Safe	ON	-	-	-	-	-	-	-	-	-	ON	-	-	Low power Charging Mode
Standby B-dot	ON	ON	-	ON	ON	ON	-	ON	-	ON	ON	ON/ -	-	On Orbit No Contact
	ON	ON	-	ON	ON	ON	-	ON	-	ON	ON	ON/ON	-	Contact to G/S
3 Axis Stability	ON	ON	ON	ON	ON	ON	ON	ON	ON	ON	ON	ON/ -	-	On Orbit
	ON	ON	ON	ON	ON	ON	ON	ON	ON	ON	ON	ON/ON	-	Contact to G/S

Power Budget and Power Analysis

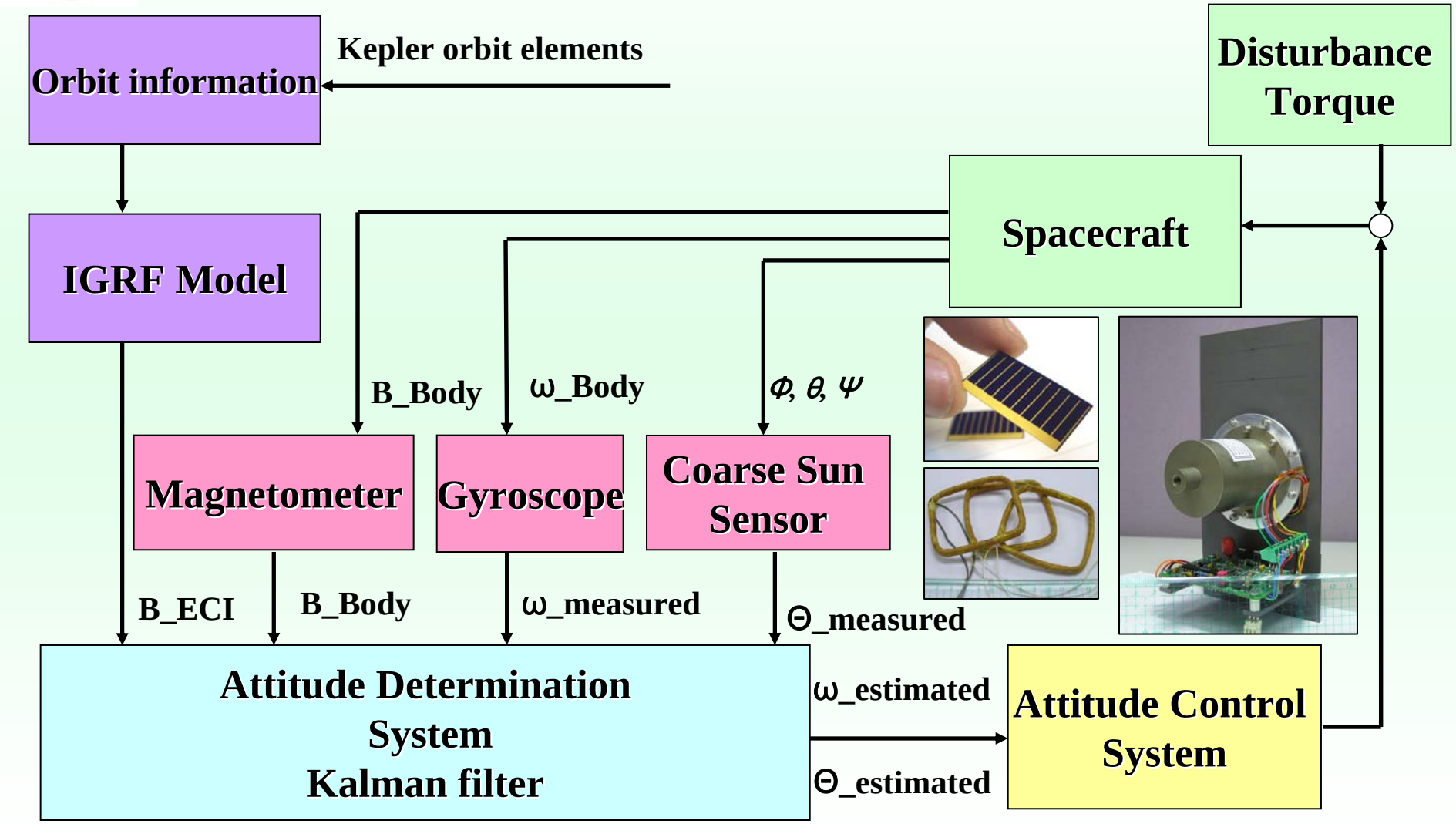
Component	Power (W)	DT cycle	Ave. PW Contact	Ave. PW(W) No Contact	Duty cycle	Ave. PW Contact	Ave. PW No Contact	DT cycle	Ave. PW(W) No Contact
Payload									
MEMS sensor	**0.100**	100%	0.100	0.100	100%	0.1	0.1	0%	0.000
TT&C									
UHF FM Contact	**2.000**	7%	0.140	0.000	7%	0.140	0.000	0%	0.000
UHF FM Standby	**0.200**	93%	0.186	**0.200**	**93%**	0.186	**0.200**	0%	0.000
VHF CW Tx	**0.400**	30%	0.120	0.120	30%	0.120	0.120	30%	0.120
VHF CW Standby	**0.100**	70%	0.070	0.070	70%	0.070	0.070	70%	0.070
ADCS									
Momentum wheel	**0.630**	**30%**	0.189	0.189	0%	0.000	0.000	0%	0.000
Magnetic coils	**0.333**	**60%**	0.200	0.200	**60%**	0.200	0.200	0%	0.000
Magnetometer	**0.175**	**30%**	0.053	0.053	**30%**	0.053	0.053	0%	0.000
Gyro	**0.600**	**40%**	0.240	0.240	0%	0.000	0.000	0%	0.000
Slave CPU	**0.072**	100%	0.072	0.072	100%	0.072	0.072	0%	0.000
Coarse Sun Sensor	**0.100**	100%	0.100	0.100	100%	0.100	0.100	0%	0.000
OBMU									
CPU	**0.072**	100%	0.072	0.072	100%	0.072	0.072	100%	0.072
SRAM	**0.230**	100%	0.230	0.230	100%	0.230	0.230	100%	0.230
EPS									
Conversion Loss(+12V)	**0.160**	100%	0.160	0.160	0%	0.000	0.000	0%	0.000
Conversion Loss(+5V)	**0.326**	100%	0.326	0.326	100%	0.326	0.326	100%	0.326
Conversion Loss(-5V)	**0.038**	100%	0.038	0.038	100%	0.038	0.038	100%	0.038
Distribuitoin Loss	**0.180**	100%	0.180	0.180	100%	0.180	0.180	100%	0.180
Total	5.416458		2.475625	2.349625		1.886625	1.760625		1.036125
	Normal Mode				**Initinal Mode B-dot**			**Safe Mode**	



Maximum Power Consumption: 2.475W

Average Power Generation: 2.535W

ADCS Block Diagram



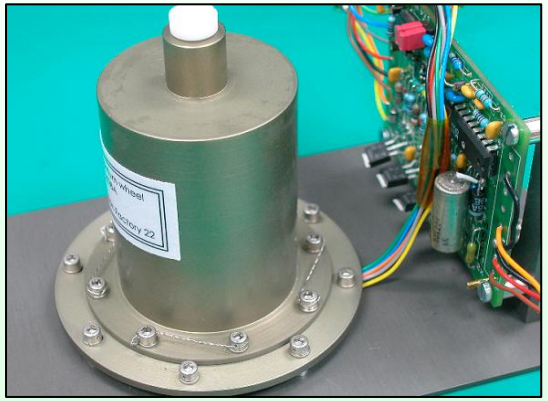
Momentum Wheel

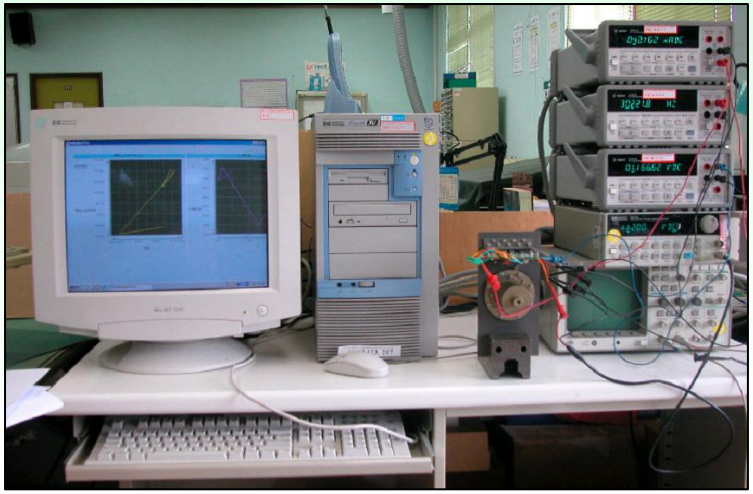
Specification

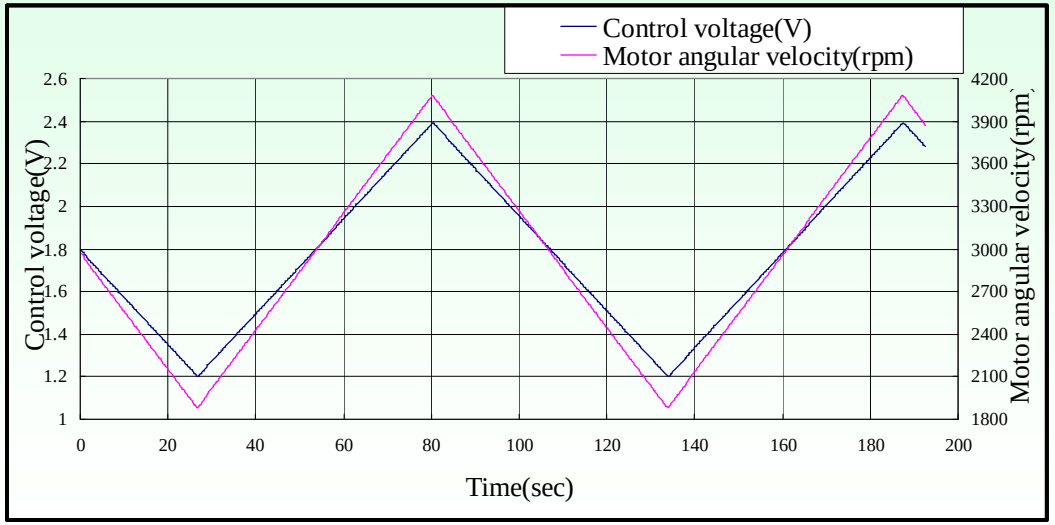
Max. Wheel Momentum ：0.01 Nms
Max. Wheel Torque：0.00001 NmMax.
Wheel Speed：4000 rpm

Mechanical/Power

Mass：300 grams (added a control box)
Size：46 dia. 82 height mm
Housing：Aluminum (AL 7075)
Power Supply：12-24 VDC
Power consumption : 0.6 W







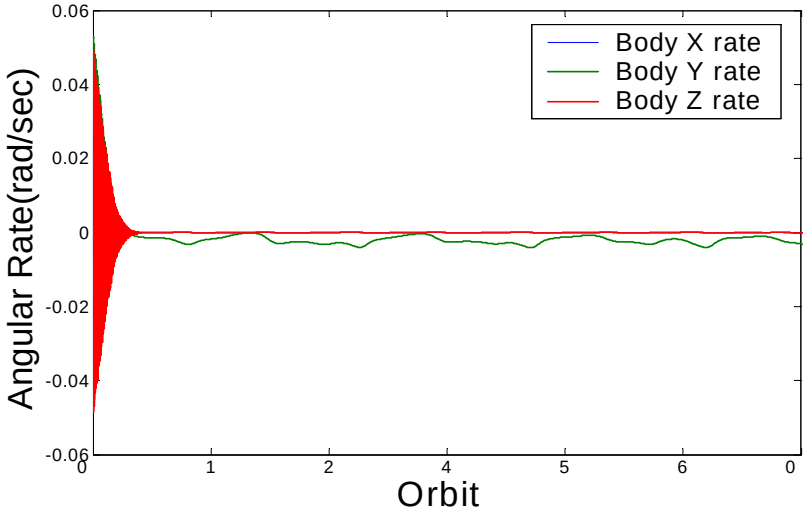
Control Mode and Simulation

Standby Mode

Sensor：Magnetometer

Actuator：Magnetic Coils

Control Law：B-dot Control

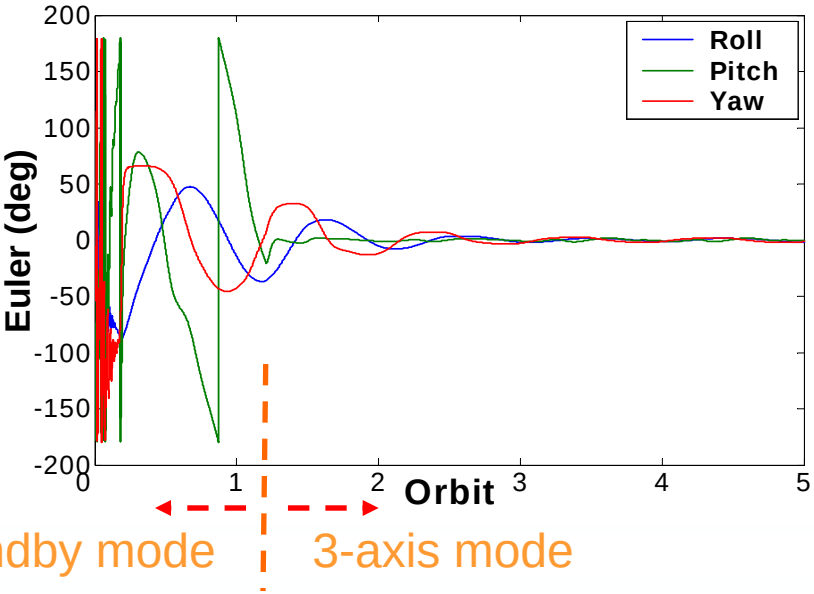


Three-axis Mode

Sensor： Magnetometer, Gyro, Coarse Sun Sensor

Actuator：Magnetic Coils, Momentum Wheel

Control Law： B-dot Control, Momentum Wheel Control, Momentum Dump Control, Pointing Control



Procession in The Loop

- S/C Dynamic Model
- Geomagnetic data
- Orbit data
- Disturbance
- Hardware Model

Host PC

RS-232

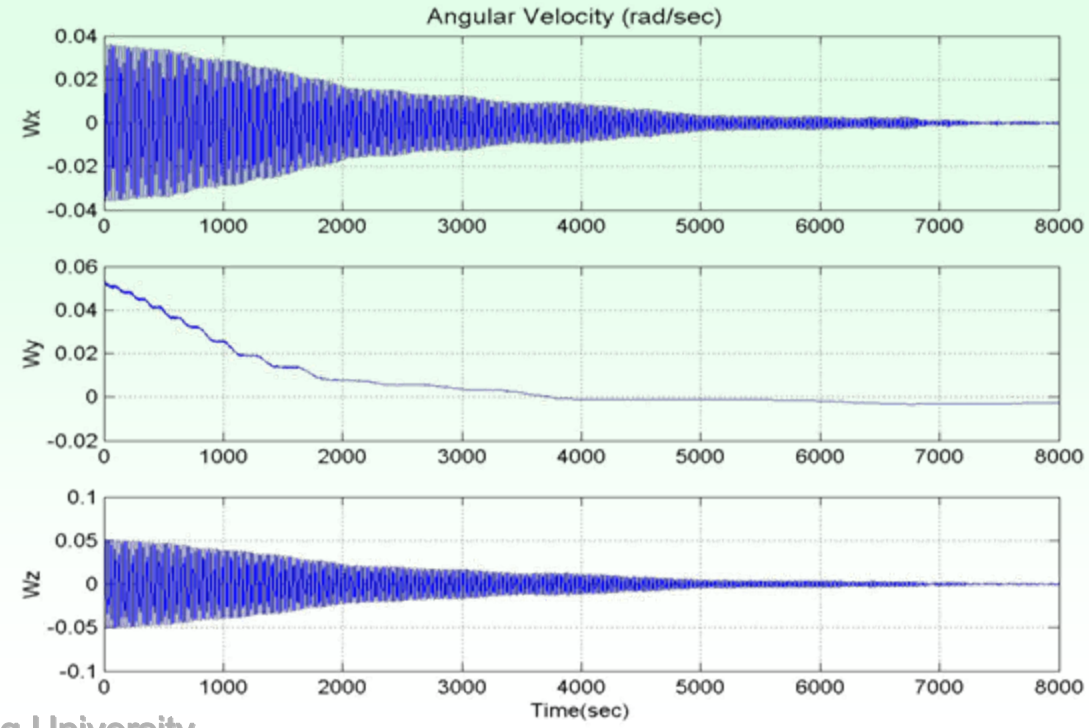
(D/A) / (A/D)

Target PC

MAG Voltage

Coil output

ADCS CPU → PWM circuit



Conclusion

- PACE is a three-axis stabilized pico-satellite.
- The design of three-axis stabilization has been conducted through component development and a hardware in the loop simulation.
- MEMS coarse sun sensors and temperature sensors are designed and fabricated, ready for test and integration.
- Detail analyses on each subsystem of the PACE have been conducted.

Thanks for your attention !