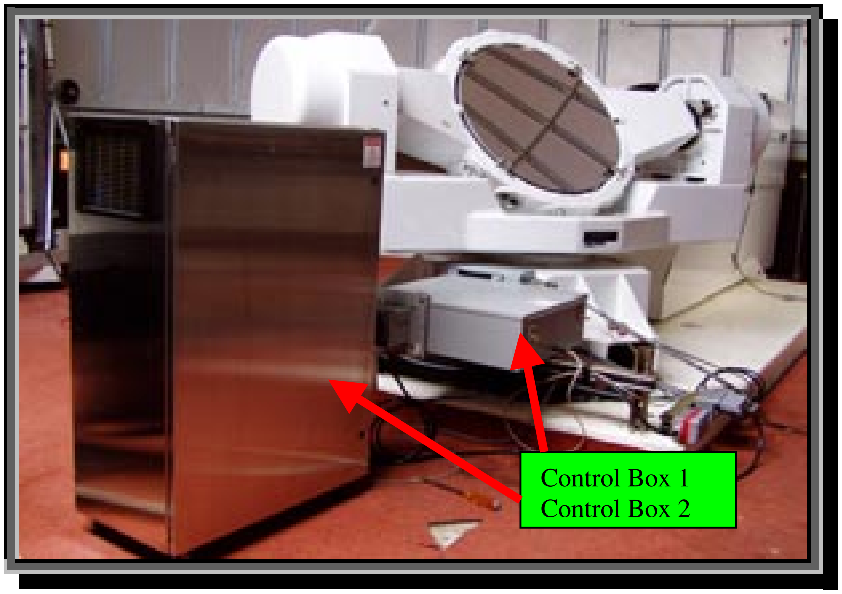
Replacement of the LURE Telescope Controller
Using
Commercial Off-The-Shelf Components

W.Lindsey, D.O'Gara, M.Waterson, J.Kamibayashi
University of Hawai`i, Institute for Astronomy
LURE Observatory at Haleakala, Maui

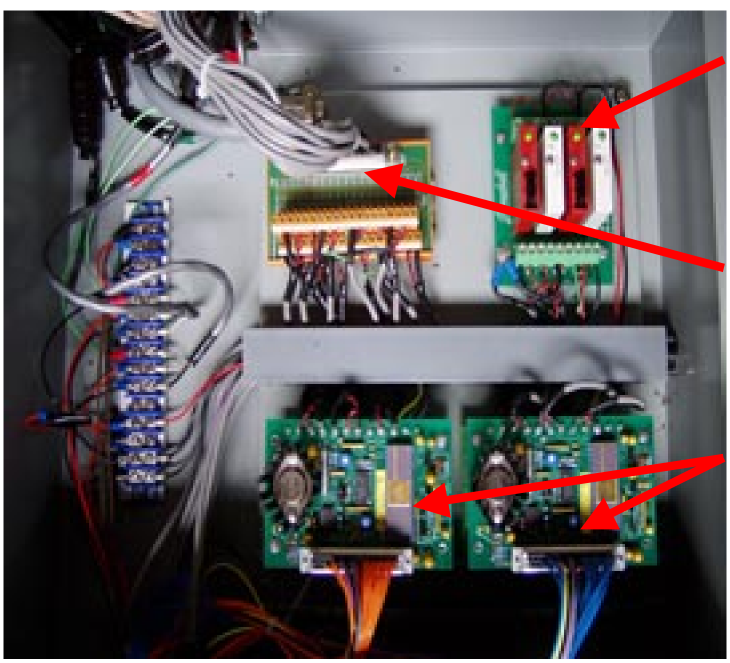
Abstract:

The original 1972 vintage telescope controller at LURE (HOLLAS) had been replaced in March 2000 with a system designed and constructed by a sub-contractor. This system did not meet specifications, and before it could be fixed, the sub-contractor when out of business. A few weeks of research convinced us that a replacement could be designed and constructed using only commercial off-the-shelf components, and could be completed in less time and for less money by using University technicians and engineers rather than going out for bid and engaging another sub-contractor. The performance of the University designed system met or exceeded the original technical specifications. The final product could be used as designed by any telescope system that uses Inductosyn® transducers, or position sensors that output A quad B signals, and is driven by DC torque motors. This paper will identify the commercial products used, the basic design of the controller, and the performance attained.

Luna-Stat Mirror and Control Boxes

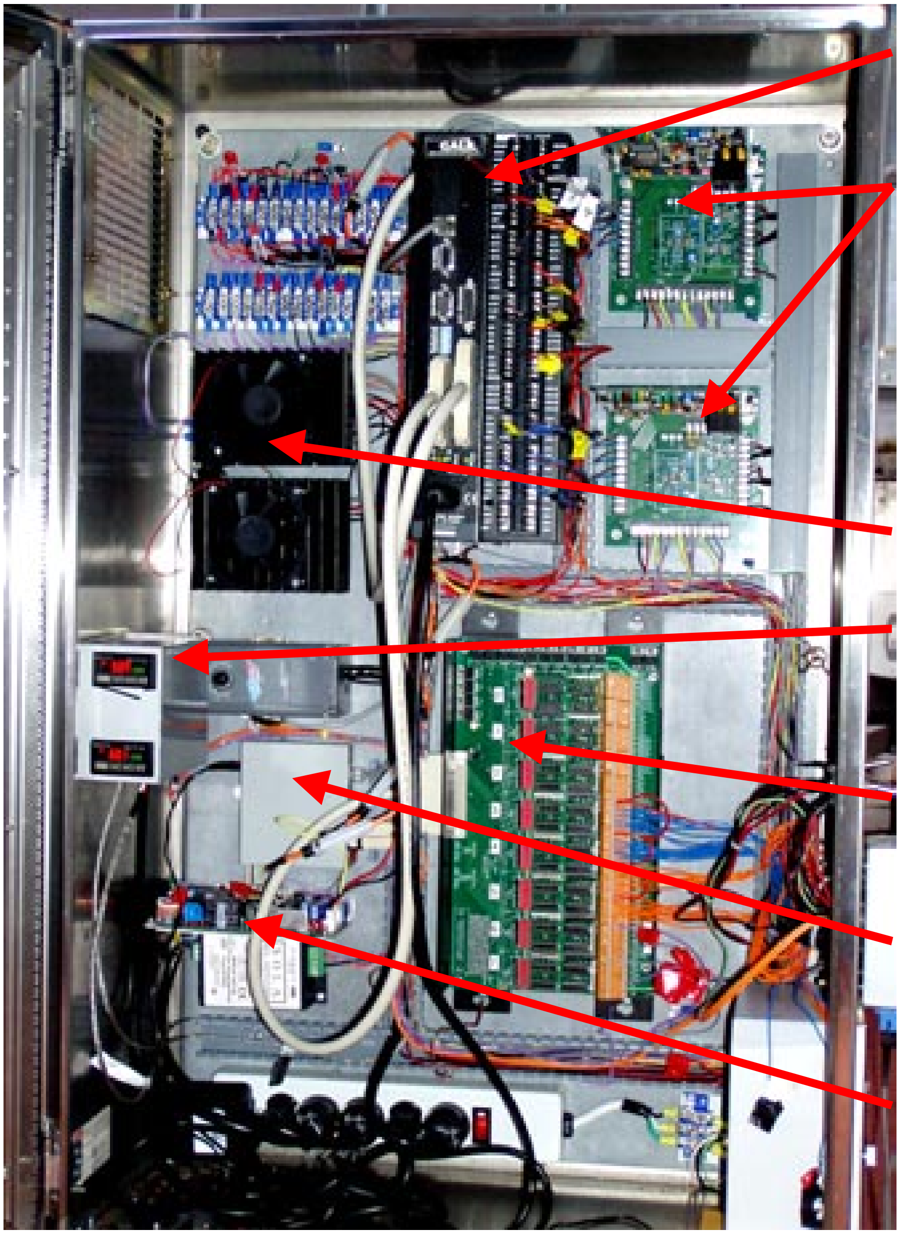


Control Box 1



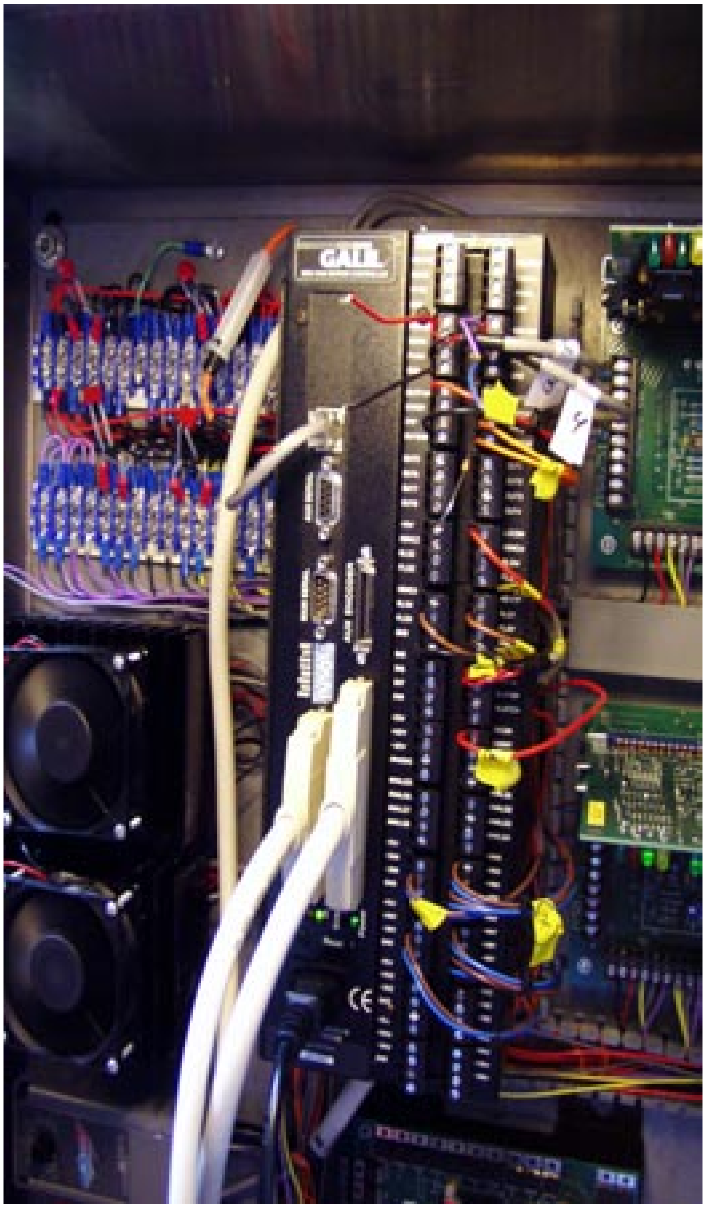
- 20pps Synchronization input from the XL-DC TrueTime Rb Clock.
- Connection for the Inductosyn® and Resolver sensors on the mount.
- Farrand® Azimuth and Elevation Resolver to Digital Converters. (Inductosyn Pre-Amplifiers located beneath the Resolver to Digital Converters.)

Control Box 2

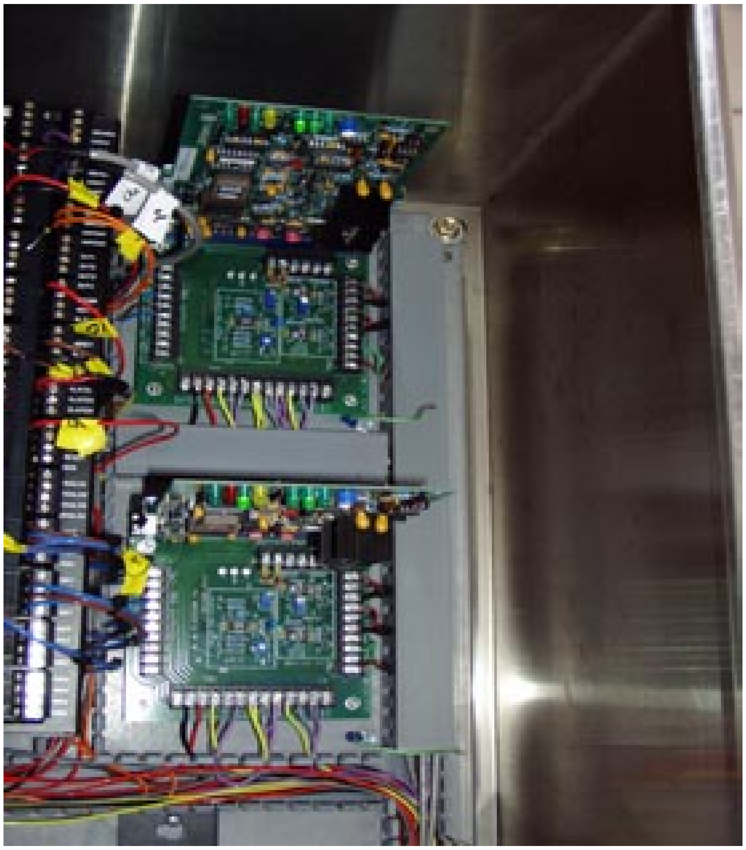


- Galil® Motion Control Computer.
- Farrand® Azimuth and Elevation Inductosyn® to Digital Converters.
- Inland® Motors Azimuth and Elevation Servo Amplifiers.
- Servo Amplifier Temperature Monitor and Displays.
- Galil Opto-Isolated Inter-Connect Module.
- Optical Fiber to 10BaseT Media Converter.
- DC Power Supplies.

Galil DMC-2120 Motion Controller Specifications

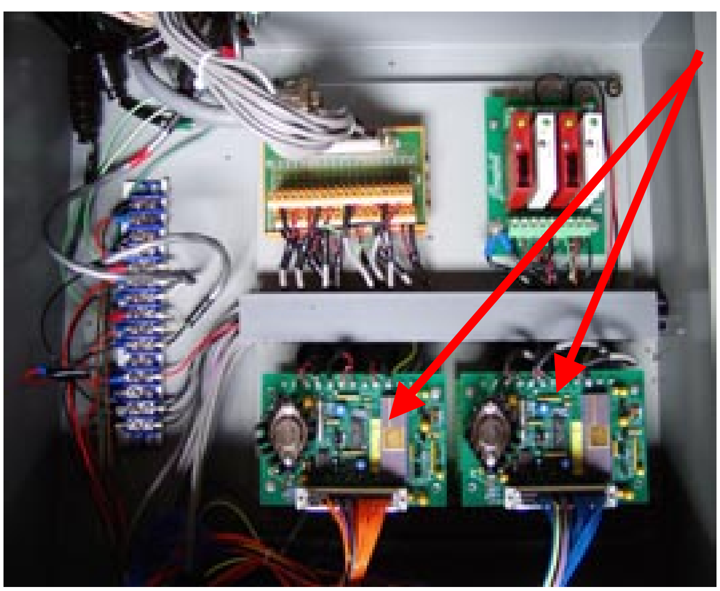


- 2 Axis control.
- Ethernet Connectivity and 1 RS232 port up to 115kb.
- Accepts up to 12MHz encoder frequency.
- Advanced PID (Proportional/Integral/Derivative) compensation.
- Velocity and Acceleration feedforward, Integration limits, Notch and Low-Pass filtering.
- Sample time of 125.0 microseconds.
- Multitasking for concurrent execution of up to 8 on-board application programs.
- Modes of Motion include Jogging, Linear and Circular interpolation and Absolute and Relative Positioning.
- 8 Uncommitted inputs and 8 outputs. Optional Interconnect Module Supplies an Additional 64 I/O Ports.



Farrand Inductosyn to Digital Converter Specifications

- **20,000 Divisions per Inductosyn Cycle (0.18 Arc Second Resolution).**
- **+/- 2 Arc Minute Conversion. (0.333 Arc Second Accuracy).**
- **10KHz Excitation Output Frequency.**
- **15.6 Degrees per Second Maximum Tracking Speed.**



Farrand Resolver to Digital Converter Specifications

- **16 Bit Cyclic Resolution (0.00549 Degree Precision)**
- **+/- 8 Arc Minute Conversion (0.133 Degree Accuracy)**
- **2.4KHz Excitation Output Frequency.**

Performance

The following tables and graphs illustrate performance while pointing to a ground target and while tracking an 82° PCA TOPEX/Poseidon pass.

Ground Target Performance

These Mount Ground Target data were extracted at one-second intervals during 6 calibrations taken over an eight-hour period. All angle data are in units of degrees.

	Azimuth	Elevation
Command Angles	148.6715	-5.0821
Minimum	148.6714	-5.0825
Maximum	148.6718	-5.0817
Samples	6081	6081
Mean	148.67154	-5.08209
Median	148.67150	-5.08210
RMS	148.67154	5.08209
Std Deviation	0.000090	0.000170

Satellite Tracking Performance

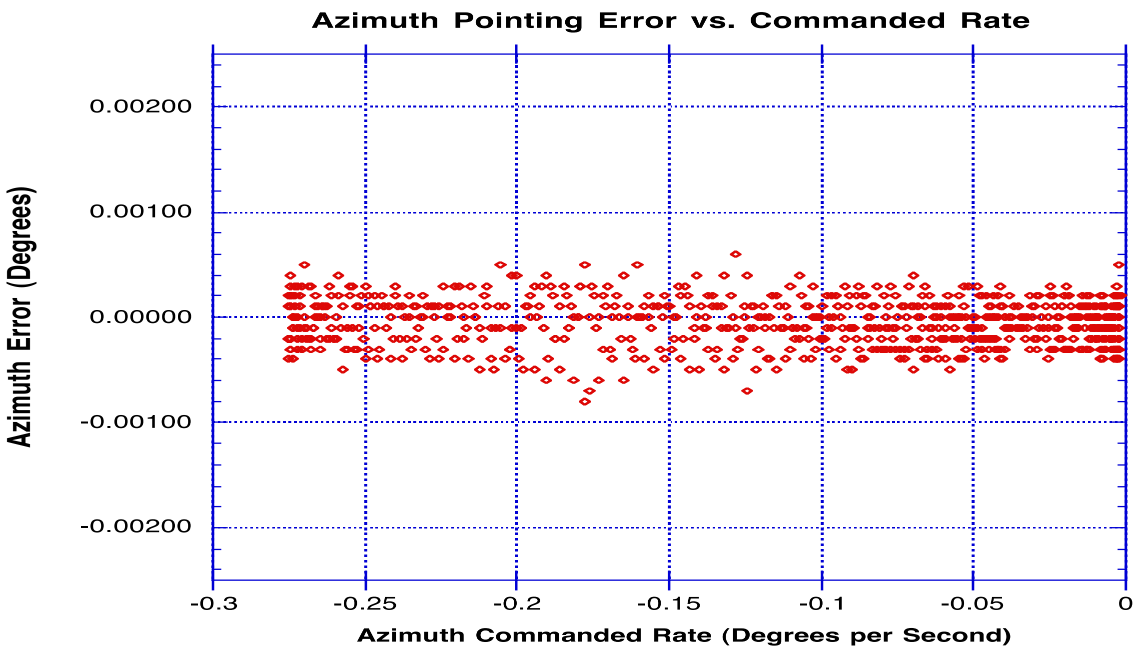
Representative Mount Tracking Error Data from a Topex/Poseidon Pass culminating at 82° Elevation. A Sample of the Pointing Error was taken once per second during the entire pass. All angle values are in units of degrees.

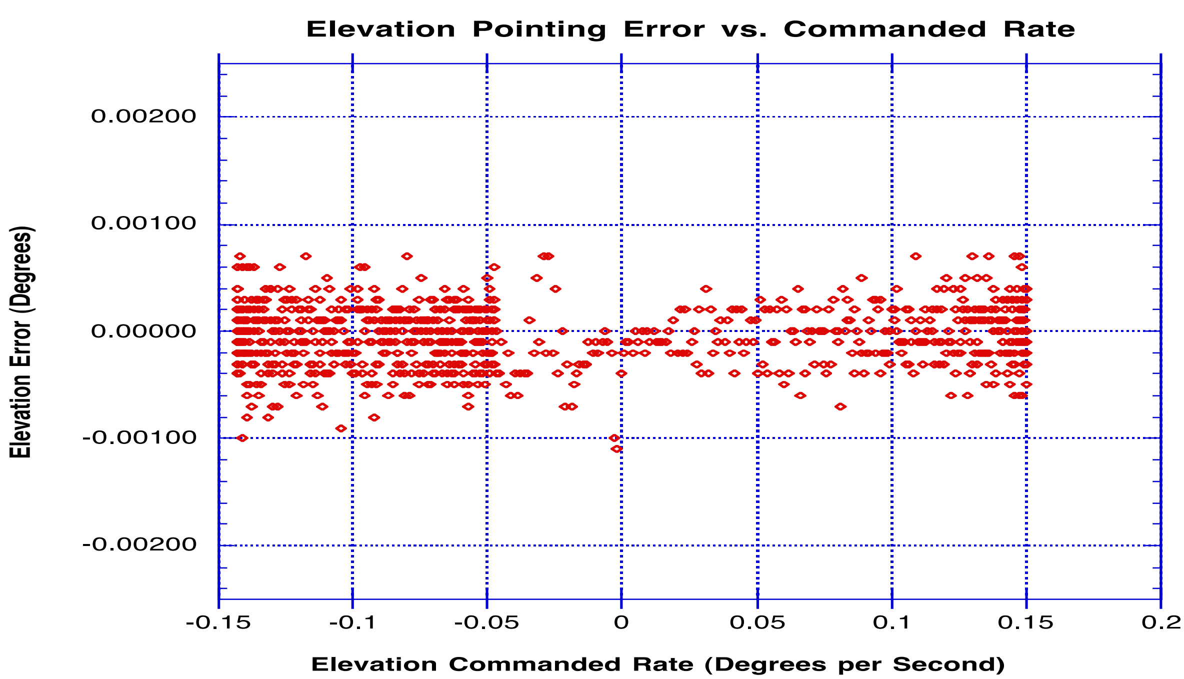
Azimuth Tracking Error Statistics

Minimum	-0.0008
Maximum	0.0006
Samples	840
Mean	-0.000061
Median	-0.000100
RMS	0.000220
Std Dev	0.000210

Elevation Tracking Error Statistics

Minimum	-0.0011
Maximum	0.0007
Samples	840
Mean	-0.000053
Median	-0.000100
RMS	0.000290
Std Dev	0.000280


Azimuth Pointing Error vs. Commanded Rate
Azimuth Error (Degrees)
0.00200
0.00100
0.00000
-0.00100
-0.00200
-0.3
-0.25
-0.2
-0.15
-0.1
-0.05
0
Azimuth Commanded Rate (Degrees per Second)


Elevation Pointing Error vs. Commanded Rate
Elevation Error (Degrees)
0.00200
0.00100
0.00000
-0.00100
-0.00200
-0.15
-0.1
-0.05
0
0.05
0.1
0.15
0.2
Elevation Commanded Rate (Degrees per Second)

Functional Overview

- **Analog Sine and Cosine signals from the Inductosyn sensors are converted to A Quad B signals by the Farrand I/D converter. These digital outputs are then read by the Galil Motion Controller and converted to Azimuth and Elevation angles by University of Hawai`i supplied software resident on the Galil.**

- **The Galil Motion Controller interprets the digital inputs and provides both direction and magnitude of axis motion.**

- **The Resolver signals are converted by the Farrand R/D Converter to a 16-bit representation of the angle. The Resolver is used for "HOMING" the mount only.**

- **The Inductosyn is used to monitor axis position once the "HOME" has been established.**

- **Physical communication layer between Tracking Computer and Galil Controller is an optical fiber and a 10Mbs Ethernet connection.**

- **Satellite Tracking Software is synchronized with the Galil Controller using a 20pps output of the Station Rubidium Clock.**

- **A TCP/IP Socket connection is established between the tracking computer and the Galil controller. Position and command information is sent/received 20 times a second (every 50milliseconds) via this connection.**

- **The Galil "JOG" mode is used to command the mount to move while tracking a satellite or star. The JOG rate is calculated by an algebraic combination of the calculated rate, the current pointing error, and a factor that is a function of the calculated rate.**

- **Positioning to Ground Targets is achieved by the Galil "Position Absolute" mode.**