Guidance Navigation and Controls

Pre-Preliminary Design Review

Outline

- Team overview
- Current areas of focus
  - Sun Sensor
  - Horizon Sensor
  - Reaction Wheels
  - Magnetic Torquer
  - Satellite Toolkit
  - Control Algorithms
- Resources and Budget

GNC Team

Team Mentor:

- Dr. E. D. Fasse (AME)

Team Members:

- Matt Angiulo (AME)
- Greg Chatel (AME)
- Jeremiah Engleman (CS)
- Mark Fairchild(AME)
- Barry Goeree (AME)
- Brian Ibbotson(NM)
- James Johnson (ECE)
- Martin Lebl (CS)
- Marty Levine (AME)
- Adam Mahan (ECE)
- Brian Mintah (AME)
- Jerry Morales (AME)
- Mathew Rippa (MATH)

Objectives GNC team

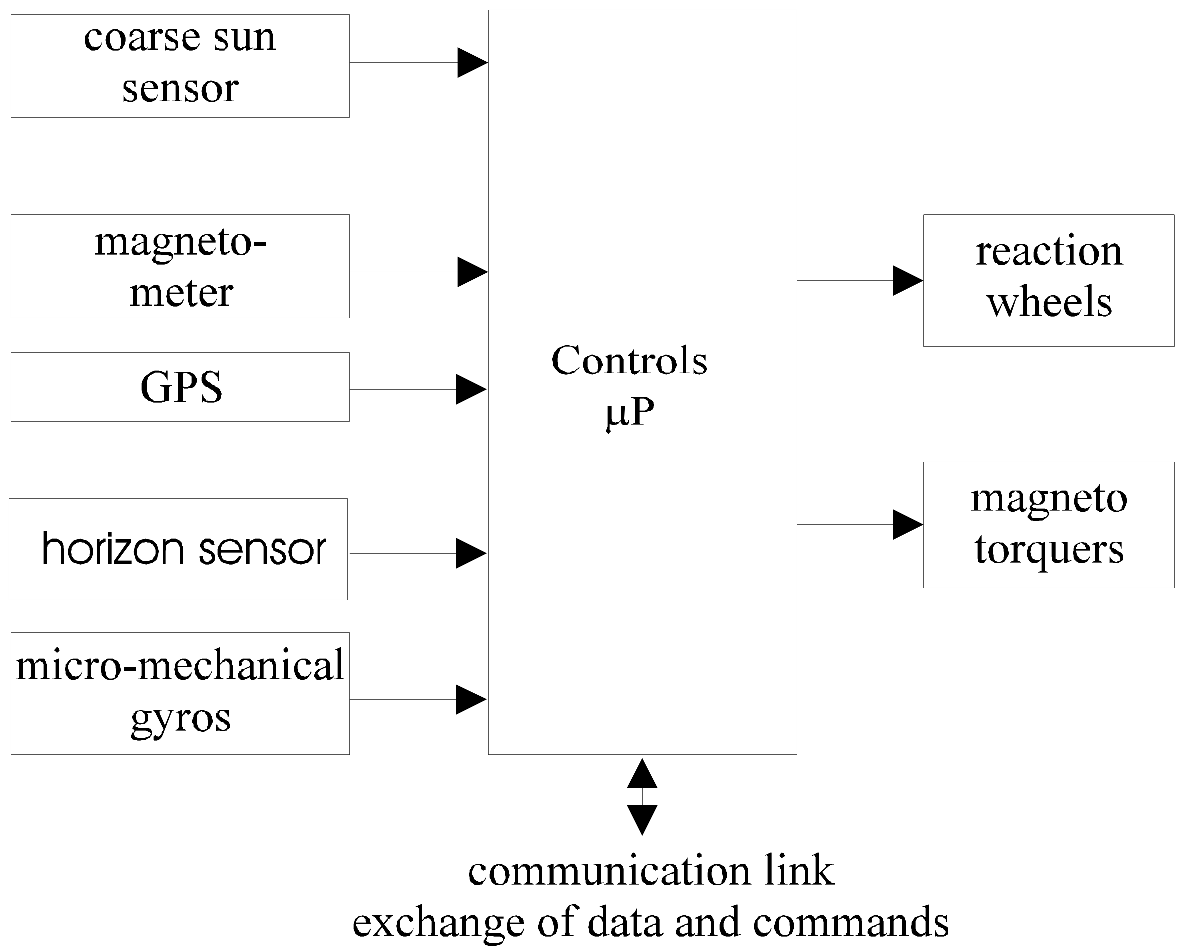
Attitude control of satellite to support:

- lightning experiment
- photometry experiment
- laser communication experiment
- maximum power generation

Specifications

- 3 axis Earth and inertial pointing
- Slew rates ~1° /second
- Pointing accuracy: 1° for Earth based pointing and 0.1° for inertial pointing
- The satellite will not be able to make changes in orbital parameters
- Low cost, low power and small

Block Diagram



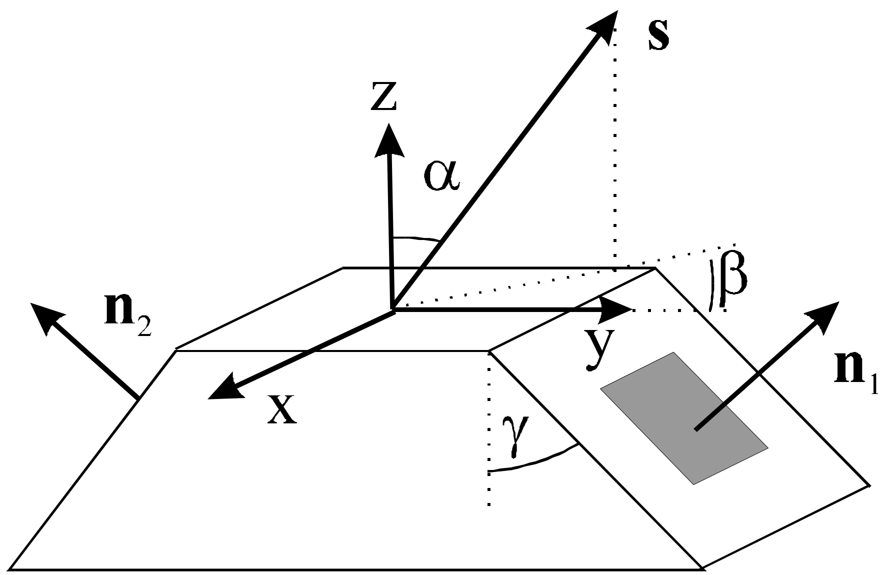
Sun Sensors

- Used to generate maximum power from the solar arrays
- Accuracy within 1 - 5 degrees
- Low cost, in house built
- Mounted on exterior of satellite

Sun Sensors

- TI's TSL230B is a programmable light intensity to frequency converter
  - digital output
  - easy to interface with micro-controller
- Two angles are required to locate sun w.r.t spacecraft
- Final placement of cells has not been determined

Angle Determination



$$\hat{s} = \begin{bmatrix} -\sin\alpha \sin\beta \\ \sin\alpha \cos\beta \\ \cos\alpha \end{bmatrix}$$

$$\hat{n}_1 = \begin{bmatrix} 0 \\ \cos\gamma \\ \sin\gamma \end{bmatrix} \qquad \hat{n}_2 = \begin{bmatrix} 0 \\ -\cos\gamma \\ \sin\gamma \end{bmatrix}$$

$$\varphi_1 = G_o\left(\hat{s} \cdot \hat{n}_1\right)$$

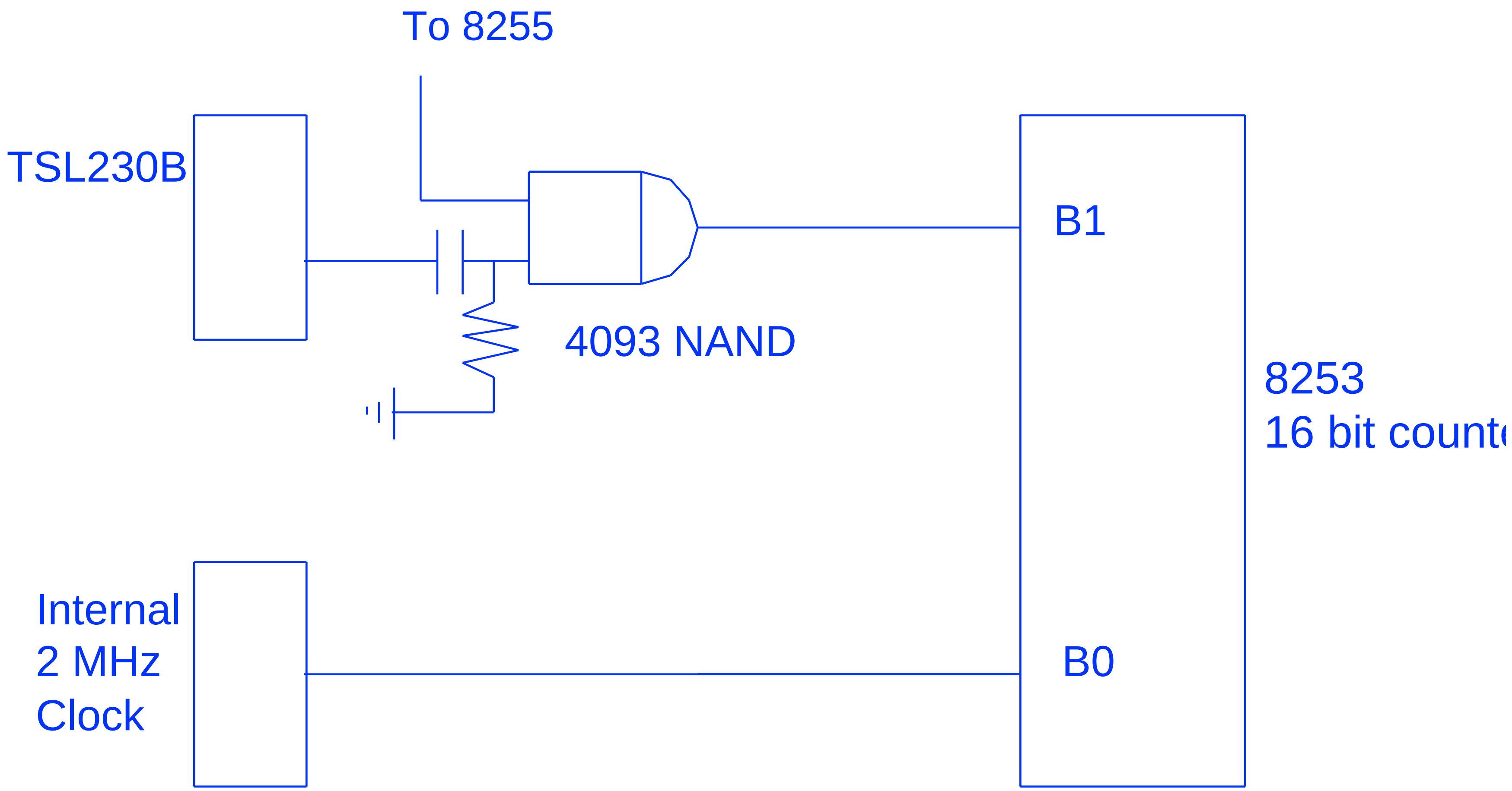
$$\varphi_2 = G_o\left(\hat{s} \cdot \hat{n}_2\right)$$

$$\tan\alpha = \frac{\sin\gamma\left(\varphi_1 - \varphi_2\right)}{\cos\beta \cos\gamma\left(\varphi_1 + \varphi_2\right)}$$

Software - main program

- Initialize 8253 counter and 8255 I/O gate
- Take readings of counts from sun sensor
- Read captured time and counts
- Calculate the frequencies
- Use frequencies to calculate angles

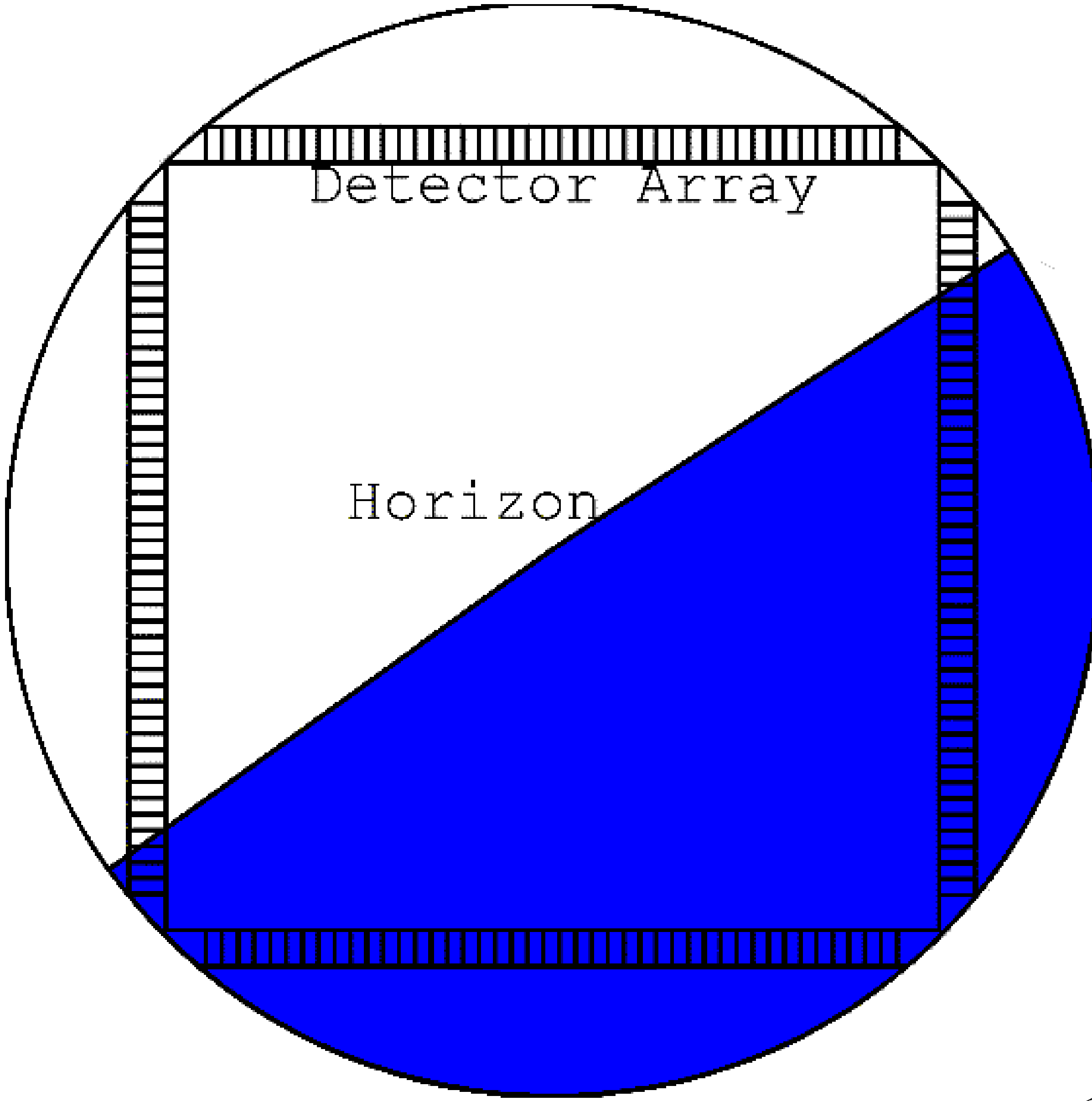
Current Test Setup

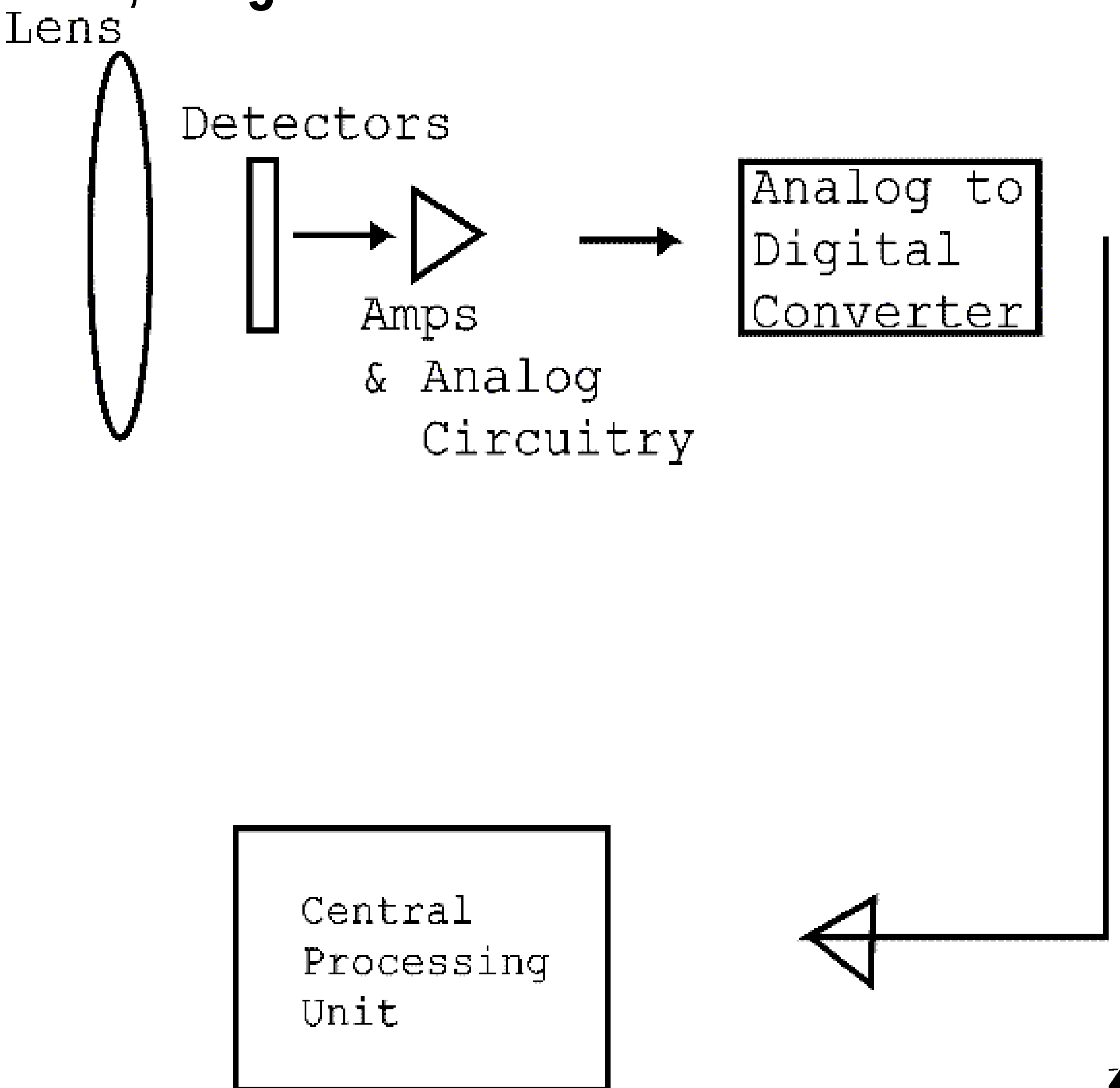


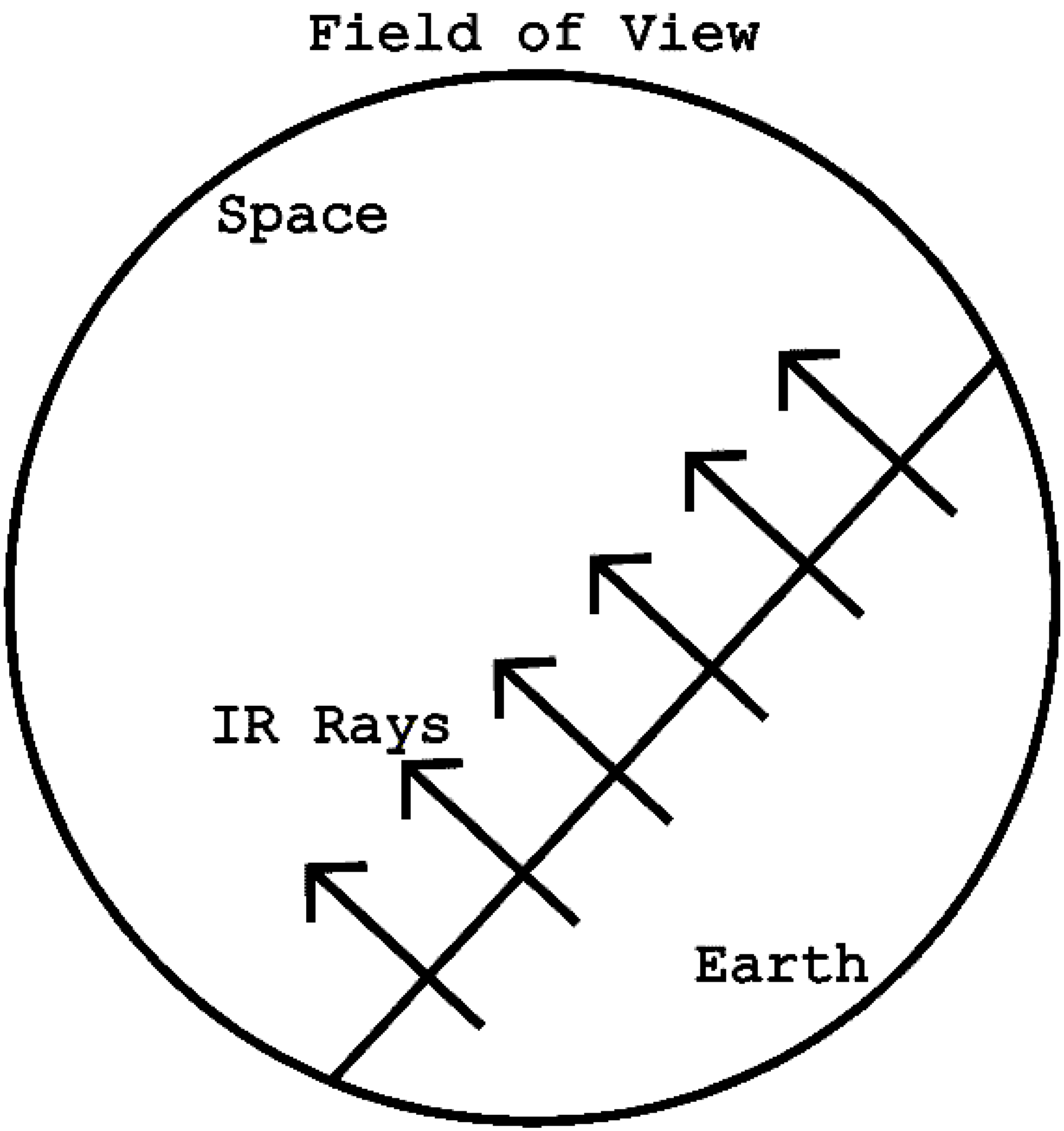
Concerns

- Debugging program
- Implementing program with working circuit model
- Modifying program to determine most accurate sensor
- Reflected light by the Earth a possible source of error

Guidance, Navigation and Controls




Lens
Detectors
Amps
& Analog
Circuitry
Analog to
Digital
Converter
Central
Processing
Unit


Field of View
Space
IR Rays
Earth

Low Cost Reaction Wheel Design

UASat
Dept. Aerospace and Mechanical Engineering
University of Arizona

Outline

- Ground Rules
- Torque and Angular Momentum Requirements
- Design Specifications
- Structure
- Bearings
- Lubrication
- Motor and Driver Design
- Test Plans

Ground Rules

- Low cost
  - standard components
  - common materials
- Size
- Power consumption
- Reliability
- Weight not critical

Torque and Angular Momentum Requirements

- Disturbance Torques

Disturbance	Symbol	Torque (Nm)
Gravity gradient	T_g	$< 8.1*10^{-6}$
Aerodynamic drag	T_a	$< 1.0 *10^{-4}$
Solar pressure	T_{sp}	$< 7.3*10^{-7}$
Magnetic field	T_m	?

- 180^o Sweep: 0.19 Nms

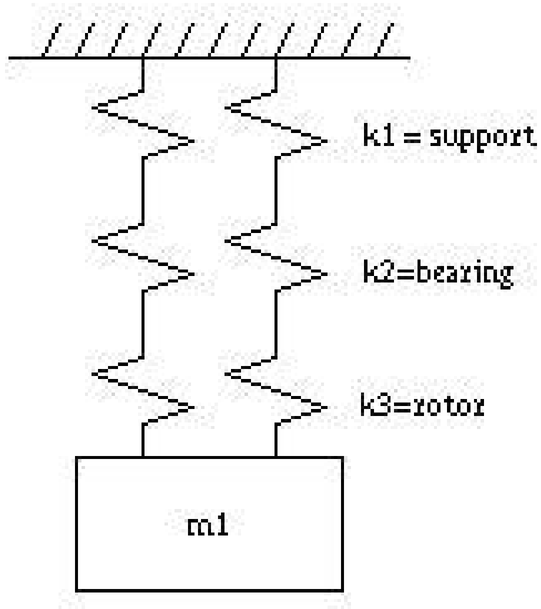
Design Specifications

Parameter	**Minimum Requir**	
Nominal operating speed	2000 RPM (5000	
Operating Life	1 year	
Storage Life		
Torque Capability	0.02 Nm	
Torque Ripple	None	
Angular Momentum	0.5 Nms max	
Power Consumption	<1W	
Weight		

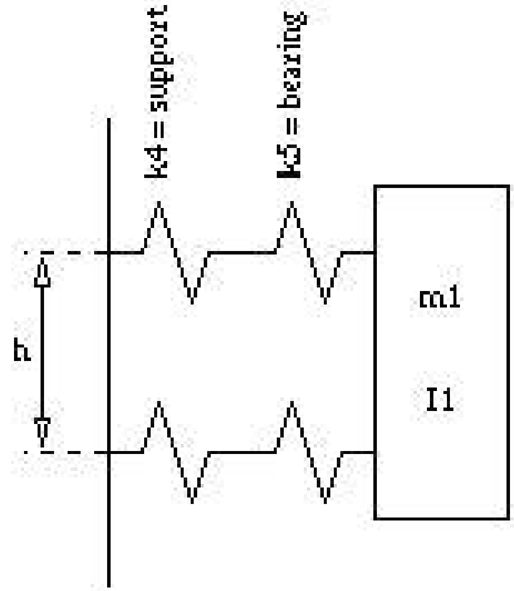
Structure

- Housing
  - Pillbox
  - Material: Aluminum alloy 6061
  - Vented design
  - Structural dynamics
    - spoked spider web for tuning natural frequency

Structure



Axial Dynamic Model



Radial dynamic Model

Structure

- Rotor
  - 15-5PH stainless steel shaft to match CTE of bearings
  - flywheel of aluminum alloy 6061
  - shaft thermal fitted and secured by nut
  - flux return ring, magnets and spacers bonded with structural epoxy
  - balancing by removing material from rim

Structure

- Bearing mounts
  - Spring loaded design
  - 15-5PH Stainless steel to fit CTE bearings
  - Sleeve outer race bearing coated with Titanium nitride to prevent fretting
  - Inner races bearing secured to shaft with spanner nuts

Bearings

- Type
  - high capacity R4 instrument bearings
  - Angular contact
- Preload: springs
- Material: 440C Stainless steel
- Load ratings: < 580,000 psi
- Tolerances: ABEC 7

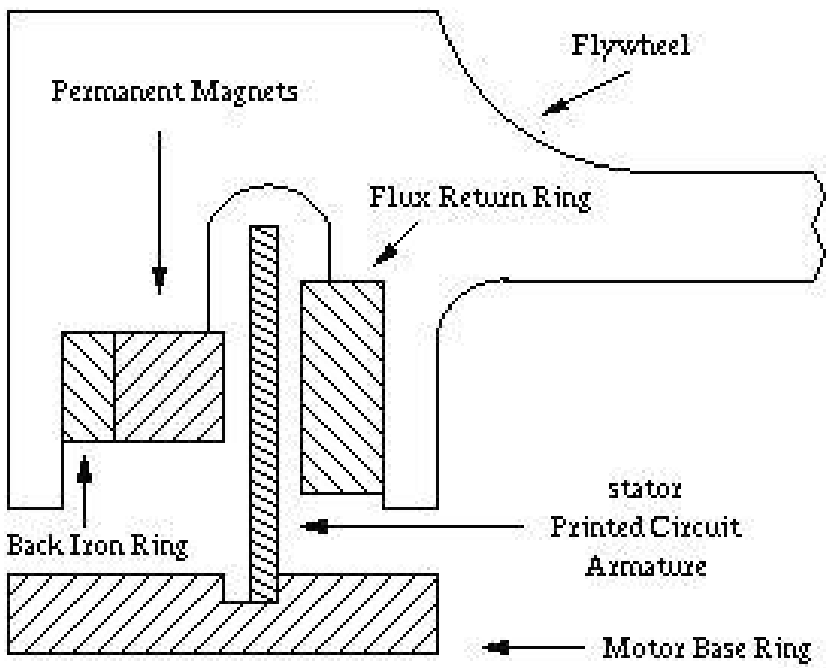
Lubrication

Pennzane X2000

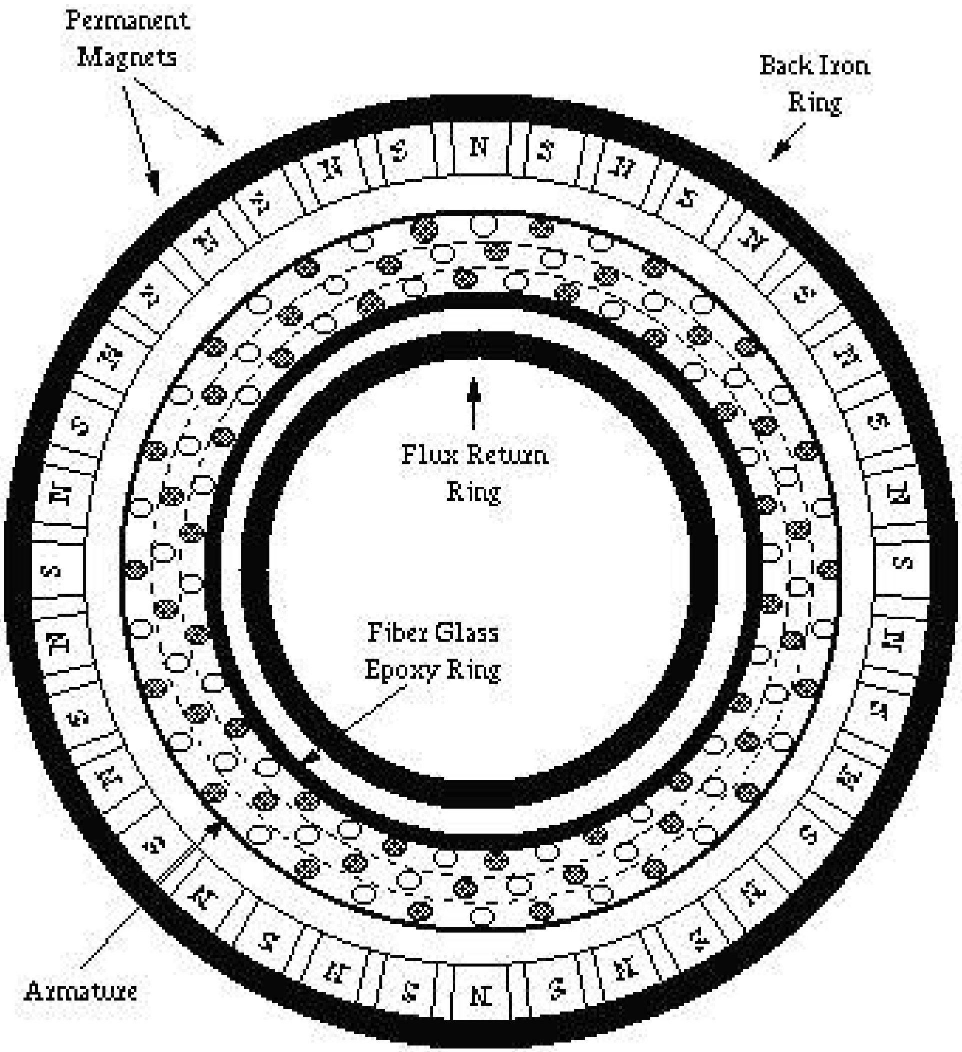
- synthesized hydrocarbon fluid
- very low volatility
- very low vacuum condensables
- additive compatibility
- low viscosity
- low pour point

Motor Design

- Three phase iron-less, brush-less motor



Motor

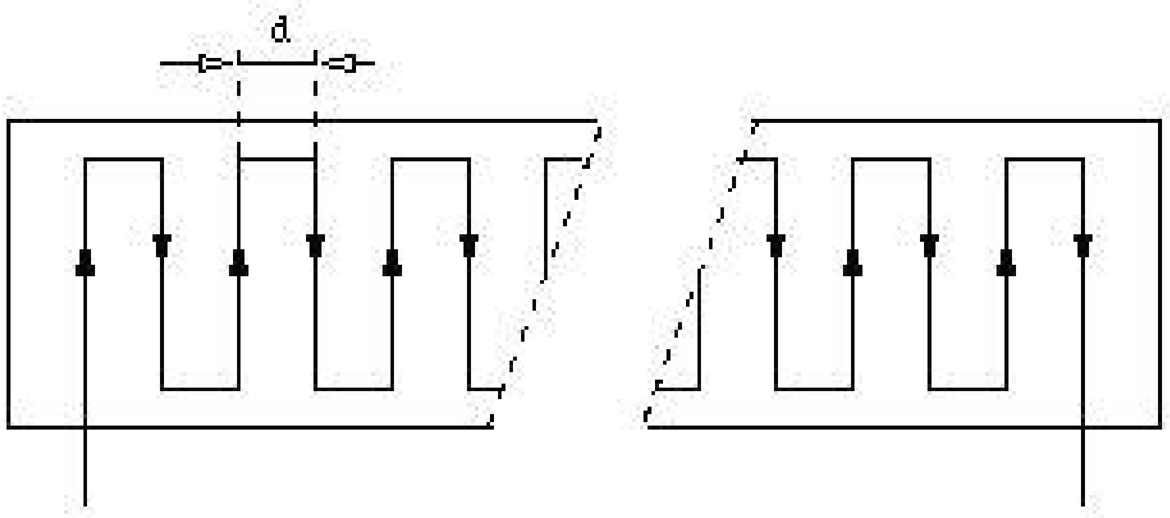

Permanent Magnets
Back Iron Ring
Flux Return Ring
Fiber Glass Epoxy Ring
Armature

Motor

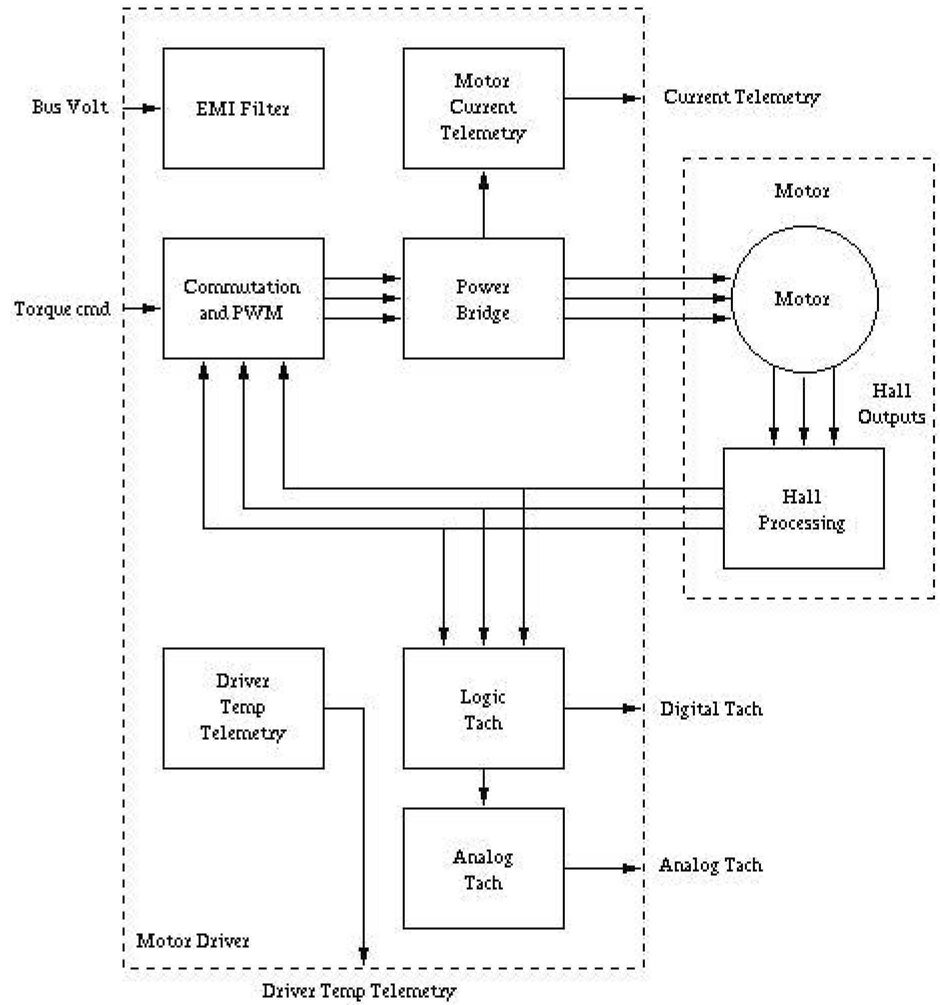
- Back iron and flux return ring of cold rolled steel. Plated with electroless nickel to prevent corrosion
- Samarium Cobalt permanent magnets
- Aluminum spacers for structural strength
- magnets bonded to ring with structural epoxy
- Rings bonded to flywheel with structural epoxy
- No thermal fit to avoid thermal stresses

Motor

- Armature
  - three flex prints bonded with film adhesive to fiberglass epoxy ring



Motor driver



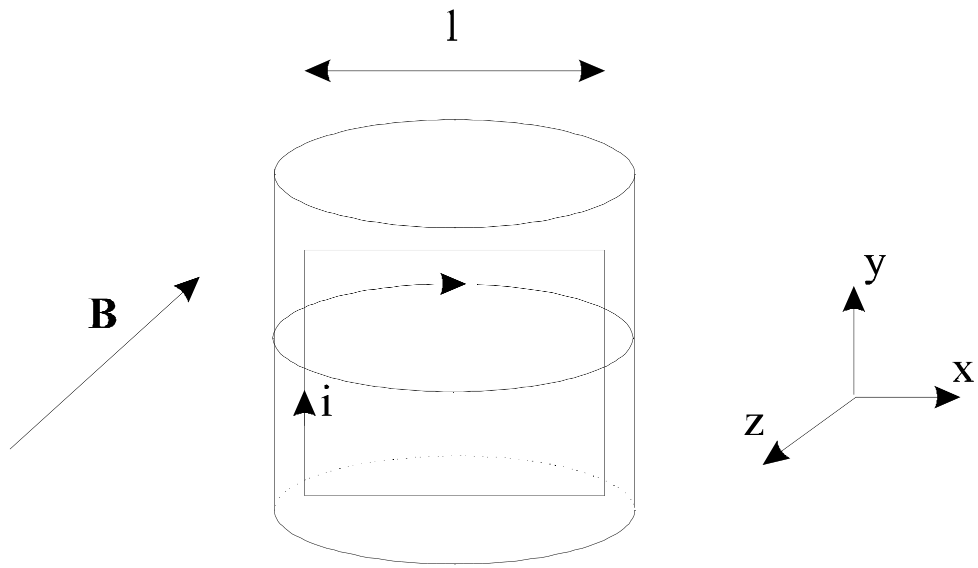
Motor driver

- Telemetry signals
  - motor driver temperature
  - direction of rotation
  - rotation speed
  - motor current

Testplan

- Functional test
- Environmental testing
  - shock
  - vibe
  - thermal cycling (burn in)
- EMI

Magneto torquers



$$\mathbf{B} = B_x\hat{\mathbf{x}} + B_y\hat{\mathbf{y}} + B_z\hat{\mathbf{z}}$$

$$\mathbf{F} = i\mathbf{l} \leftrightarrow \mathbf{B}$$

$$\tau = il^2\left\{B_y\hat{\mathbf{x}} - B_x\hat{\mathbf{y}}\right\}$$

$$\tau_x = Nil^2 B_y$$

Where i is the current, N the number of turns and l is the length of the wire. For an Ohmic loop, V=iR, where,

$$R = \frac{4lN\rho}{A}$$

ρ is the resisitivity, A is the cross sectional area of the wire

$$i = \frac{VA}{4lN\rho}$$

$$\tau_x = \frac{VAlB_y}{4\rho}$$

Budget

- Hardware and software

Item				
Diverse software				
Micro mechanical gyros				
Magnetometer				

Budget

- Available and missing tools, components and facilities

Item	Availability
Assembly / testing space	Controls lab
Machine Shop	AME shop
Electronics Shop	Needed
Computers	5 Pentiums available
MATLAB - simulations	Available
CAD package	Available
PCB layout/Circuit diagram/Simulation	Needed

Budget and support

- Team level support received
  - Space grant (actuator design)
  - WASEO grant (actuator design)
  - Use of AME controls lab

Conclusion

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