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Development of a PMAD System for Flywheel Based Energy Storage System

Glenn Research Center

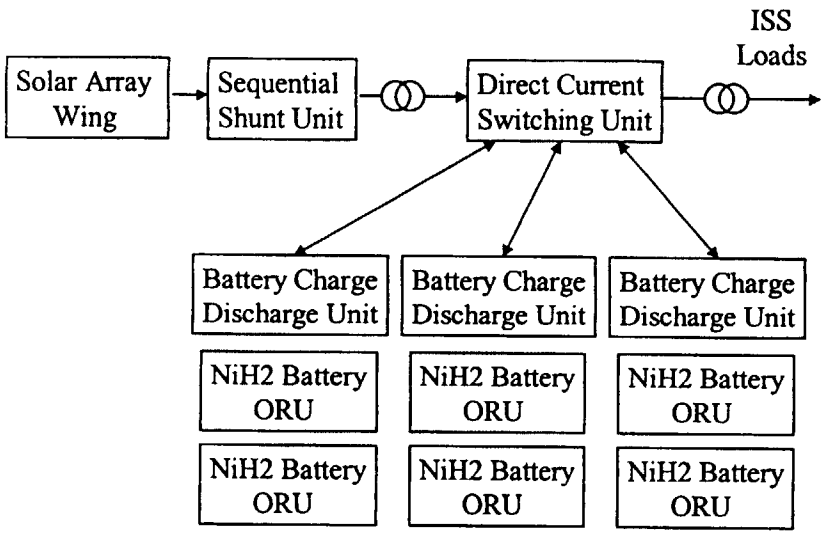
at Lewis Field

What We Will Discuss:

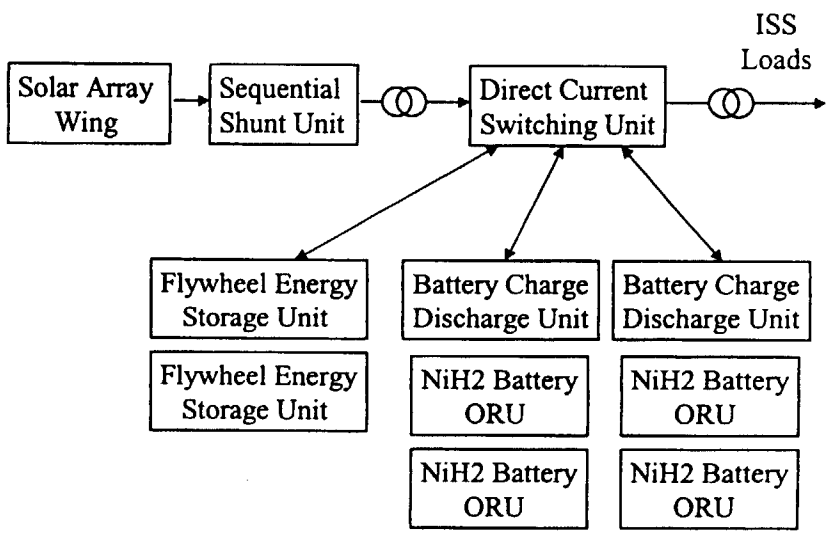
- Flywheel Energy Storage System (FESS) program objective
- Benefits of Flywheels for International Space Station (ISS)
- FESS Development Team
- FESS Electrical Requirements
- FESS Electrical Architecture
- Electrical Subsystem Functionality
- Conclusion

Program Objective

ISS Power System Channel Baseline



ISS Power System Channel with Flywheels



- To demonstrate flywheel technologies operating together as a system and having improved performance characteristics over batteries in a low earth orbit energy storage application (ISS).

Benefits of Flywheels for ISS

- 15 year life vs. 5 year design life for NiH2 batteries
- Energy efficiency: 84% roundtrip vs. 67% (spec'd) for BCDU/battery combination
- Cost: projected to be $100's M for fully populated station over life

FESS Development Activities

- University of Texas, Center for Electro Mechanics – Flywheel Module design and development
  - Rotor design
  - Magnetic Bearing system design (including control software)
  - Motor/Generator design
  - Mechanical Bearing design
  - Module Integration
- TRW - Electronics design and development
  - Motor drive electronics
  - Magnetic bearing drive electronics
  - Magnetic Bearing and Motor Drive DSP development
  - System Controller design
  - Electronics Integration

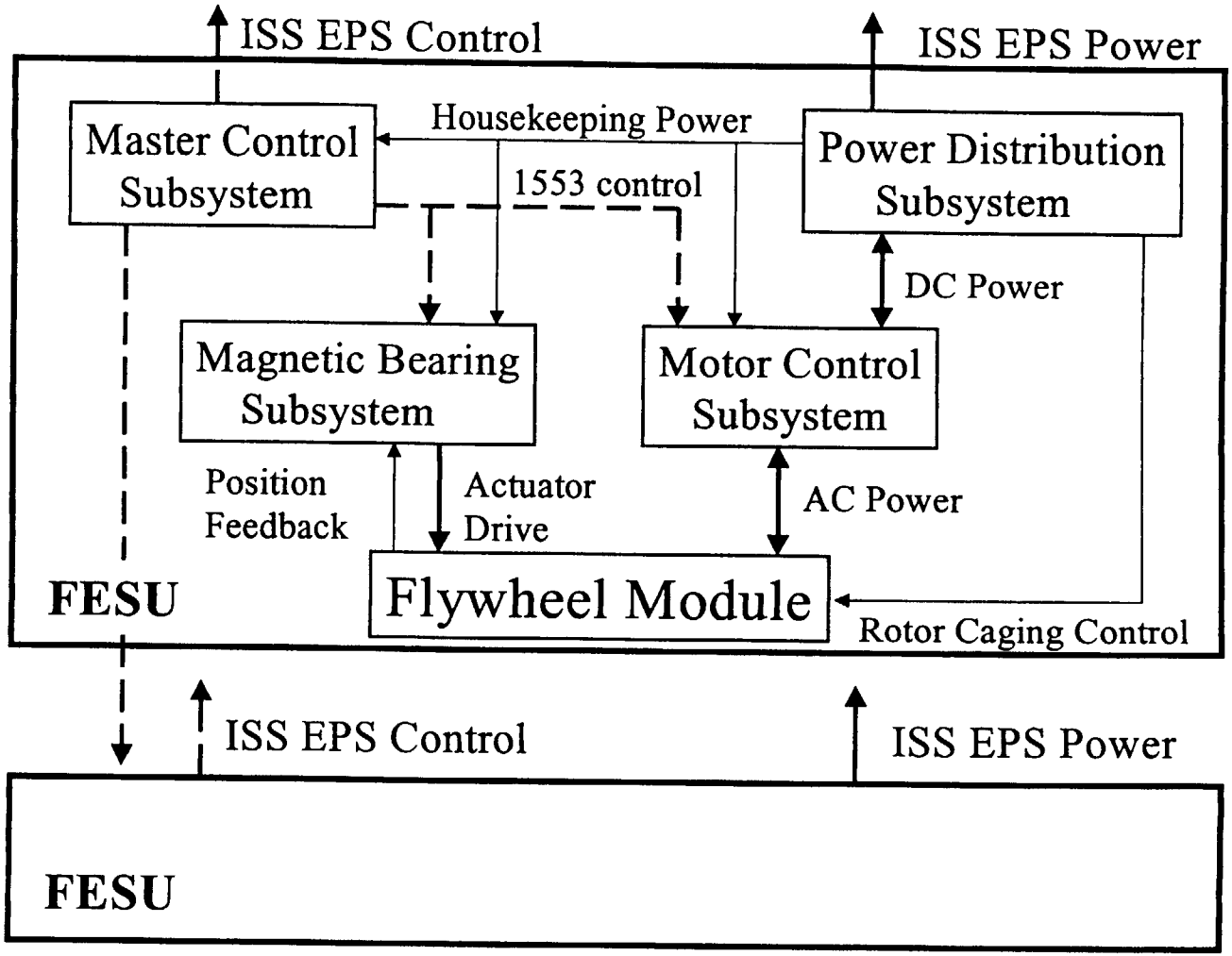
FESS Development Activities (cont.)

- GRC Development Unit testing
  - Motor control algorithm design
  - Magnetic Bearing sensor evaluation
  - FESS/ISS EPS integration testing
  - Advanced concepts development
    - Combined power and torque control
    - Passive Magnetic Bearings
    - Alternate Magnetic Bearing Controls

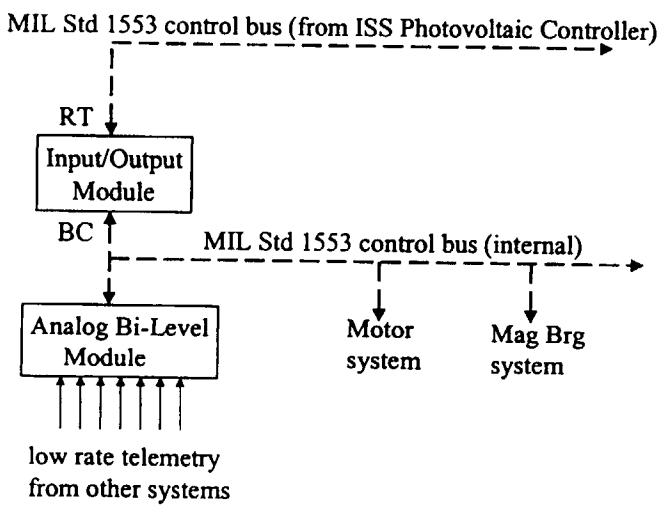
FESS Electrical Requirements

- 6.6 kW input or output power for charge or discharge
- 5.25 kW-hr energy storage from full speed to minimum speed
  - Enough for 2 contingency orbits of operation
- 130 to 173 VDC primary bus voltage
- 84% round-trip energy efficiency, including fixed losses and power electronics
- Autonomous operation and transition from charge to discharge
- Parallels with ISS NiH2 batteries and Battery Charge/Discharge

FESS Electrical Architecture

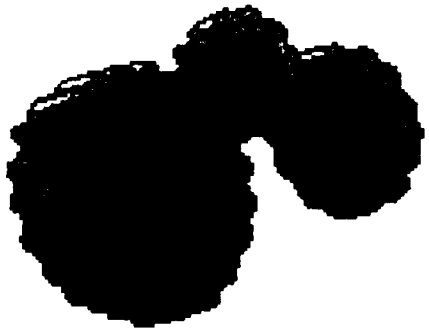


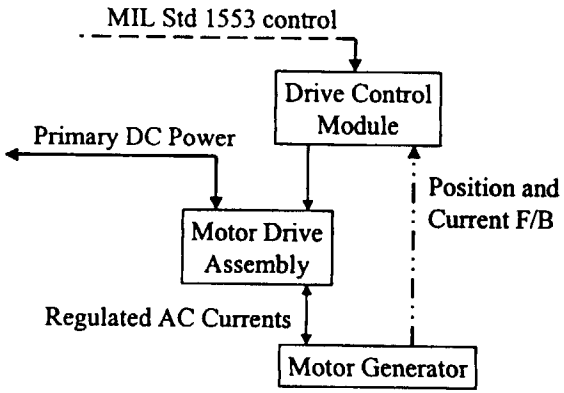
FESS Master Control Subsystem



- Provides communication to ISS EPS via MIL Std 1553
- Controls FESS operations and sequencing
- Collects telemetry to monitor state-of-health and to transmit to ground
- Makes flywheel "look like a battery"

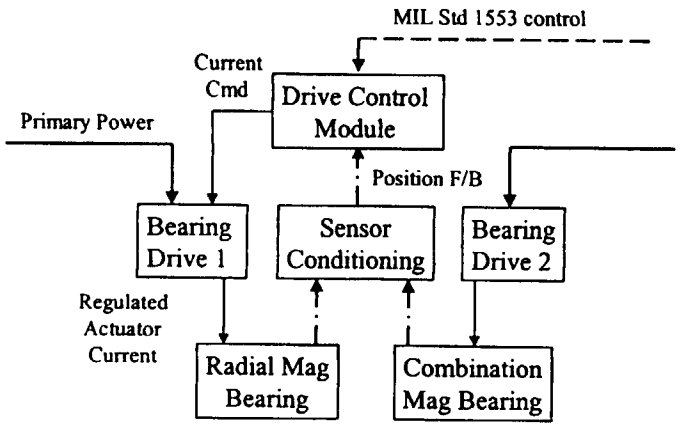
FESS Motor Drive Subsystem





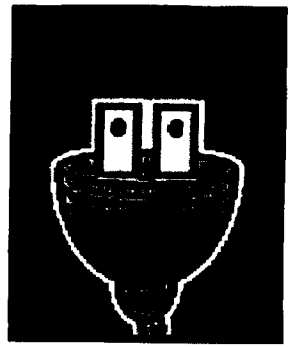
- Motor Drive hardware is common Power Electronics Building Block converter
- Inverter operates as buck converter during charge, boost converter during discharge
- 4 Pole Permanent Magnet Synchronous Motor selected
- Status: Bidirectional power control of charge current and discharge voltage demonstrated

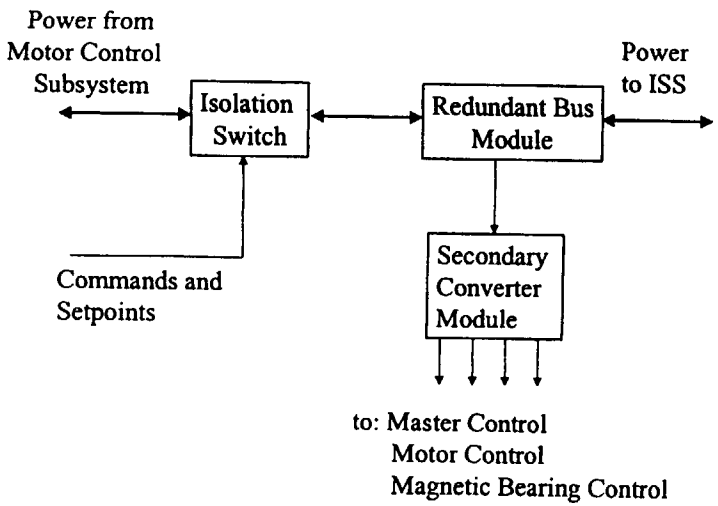
FESS Magnetic Bearing Subsystem



- Magnetic Bearing Drive hardware is common Power Electronics Building Block converter
- Control designed to minimize input current/energy
- Control designed to filter imbalance effects
  - Operates on disturbances
- Status: Control of levitation demonstrated to 60,000 RPM

FESS Power Distribution Subsystem





- Supplies power to control DSPs and magnetic bearing PWMs
- Uses either ISS primary or energy from flywheels as a source
- Multiple sources provide fault tolerance for communication and wheel levitation
- Fault Isolator protects against shorts on the power bus

Conclusion

- FESS will demonstrate some of the benefits of flywheel technology for LEO energy storage
- Development team is in place
- Functionality of motor drive and magnetic bearing subsystems has been demonstrated
- Performance characterization and improvement is on-going