High-Speed Enhancement to HTSI Event Timer System

David McClure, Charles Steggerda, Scott Wetzel

Honeywell Technology Solutions Inc.,

7515 Mission Drive,

Lanham, MD USA 20706

15th International Laser Ranging Workshop
"Extending the Range"
October 15-20, 2006, Canberra, Australia

High-Speed Enhancement to HTSI Event Timer System

Abstract

HTSI has developed a high-performance Event Timer Controller to pair with the HTSI Event Timer that allows acquisition of UTC tagged event epochs with <2ps jitter and 0.5ps resolution from up to 12 input event channels at continuous asynchronous event acquisition rates of over 50kHz. The increase in sustainable data rate allows easy integration of multiple or arrays of detectors and generation of a single real-time stream of UTC epoch'd event data with associated channel ID flags.

This paper describes the upgrades to the HTSI event timer system that enable the high-speed capability. The content will include a data comparison of ILRS stations utilizing the HTSI event timer as well as a discussion of current usage applications and potentials for future use.

HTSI Event Timer Description

The HTSI Event Timer (ET) generates precise epoch time-tags ideal for Satellite Laser Ranging, Lunar Laser Ranging, and other precision timing applications.

In the single vernier configuration, the ET provides better than 2 ps of resolution and less than 4 ps of Root-Mean-Square (RMS) jitter.

In the four vernier configuration, the ET provides measurement redundancy and increases the effective resolution to <500 fs with an RMS jitter of < 2 ps.
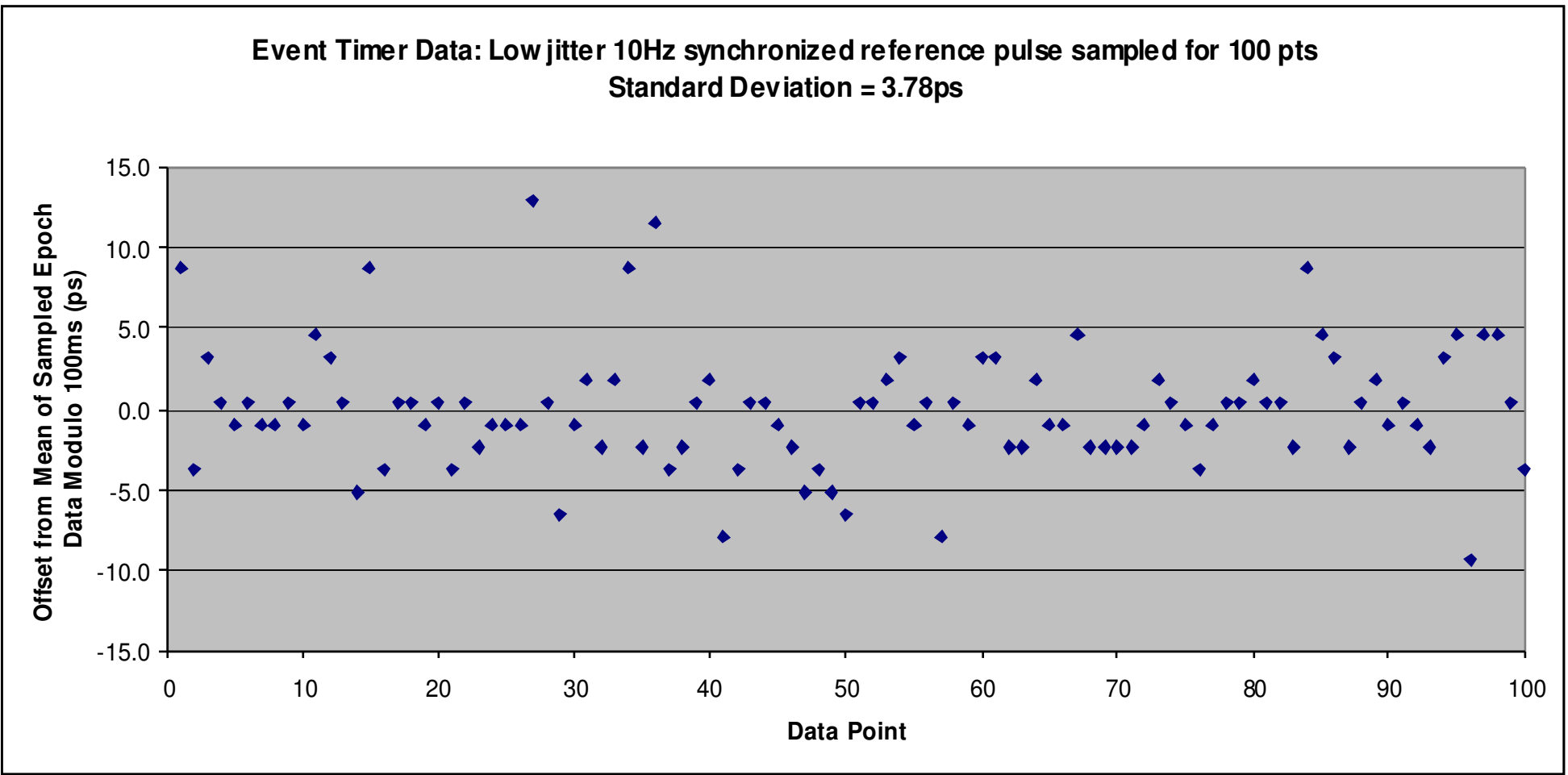
Summary of Specifications

Clock Speed (Internal)	500MHz, Locks to external 10MHz
Input Channels	12 SMA inputs; NIM type; 50Ohm termination; negative pulses (unused channels do not require termination)
Resolution	Better than 2ps (1 vernier); 500 femotoseconds (4 vernier)
Dead-Time	100 Nanoseconds
RMS Jitter	< 5ps for 1 vernier; <2ps for 4 vernier
FIFO Depth	512
Interface	32 bit DIO, Optional computer allows additional interfaces
Software	UNIX (HP-UX, Linux), MS Windows, etc
Power	Auto ranging (100-240V; 50-60Hz)

HTSI Event Timer Past Performance – Ground Station

- **MOBLAS 7** – (Prototype Event Timer; 1998; 3ps RMS)
  - 5 Hz fire, 2 events per frame
  - Use of the HTSI Event Timer produced an immediate 30-40% improvement in MOBLAS 7 data quality over the HP-5370 TIU (Lageos-1 data improved from 9 mm RMS to 5 mm RMS).

- **SLR2000 Prototype** – (Delivered in 1998; 4ps RMS)
  - 2 kHz fire, multiple events per frame, quad PMT

- **MLRO** – (Used in Greenbelt, MD in 1998 and Matera, Italy since 2000; 2ps RMS)
  - 10 Hz fire, 8 events per frame
  - Multiple laser & PMT detection path signals sampled by one event timer.
  - Supported station in achieving 2 mm calibration and 5 mm LAGEOS RMS.
  - Supported station in acquiring two-color and lunar data.

- **GUTS** – (Used in MD in 2002 and Tanegashima, Japan since 2004; 4ps RMS)
  - 10 Hz fire, 4 events per frame
  - Supported station in achieving 2 mm calibration and 5 mm LAGEOS RMS.
  - Supported station in acquiring data from geosynchronous targets.

- **NRL** – Being developed as a stand alone ET for delivery in 2006/2007

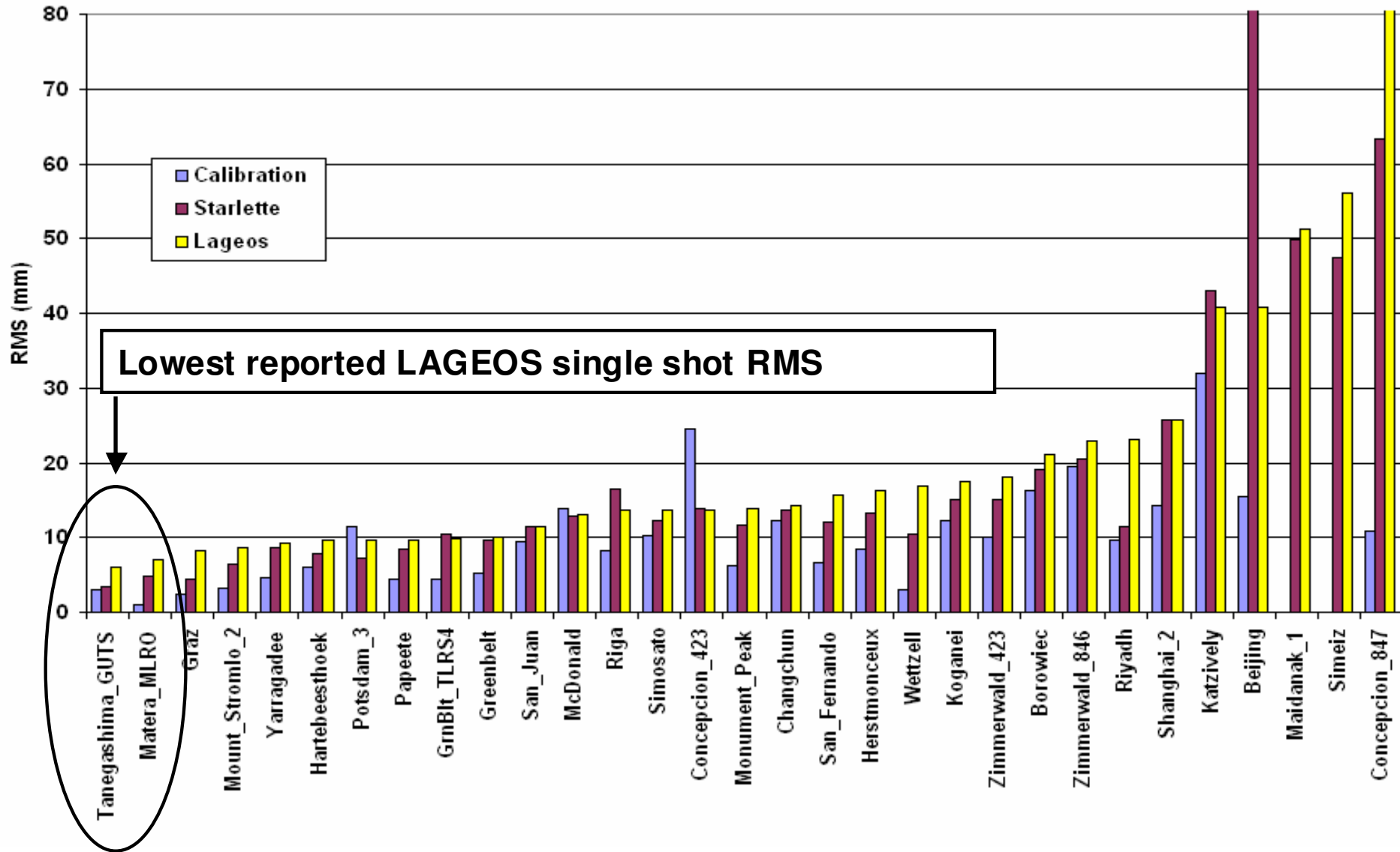- **GUTS Spare** – Being developed for delivery in 2007

Event Timer Accuracy (single vernier)

This graph demonstrates the Event Timer RMS when sampling 100 events from a reference pulse. The data below is raw and unfiltered.

Event Timer Data: Low jitter 10Hz synchronized reference pulse sampled for 100 pts
Standard Deviation = 3.78ps

ILRS Single Shot RMS (2Q 2006)
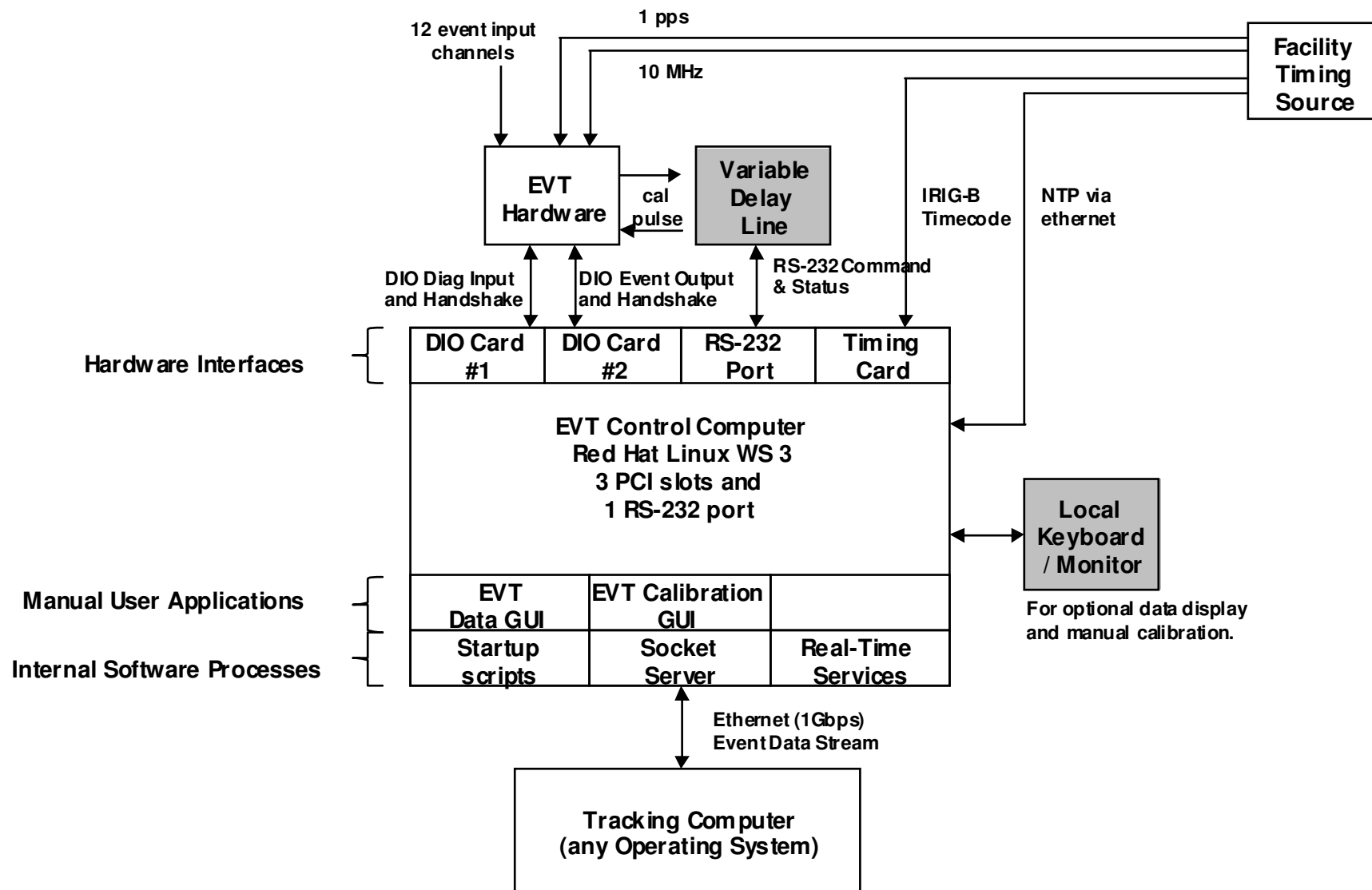## MLRO & GUTS Station Performance Using the HTSI Event Timer

Event Timer Controller Data Rate Background

Challenge: The HTSI ET has always supported Mega-event per second sample rates, but has been limited by the speed of its control computer.

- The GUTS and MLRO ET controller used non-DMA DIO to communicate with the ET at a maximum event rate of approximately 200 events per second (while also performing tracking and controlling other equipment). Counter and verniers were manually addressed by the controller.

- For SLR2000, HTSI converted the ET to use a high-speed DIO card. In addition, the counter and vernier are auto-addressed allowing for DMA transfer operations. This data rate is still limited from sharing control computers with other tasks, 10 Mbps Ethernet speeds and generation of event interrupts.

Solution: HTSI has developed an enhanced Event Timer controller to provide a real-time stream of epoch'd ET data across a dedicated LAN to a station tracking computer. DIO transfer rate is maximized by allowing the ET FIFOs to buffer data. Data is immediately calibrated, combined with UTC coarse time, sent to Ethernet, and received on the tracking computer.
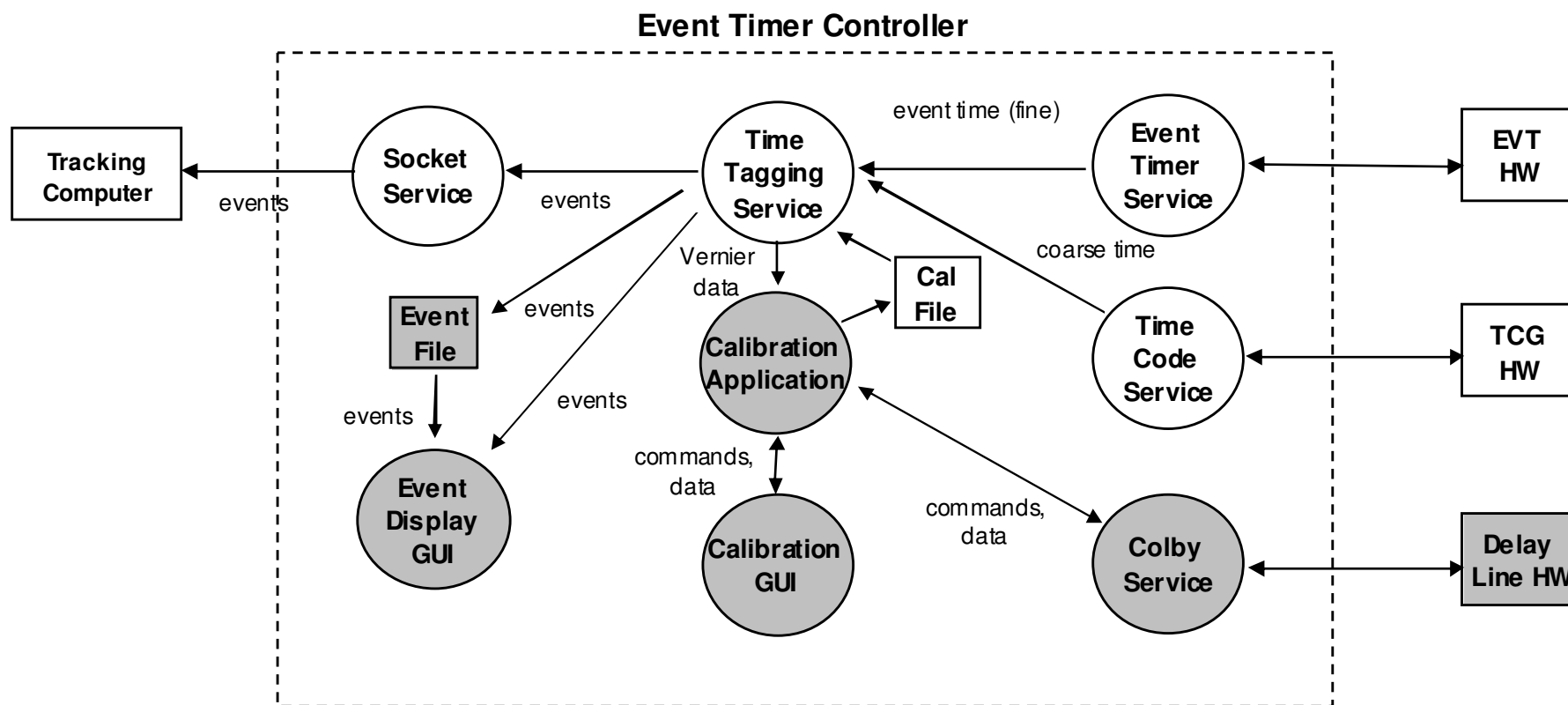
Enhanced Event Timer Controller: Block Diagram

12 event input channels

1 pps

10 MHz

Facility Timing Source

EVT Hardware

cal pulse

Variable Delay Line

IRIG-B Timecode

NTP via ethernet

DIO Diag Input and Handshake

DIO Event Output and Handshake

RS-232 Command & Status

Hardware Interfaces

DIO Card #1	DIO Card #2	RS-232 Port	Timing Card

**EVT Control Computer
Red Hat Linux WS 3
3 PCI slots and
1 RS-232 port**

Local Keyboard / Monitor

For optional data display and manual calibration.

Manual User Applications

EVT Data GUI	EVT Calibration GUI	
Startup scripts	**Socket Server**	**Real-Time Services**

Internal Software Processes

Ethernet (1Gbps) Event Data Stream

Tracking Computer (any Operating System)

Shaded devices are optional

# Enhanced Event Timer Controller: Software Architecture

The Event Timer Software architecture is based on modular C++ UNIX processes inherited from the MLRO and GUTS software heritage. Event Timer and Time Code Generator data is merged to produce a real-time stream of event epoch data.

Event Timer Controller

Shaded devices are optional

Enhanced Event Timer Controller: Initial Results

DIO Performance: Initial DIO laboratory performance tests were able to read reference pulse event times from the ET FIFO buffer at a sustained rate of 5Msamples/sec (**1.25 Mevents/sec** with a 3 vernier + 1 counter ET).
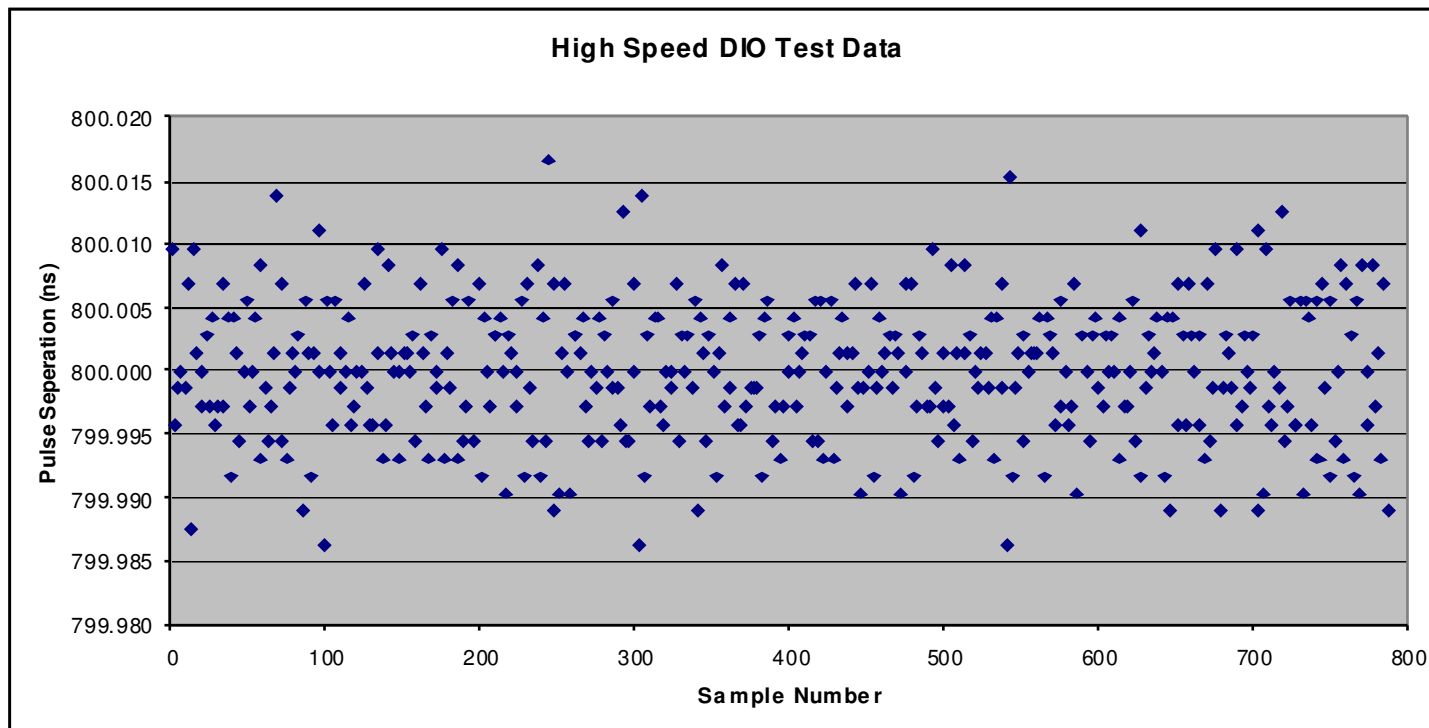
LAN Performance: Initial tests demonstrate that it is possible to sustain network transfer rates of **61,035 events per second** on our current 100Mbps testing LAN (no network traffic analysis tool was available to determine actual network bandwidth usage). Further increase in speed is theoretically possible after tuning of packet sizes and enhancing our laboratory with a 1Gbps network switch.

Enhanced HTSI Event Timer System
Future Application

- Currently the HTSI Event Timer has been used to support:
  - 10Hz single and dual laser fire and return with station calibration events (single and multi-wavelength)
  - 10Hz geosynchronous and lunar laser ranging (multiple shots in the air)
  - 2kHz tracking with 3 high-rate event inputs (6KEvents/sec)

- The Enhanced HTSI Event Timer System facilitates future needs:
  - 2kHz operations with multiple fire and detection events (i.e. for multiple wavelengths / dual PMTs)
  - 2kHz operations with additional station delay diagnostic event inputs
  - Use of arrays of detectors at 2kHz (3x3; 3x4; 4x4 would require external event coupling)
  - Laser fire and return pairs at greater than 2kHz
  - Time transfer experiments (ground and on-orbit)
  - Reduced event timer integration time
  - Reduced real-time tracking controller complexity and cost (ethernet vs. DIO)