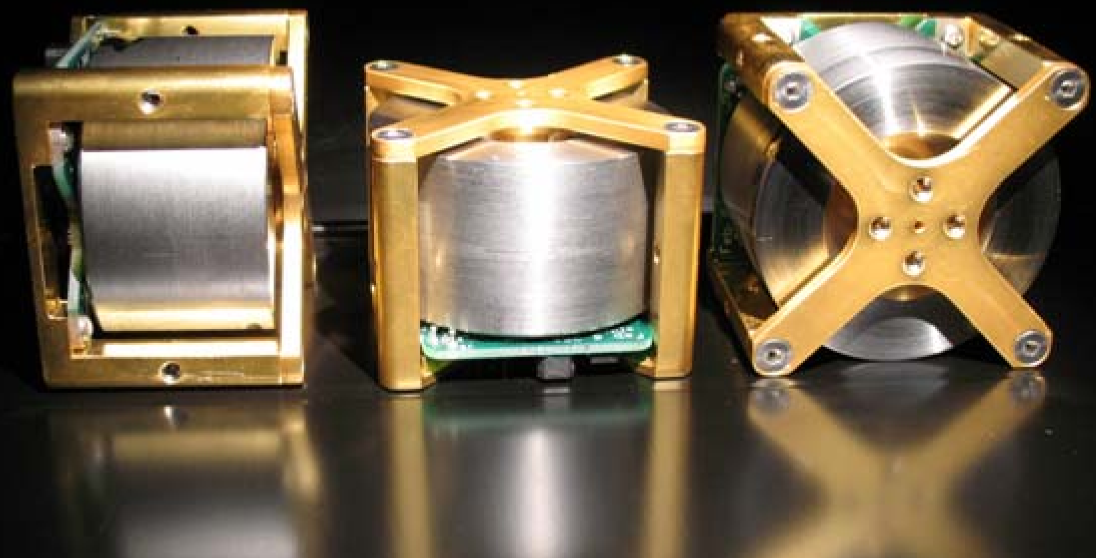

Enabling Reaction Wheel Technology for High Performance Nanosatellite Attitude Control

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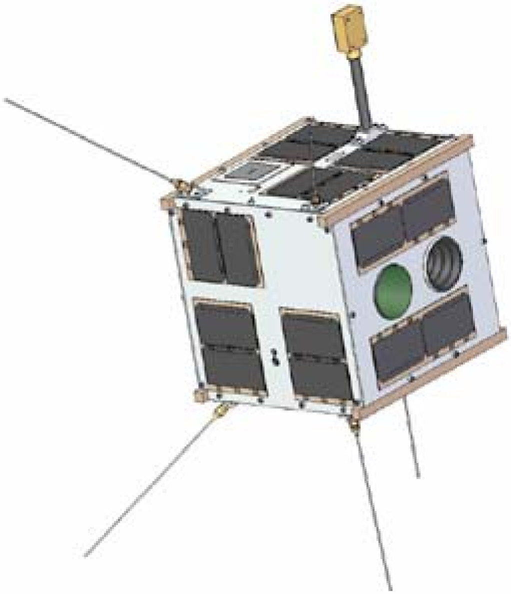
SSC07-X-3

Requirements

- SFL CanX satellite program had an urgent need for 15 wheels.
  - 5 x 5 x 4 cm volume
  - 30 mNm-sec capacity
  - 0.1 W @ 10 mNm-sec
- Contract signed October 2006
- CanX-2 launch October 2007



CanX-3 BRITE

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Commercial Motors

Mechanical Problems

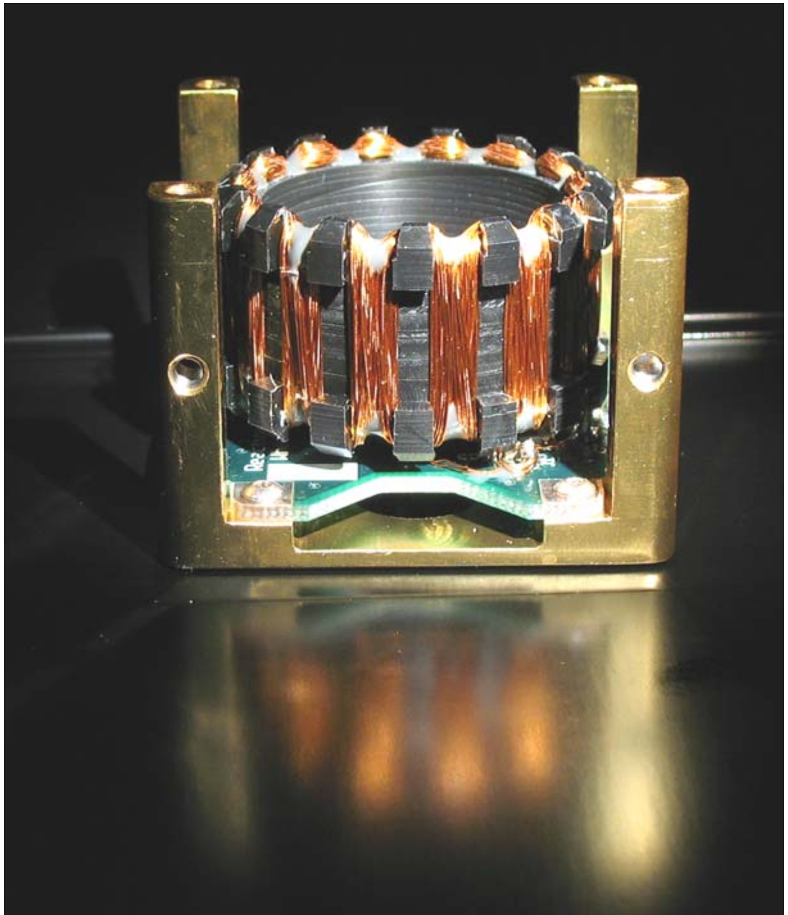
- Optimized for low inertia
- Thin short output shafts
- Bearings designed for speed, not load

Electromagnetic Problems

- Back-iron losses
- Magnetic field dipole leakage
- No redundancy

FAULHABER BLDC motors, used in a number of successful wheels

Custom Motor



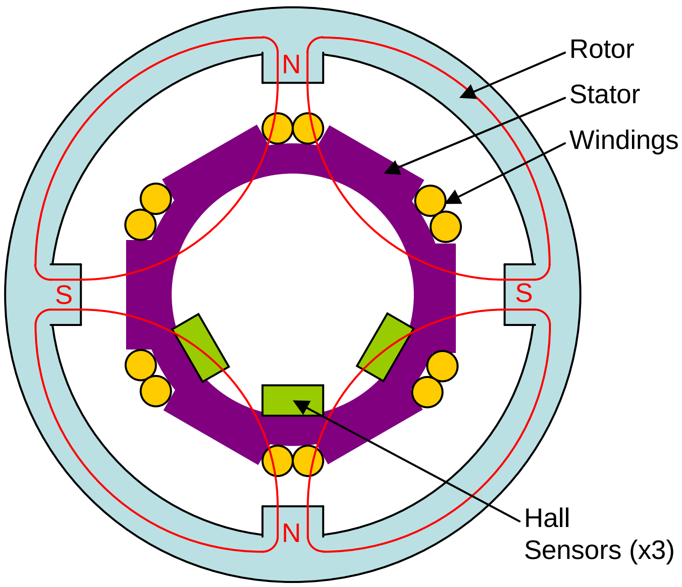
Mechanical Benefits

- Optimized for high inertia
- Non-cantilevered shaft
- Control over bearing design

Electromagnetic Benefits

- Loss-free rotating back-iron
- Many poles, so no dipole moment
- Redundant windings, Hall sensors, etc.

Magnetic Design



- Simple analytic modeling, using field-path sketches
- 4-pole motor shown for clarity

- Empirical field mapping using lathe
- Determine that motor must be Y-wound

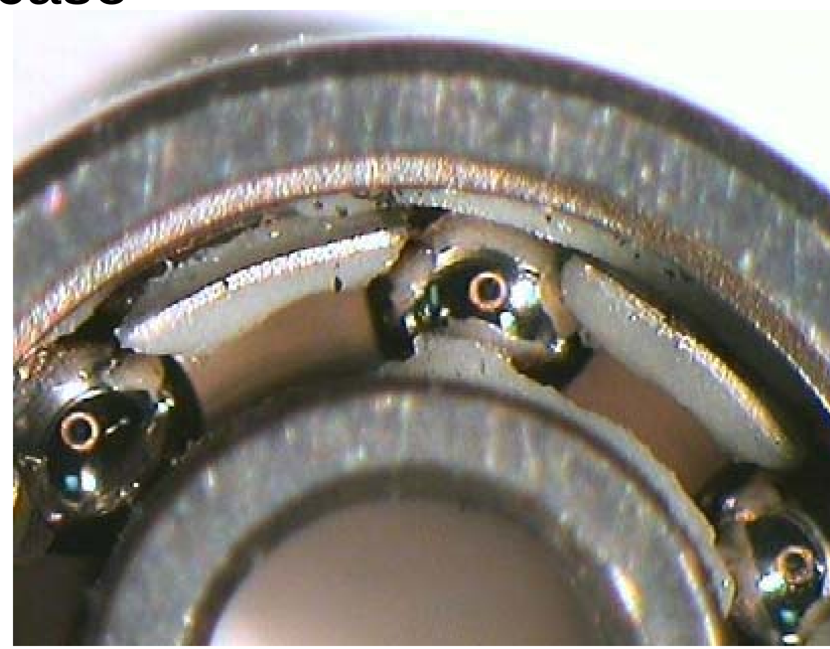
Enclosure

- Many wheels use a hermetic enclosure
  - Enclosed gas to allow use of standard grease
  - Enclosed vacuum to prevent windage
- Requires seal and electrical feedthrough
- Reduces wheel radius, requiring higher speed

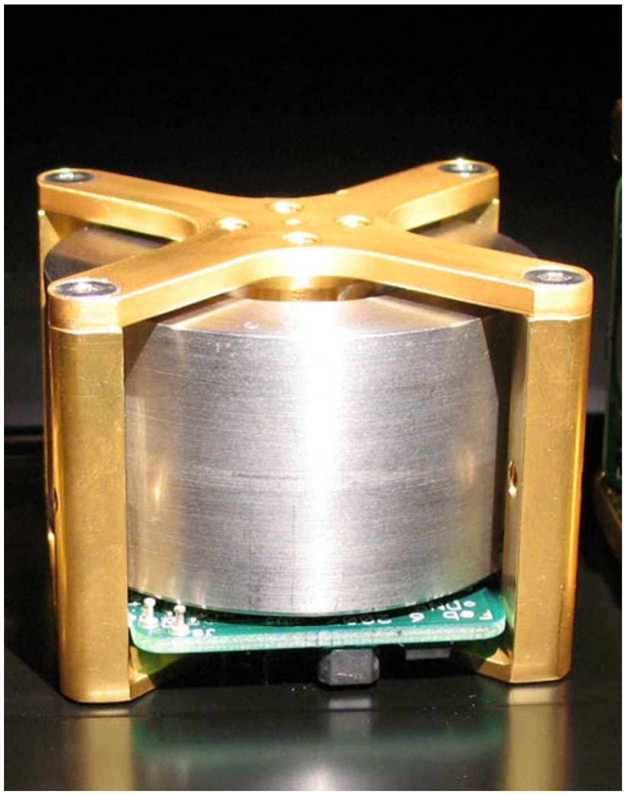
Decision: No Enclosure

Bearings

- Friction requirement
  - $F \propto d_m^3$
  - Cannot use angular contact, roller, etc.
- Axial launch load is limiting case
  - Stress is 4x radial load
- Nanosatellite secondaries
  - No launch-time spinup
  - No caging mechanism
- Passive offload needed
  - Springs
  - Dampers
  - Aerodynamics



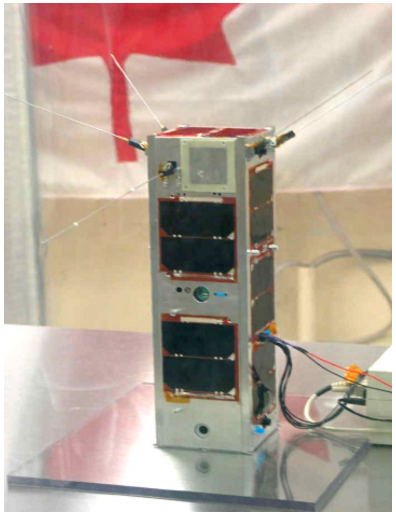
Result



Nominal Momentum	30 mNm-sec @ 5600 RPM
Nominal Torque	> 2 mNm
Control Mode	Speed or Torque
Command / Telemetry	UART or I2C
Mechanical	50 mm x 50 mm x 40 mm, 185 g mass
Supply Voltage	3.4 to 6.0 V
Supply Power	2.0 W at full torque 0.4 W @ 6000 RPM steady-state 0.1 W @ 2000 RPM steady-state
Environment	-40ºC to +70ºC operating temperature 12 g_{RMS} Vibration
Redundancy	Dual-wound Motor

Conclusion

- 12 Months from start to launch
- More than 20 units built
  - Satellite mass production!
- Vertically integrated design can be endlessly customized
  - Size
  - Redundancy
  - Interfaces



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