Mechanisms Overview

August 2001

www.honeywell.com/space/CEM
# Space Systems Glendale Product Areas

## Commercial Products
- Larger Volume Standardized Products
- Standardized Mechanisms

## Special Projects
- Unique Low Volume Products
- Specialty Mechanisms

## Space Station
- Data and Vehicle Management
- Multiplexers/Demultiplexers

## Human Space
- Displays and Software
- Displays
- Software Development System
Mechanisms Design Heritage

- Over 30 Years experience in custom mechanisms for Military, NASA and Commercial programs
- Spin Systems Key Technologies and Heritage
  - Several Encoder Methods
  - Power and Data Transfer Assemblies
  - Low ripple and jitter motors
- Gimbal and Pointing Systems Heritage
  - Precision Pointing Gimbals and electronics
  - RF Rotary Joints and Flex capsules
  - Deployment Systems
  - Controls/Structure Interactions and Damping
  - Disturbance Compensation/Reduction
- Commercial Rotary Actuators and Gimbals
  - Communication Antennas
  - Thruster Control
  - Solar Array Drives
Rotary Actuator Types

- **Ambassador Series:**
  - High volume production (1400+)
  - LEO Constellation tailored design
  - Application:
    - Antenna dish deployment and pointing

- **Galaxy Series:**
  - Currently in production
  - LEO / GEO tailored design
  - Applications:
    - Subreflector rotation
    - Antenna dish deployment & pointing
    - Thruster pointing
Honeywell Mechanisms Design Philosophy

- Design products with inherent modularity
- Insure individual rotary actuators can be used easily in single axis or two axis gimbal modes
- Minimize part count for lower production costs
- Design for manufacturing and assembly through close relationship with production personnel
- Insure flexibility in the design to meet customer specific requirements with minimal non-recurring costs.
Galaxy Series Rotary Actuators and Gimbals

- Modular Packaging Concept
  - Low part count (12)
  - 2.2 Kg (4.9 lbs) per axis weight
  - Precise step accuracy (0.0075 deg)
    - Theoretical step size versus actual step size
  - Small step size (0.009375 deg)
  - Non-redundant coarse potentiometer
  - Conductive track for ground path across output bearings
  - Redundant Fine potentiometer for position telemetry

- Target Applications
  - Antenna deployment and pointing
  - Thruster pointing
Assembly of GX-090221 Actuator

- STOP RING
- OUTPUT FLANGE
- BEARINGS
- POTENTIOMETER
- MOUNTING FLANGE
- HARMONIC DRIVE ASSEMBLY
- MOTOR & FINE POTENTIOMETER ASSEMBLY
System Applications of Galaxy Series Rotary Actuators

Rotary Actuator Level
- Subreflector Rotation
- Single Axis Deployment & Positioning

Two Axis Gimbal Level
- Reflector Deployment and Pointing
- Thruster Deployment and Pointing (Proposed design)

Two Axis Gimbal w/ Interface
- Spot Beam Antenna Deployment and Pointing
- Thruster Deployment and Pointing (Proposed design)

Features:
- Primary and Secondary Circuits Separated on Two Connectors
- Modularity
- Extended Thermal Environments
  - Non-Op: -60degC to +117degC
  - Op. (Flight): -45degC to 105degC
Specialized Mechanism Programs
Hubble Space Telescope

Honeywell supplied two key subsystems for the Hubble Space Telescope: Reaction Wheel Assemblies and an Antenna Pointing System.

To keep its sharp focus, the Hubble relied on Honeywell reaction wheel assemblies and isolation system for positioning and stability. To send images and data back to Earth, the giant telescope linked with NASA’s Tracking and Data Relay Satellite System via a Honeywell antenna pointing system.

Honeywell supplied similar reaction wheel and pointing systems for the Solar Max and Magellan missions, as well as for missions like Topex and Explorer Platform.
Honeywell provided mechanisms and momentum controls for Mitsubishi Electric Corporation’s Advanced Microwave Scanning Radiometer (AMSR), an instrument used on NASA’s Earth Observing System satellite -- EOS-PM1.

SSO built and delivered an Antenna Drive Assembly and a Momentum Wheel Assembly to control AMSR. The Antenna Drive Assembly, a spinning mechanism, is crafted to be the interface between the AMSR instrument package and the EOS-PM1 satellite bus, providing signal and power transfer and precision compensation for the momentum created by this rotation. These products demonstrate Honeywell’s heritage in designing and building spinning mechanisms for a number of successful satellite programs.
When NASA’s Galileo spacecraft viewed Jupiter’s moon, Ganymede, the flyby was made possible in part by Honeywell Space Systems’ Spin Bearing Assembly and Scan Actuator Subsystem. Because the Galileo spacecraft is stabilized by a spinning motion of about 3 rpm, the spin bearing assembly was designed to “despin” and point an instrument platform carrying several sensitive scientific instruments. The result is precision pointing of the instruments.

Honeywell’s scan actuator subsystems were used to point another series of instruments during flyby encounters with Jupiter and its satellites.

- Single axis gimbal for pointing instruments on Galileo orbiter
- 200 circuit flex capsule
- 0.5 N-m torque output
- 16 bit optical encoder
- Redundant motors
- ±105 deg angular travel
- 0 to 1.0 deg/sec angular rate
- 19.5 Kg weight
Honeywell designed, developed and produced the **High Gain Antenna System (HGAS)** for the Ocean Topography experiment (TOPEX) satellite.

The system consisted of a deployment mast, gimbals and electronics and allowed the TOPEX spacecraft to maintain a two-way communications link between NASA’s Tracking and Data Relay Satellite System and Earth.

Honeywell also provided four **Reaction Wheel Assemblies** that stabilized and controlled the satellite’s attitude.
Solar Maximum Mission (SMM)

High Gain Antenna System
EOS-AM Gimbal Assembly Description

Honeywell designed and built the Stepper-Gimbal Assembly for the Earth Observing System Satellite (EOS) AM high gain antenna.

The two-axis gimbal pivot the craft’s antenna dish and electronics, which gathered and transmitted data.

EOS was among the first NASA spacecrafts using Honeywell’s stepper-gimbals.

- Azimuth/Elevation Rotary Actuator
- Redundant Absolute 14-bit Optical Encoders
- Redundant Coaxial and Power/signal Cables
- Mechanical Stops: Az ± 202°, El -29° & + 97°
- Titanium and Aluminum Structure
- 36 lbs. Total Weight
- 1.2 Deg/sec Slew Speed
- Life Test– 10 Yr Duty Cycle
- Delivered September 1995
Advanced Gimbal System (AGS)

- **Control torque**
  - Elevation: 34 N-m
  - Lateral: 34 N-m
  - Roll: 14 N-m

- **Angular range**
  - Elevation: +100/-60 deg
  - Lateral: ±60 deg
  - Roll: ±60 deg

- **Pointing accuracy**
  - Using ideal inertial sensor: 0.1 arcsec
  - Using gimbal resolvers: 27.7 arcmin
DMSP Scan Drive Assembly (SSMIS)

- 31.6 RPM
- 7 year life
- 50 Sliprings
- Redundant Optical Encoder
- 2.9 ArcSec Accuracy
- Redundant Motors
- 25 lbs
SeaWinds Scatterometer Antenna Subsystem

- Major Subassemblies
  - Spin Actuator Assembly
  - Antenna Assembly
  - Electronics Assembly
  - Base Structure Assembly
- Selectable 18 or 20 rpm spin rates
- Redundant 15 bit encoder
- Redundant brushless DC motors
- Dual Channel RF rotary joint
- 4.5 year design life
- Delivered 6/97 for ADEOS II
- Delivered 4/98 for QuikScat - launched 6/99
ISS Assembly/Contingency Subsystem (ACS)

Antenna Gimbals

Two-axis Pointing Gimbal for the ISS High-gain Antenna

Application: Primary Communication for ISS to Ground

<table>
<thead>
<tr>
<th>Characteristics</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Drive Config</td>
<td>Stepper Motor</td>
</tr>
<tr>
<td></td>
<td>30:1 Anti-Backlash Spur Gear</td>
</tr>
<tr>
<td></td>
<td>80:1 harmonic Drive</td>
</tr>
<tr>
<td>Coverage</td>
<td>-1 deg to +135 deg (Elev.)</td>
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<tr>
<td></td>
<td>±236 deg (Azim.)</td>
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<tr>
<td>Output Step Size</td>
<td>0.01875</td>
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<tr>
<td>Angular Rate</td>
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<tr>
<td>Holding Torque</td>
<td>9 in-lbs</td>
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<tr>
<td>Torsional Stiffness</td>
<td>15,000 in-lbs/rad</td>
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<td>Envelope</td>
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<td>Weight</td>
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<td>Payload Capability</td>
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<td>Connections</td>
<td>1 TS Quad</td>
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<tr>
<td></td>
<td>1 Coaxial</td>
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<tr>
<td>Life</td>
<td>19.5 years</td>
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<tr>
<td></td>
<td>18.9 ((10^6)) deg motion @ 0.06 deg/sec</td>
</tr>
<tr>
<td></td>
<td>550 ((10^6)) deg motion @ 9 deg/sec</td>
</tr>
<tr>
<td>Direction Changes</td>
<td>190,000</td>
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ISS Space-to-Ground Subsystem (SGS)

Antenna Gimbals

<table>
<thead>
<tr>
<th>Characteristics</th>
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<tbody>
<tr>
<td><strong>Drive Config</strong></td>
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<tr>
<td>Stepper Motor</td>
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<tr>
<td>19:1 Anti-Backlash Spur Gear</td>
</tr>
<tr>
<td>160:1 harmonic Drive</td>
</tr>
<tr>
<td><strong>Coverage</strong></td>
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<tr>
<td>±121 deg (Elev.)</td>
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<tr>
<td>±48 deg (Cross Elev.)</td>
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<tr>
<td><strong>Output Step Size</strong></td>
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<tr>
<td>0.005</td>
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<tr>
<td><strong>Angular Rate</strong></td>
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<tr>
<td>0 to 5 deg/sec</td>
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<tr>
<td><strong>Holding Torque</strong></td>
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<tr>
<td>90 in-lbs</td>
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<td><strong>Torsional Stiffness</strong></td>
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<td>375,000 in-lbs/rad</td>
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<td><strong>Envelope</strong></td>
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<td>12” x 12” x 25.0”</td>
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<td><strong>Weight</strong></td>
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<td>70 lbs</td>
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<td><strong>Payload Capability</strong></td>
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<td>75 lbs</td>
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<tr>
<td><strong>Connections</strong></td>
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<tr>
<td>1 Two Axis Rotary Joint</td>
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<tr>
<td>14 bit Optical Encoder</td>
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<tr>
<td><strong>Life</strong></td>
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<tr>
<td>19.5 years</td>
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<tr>
<td>18.9 (10^6) deg motion</td>
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<tr>
<td>@ 0.06 deg/sec</td>
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<tr>
<td>293 (10^6) deg motion</td>
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<tr>
<td>@ 3 deg/sec</td>
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<tr>
<td><strong>Direction Changes</strong></td>
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<tr>
<td>400,000</td>
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</table>

Two-axis pointing gimbal for the ISS parabolic antenna
APS Antenna Gimbal Drive

- Redundant Brushless DC Motors
- Direct Drive
- 40 W Peak Power
- 20 in.-Oz Output Torque

- Redundant Single-speed Resolvers
- ± 4 Arcmin Accuracy
- Duplex Bearing Pairs - 1 Fixed, 1 Floating
- Flex Capsule for Power and Telemetry Transfer
- Low Loss RF Rotary Coupler
- Lubrication Type Determines Life
Explorer Platform (EP) Modular Antenna Pointing System (MAPS)

Antenna Gimbals with Deployed Mast

Steering Control Electronics (2) and Remote Interface Units (2) on Mast Canister
Gimbal Torquer Drives (GTD)

- Roll and pitch drives
- 3.8 ft-lb, 24 pole BDC, low ripple motors
- Resolver commutation
- Output torque
  - Roll: 74 ft-lb
  - Pitch: 243 ft-lb
- System weight
  - Roll: 28 lb
  - Pitch: 31 lb

Delivered for a Restricted Program
Honeywell designed, developed and built the **Optical Chopper Assembly (OCA)** for the Pressure Modulated Infrared Radiometer (PMIRR), a scientific instrument that flew aboard the Mars Observer.

Honeywell’s OCA functioned as an optical switch alternating beam paths between detectors within the PMIRR instrument.
## Control Electronics Heritage

<table>
<thead>
<tr>
<th></th>
<th>Drive Electronics</th>
<th>Control Electronics</th>
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<tbody>
<tr>
<td>AGS</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>SeaWinds</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>AMSR</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>STAPS</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>HGAS/MAPS/TOPEX</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Galileo SAS/SBA</td>
<td>Yes</td>
<td>Yes</td>
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<tr>
<td>DMSP SSMIS</td>
<td>No</td>
<td>No</td>
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<tr>
<td>QuikScat</td>
<td>Yes</td>
<td>Yes</td>
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<tr>
<td>EOS-AM</td>
<td>No</td>
<td>No</td>
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<tr>
<td>ACS</td>
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<td>No</td>
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<tr>
<td>SGS</td>
<td>No</td>
<td>No</td>
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</tbody>
</table>
Flex Capsule and Cable Wrap Assembly Heritage

- Galileo SAS - 200 channel flexcapsule assembly - +/- 100 degrees
- ISS SGS - Two axis cable wrap including 6 coaxial cables
- ISS ACS - Two axis cable wrap, coaxial cables
- APGS - Optical fiber cable wraps
RF Rotary Joints

- Dual Channel Rotary Joint (SeaWinds, & QuikScat @ 12 GHz)
- Single Channel Rotary Joint (STAPS, HGAS, TOPEX, & MAPS @ 3 GHz)

Honeywell worked with RF rotary joint suppliers to qualify the design. Honeywell furnished the bearings and lubrication system.
Deployment Systems Heritage

- Controlled Deployment - Velocity controlled with an eddie current damper, latched into place (TOPEX)

- Deploy/Retract Mechanisms - Controlled with a redundant drive motor (HGAS & MAPS)

- Launch Retention - Several designs using pyro devices, flangibolts, paraffin actuators (VISS, TOPEX, Polar Laboratory)
Position Sensors

- Single & Multi-Speed Resolvers
  - CMG’s/HGAS/STAPS/AGS/TOPEX/APS

- Inductisyns
  - APGS

- Optical Encoders
  - Incremental
    - Iridium/ACS
  - Absolute
    - Galileo/EOS-AM/SGS

Honeywell has experience with all types of sensors
Expanded Production Capability

- State-of-the-art assembly, integration & test area (Class 100,000 and 100 flow hoods)
- Grand Opening of enhanced facility (March ‘99)
- Accommodates production of various types of actuators (linear, rotary, solar array drives, and gimbals)
On-Line Work Instructions

**On-line database:**

- Each work station has a monitor which has access to the electronic work instructions.
- Each necessary record is referenced in the work instructions and hyperlinked to an input table. All information is stored on a database by end item serial number.
- Paper back-up system is in place.
- Information is entered by keyboard or bar code.
- All prints and Mspecks are accessible on line.

![Image of a computer monitor and keyboard with text overlay](image.png)
Automated Test Equipment Console

- Automated Multi-channel test console in place.
  - Capable of testing 8 units simultaneously.
  - Lab View based operating system
  - Modular hardware and software design
    - Replaceable stepper motor drivers (3-phase or 2-phase)
    - Same application software can be activated to test up to 8 units.
      - One application simplifies software change process.
      - Minimizes possibility of errors
  - Expandable to test power / signal data transfer assemblies (Solar Array Drives) - Planned for the future
Concurrent Data Reduction

- Real Time Data Reduction
  - Numerical print out
  - Graphical print out
  - Real time data evaluation (PASS / FAIL criteria)

- Data Trending Capability
  - Currently being implemented
  - “In Family” data comparison
  - Simplification of data packages for internal and customer review

---

### Test Information

<table>
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<tr>
<th>Program</th>
<th>File Name</th>
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<table>
<thead>
<tr>
<th>Test Name</th>
<th>Test Time</th>
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<tbody>
<tr>
<td>5.1</td>
<td>8:00 am</td>
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<table>
<thead>
<tr>
<th>Test Paragraph</th>
<th>Test Date</th>
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<tbody>
<tr>
<td>5.1</td>
<td>1/10/99</td>
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<table>
<thead>
<tr>
<th>IT Document</th>
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<tr>
<td>IT12345678</td>
<td>pX0000000000000</td>
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<table>
<thead>
<tr>
<th>Tester</th>
<th>Total Test Time</th>
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<tbody>
<tr>
<td>Rick Self</td>
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<table>
<thead>
<tr>
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<table>
<thead>
<tr>
<th>Serial Number</th>
<th>Temperature</th>
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<tr>
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<td>Ambient</td>
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</table>

**Pre Test Comments**

- ME5 - post-vibe mechanical/electrical measurements & 25C (0-240 steps in 1 step increment)

### Results

<table>
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<tr>
<th>Parameter</th>
<th>Max</th>
<th>Min</th>
<th>Units</th>
<th>Spec Max</th>
<th>Spec Min</th>
<th>Pass/Fail</th>
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<tbody>
<tr>
<td>Mechanical Output Position Error</td>
<td>0.003</td>
<td>-0.0069</td>
<td>deg</td>
<td>0.035</td>
<td>-0.035</td>
<td>Pass</td>
</tr>
<tr>
<td>Fine Primary Potentiometer - Deviation</td>
<td>0.003</td>
<td>-0.0064</td>
<td>volts</td>
<td>0.0178</td>
<td>-0.00782</td>
<td>Pass</td>
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<tr>
<td>Fine Secondary Potentiometer - Deviation</td>
<td>0.0198</td>
<td>-0.0042</td>
<td>volts</td>
<td>0.0178</td>
<td>-0.00782</td>
<td>Pass</td>
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<td>Course Primary Potentiometer - Deviation</td>
<td>0.0000</td>
<td>-0.0008</td>
<td>volts</td>
<td>0.0056</td>
<td>-0.0056</td>
<td>Pass</td>
</tr>
<tr>
<td>Course Secondary Potentiometer - Deviation</td>
<td>0.0000</td>
<td>-0.0008</td>
<td>volts</td>
<td>0.0056</td>
<td>-0.0056</td>
<td>N/A</td>
</tr>
</tbody>
</table>

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### Plotted Data

**Primary Potentiometer Plotted Data (VDC)**

**Coarse Potentiometer Plotted Data (VDC)**

**Mechanical Output Position Error (deg)**

---

**Tester Signature ________________________________ Date:_________________**

**Engr Signature:     _______________________________ Date: _________________**

**REF TMR (If Required):___________________________**

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**Honeywell**
Multiple Unit Test Capability

- Thermal Vacuum Testing
  - Multiple unit test capability
    - 4 rotary actuators simultaneously
    - Quick set up test fixtures
    - Test console has been programmed to perform standard test routines

[Images of test equipment and setups]
Conclusions

- Modular Product Design
  - Interchangeability of parts / Component and subassembly performance characterization / Low part count
  - Multiple applications

- Advances in Production Capability
  - On-line work instructions / Automated Test Console / Expanded facilities

- Customer Emphasis
  - Customer tailored testing profiles and sequencing / Expanded thermal operational range translates to a more reusable design (better suited for Hall thruster application)