A Control Moment Gyro for Dynamic Attitude Control of Small Satellites

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Outline

1. Control Moment Gyros vs Reaction Wheels
2. Control Electronics and Interfaces
3. Qualification Testing
4. Conclusion

CONTROL MOMENT GYROS VS REACTION WHEELS

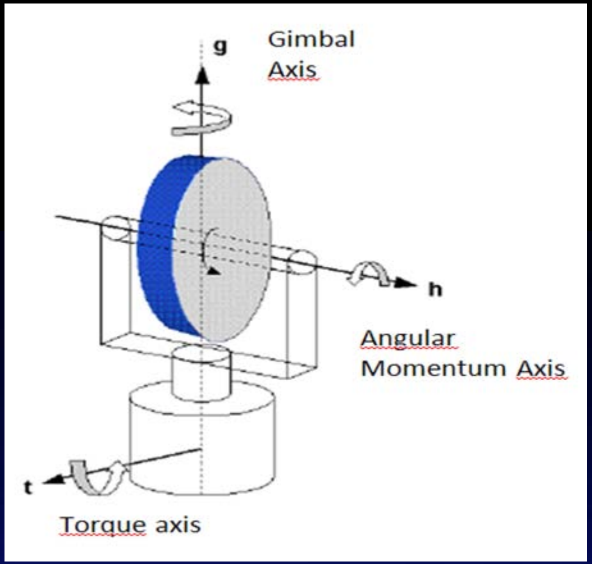
Enabling increased small satellite performance

- Until recently, CMGs have only been used on large spacecraft.
  - Mechanical complexities more justifiably overcome for performance gains.
- Advances in CAD packages are making it possible to develop more complex actuators.
- CMGs offer a higher torque and low power consumption per unit kg.
  - This is attractive for high performance small satellite missions.

ISS CMG

Control Moment Gyros

- CMGs deliver torque into the spacecraft by changing the orientation of a spinning disk, changing the vector of the angular momentum
- This vector change represents a significant torque on spacecraft.
- Unlike reaction wheels, this is performed with relatively little power.
- As with reaction wheels, the CMGs are configured as 4 units for torque in all axes.
- Steering logic [developed in REF 1 (in paper)] solves singularity problem.



Example Performance Comparison

Parameter	CMG Microsat	Standard Microsat
Satellite mass (kg)	50	50
Actuator number and type	4 CMGs	4 RWs
Cluster mass (kg)	~1	4
Power consumption per actuator (Watt)	0.75-4	0.8-3.5
Max. Angular Momentum (Nms)	1.1	0.36
Maximum Torque Production (mNm)	52.5	20
Slew Rate Average Speed (°/s)	3	1.85

Small Satellite CMG Sizing

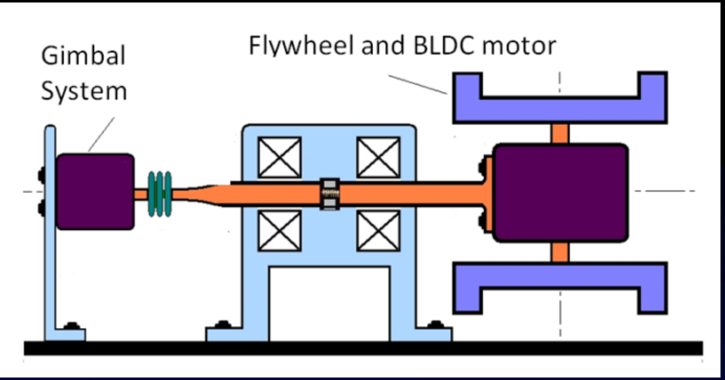
- A single axis CMG unit was selected .
- The system has limited gimbal angle to eliminate the need for slip rings.
- A spin rate of 10,000RPM provides an angular momentum of 5Nms.
- Depending on rate of change of the disk position, torques produced can be upwards of 100mNm.

Summary of advantages of CMGs

- Agility:
  - Torque amplification property of CMGs makes them ideal for missions with stereoscopic imaging, target tracking, tactical imaging of the target area, formation flying objectives.
  - (Slew rates higher than 3 °/s could be achieved. With RWs 0.1-1º/s can be achieved.)
- With their higher momentum capacities (constant spinning speeds), satellites become more stable platforms.
- Power, mass, volume advantageous compared to alternative actuators

Mechanical Configuration

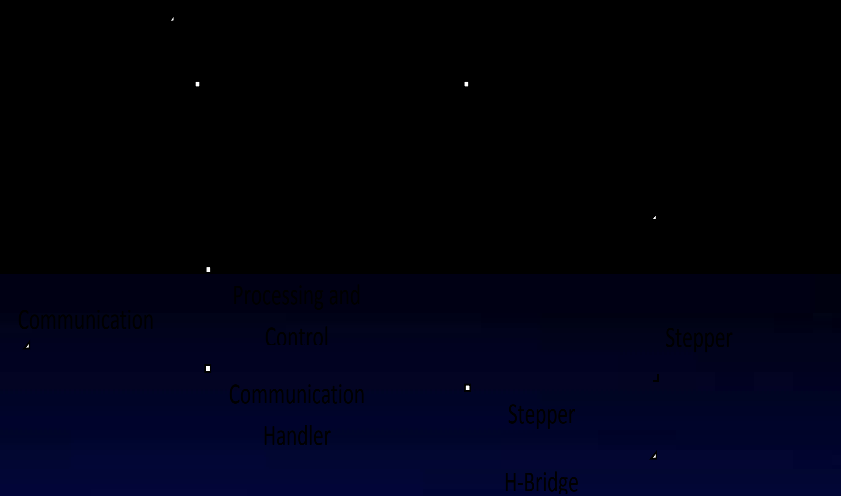
- Brushless DC-Motor is used for the flywheel.
- Stepper Motor with gearing for the gimbal control system.
- Flywheel is rotated around a single axis.
- [Detailed mechanical configuration not available due to sensitive commercial nature.]



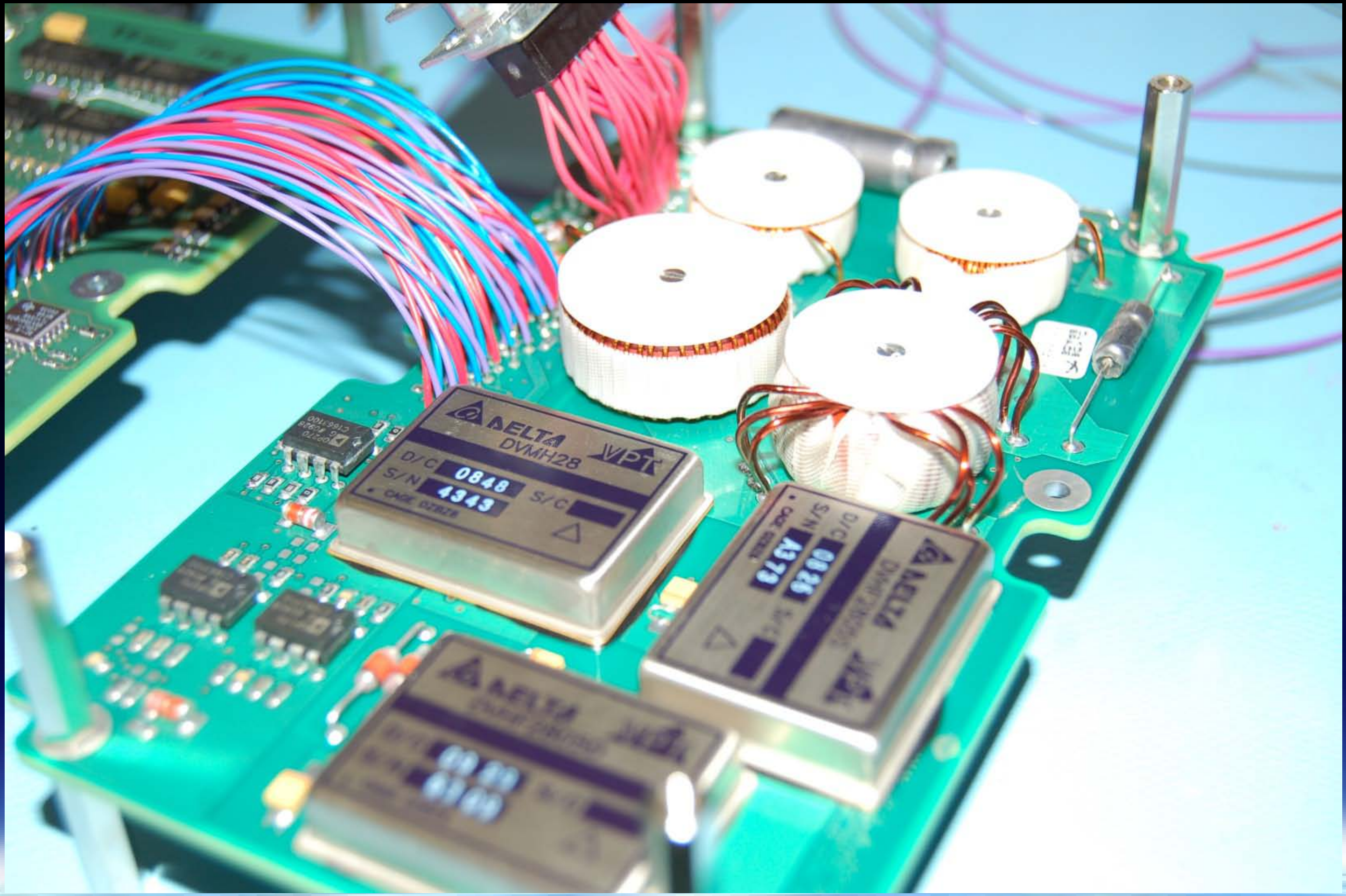
CONTROL ELECTRONICS AND INTERFACES

Electrical Configuration

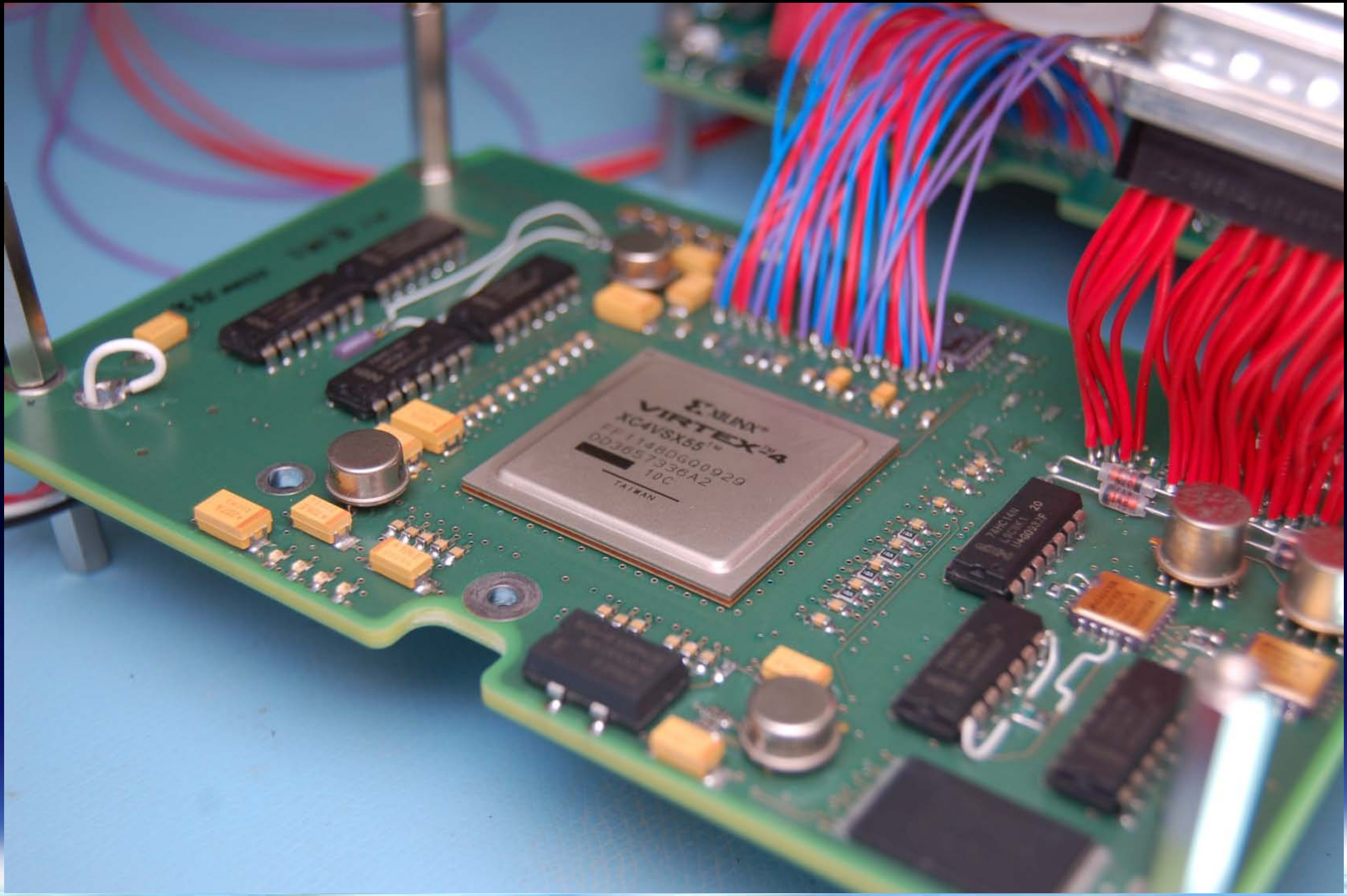
- Input stage provides significant filtering of all signals in order to meet the MIL-461E EMC requirements.
- An FPGA provides the control and commutation of both motors simultaneously. It also provides RS485 interface.
- The H-Bridge/3-Phase motor drive stages provide the power interface to the motors.
- All electronics were TID tested and passed to 30kRads. Single event tolerant by design (e.g. TMR in FPGA)



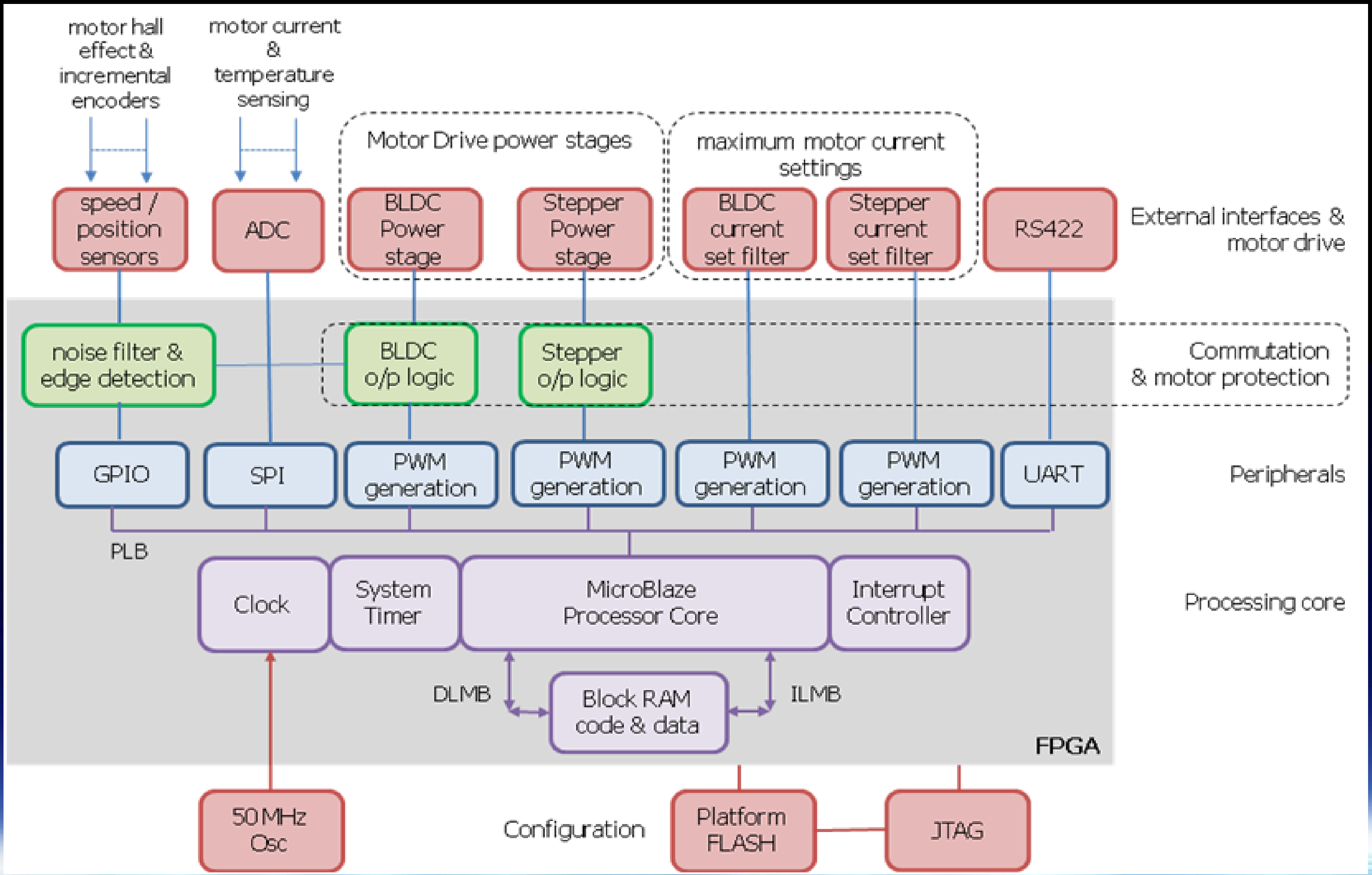
Engineering Model of Power, Filter and Motor Drive Stage Module



Engineering Model of FPGA/Control Board



FPGA board Block Diagram



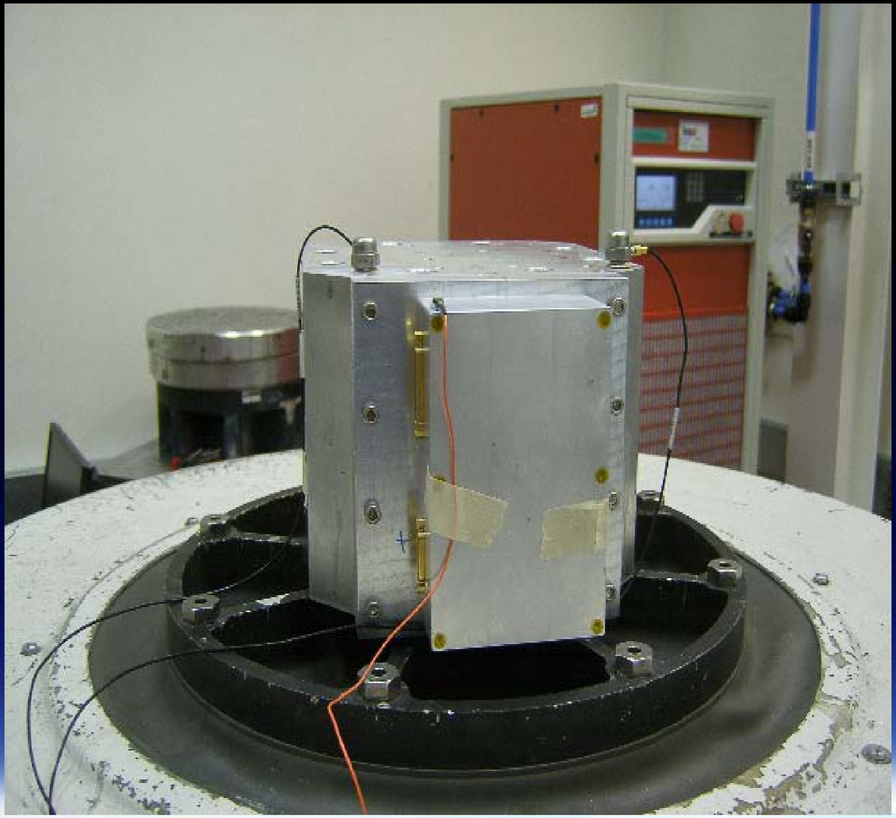
QUALIFICATION TESTING

Development schedule

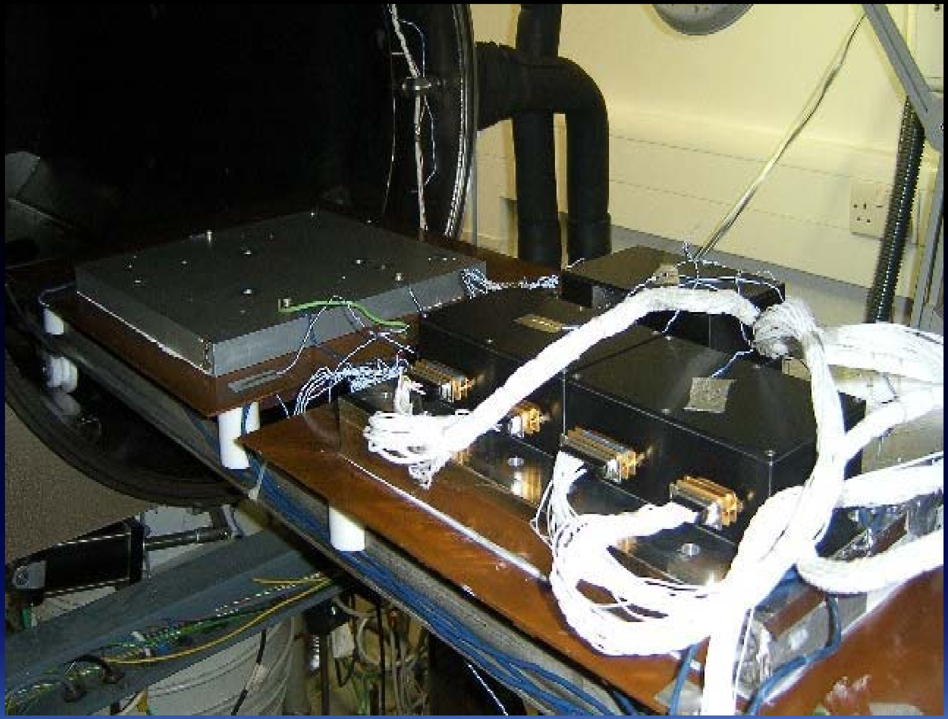
- CMG development programme had aggressive schedule.
- Both Electronics unit and then the complete CMG unit were subjected to full suite of qualification tests.
- Electronics were developed, qualified and (Seven) flight units produced and tested in a 7.5 month period.
- The integrated CMG units were then tested over the preceding 4 month period.

MIL-STD-461E EMC testing of electronics using CMG test bed with representative motors and loads.

Qualification model on vibration table during multi-axes random vibration tests.



Flight Models prepared for thermal vacuum testing



Qualification Status

- Both the electronics and the integrated CMG units passed the environmental test programme.
- The units have now completed qualification and acceptance test.
- It is expected that the units will fly on a small satellite mission within the next 18-24 months.

CONCLUSIONS

Conclusions

- Advances in technology and control techniques have enabled practical CMG design for small satellite missions.
- High performance control electronics can now be produced to meet the challenging mass and volume constraints of small satellites.
- Advances in motors, bearings and lubricants have enabled more robust mechanical configurations to be adopted.
- A higher proportion of small satellites missions are expected to adopt CMGs instead of reaction wheels to capitalize on the significant performance improvements.

Questions?

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