SGSLR Range Control Electronics Design and Implementation

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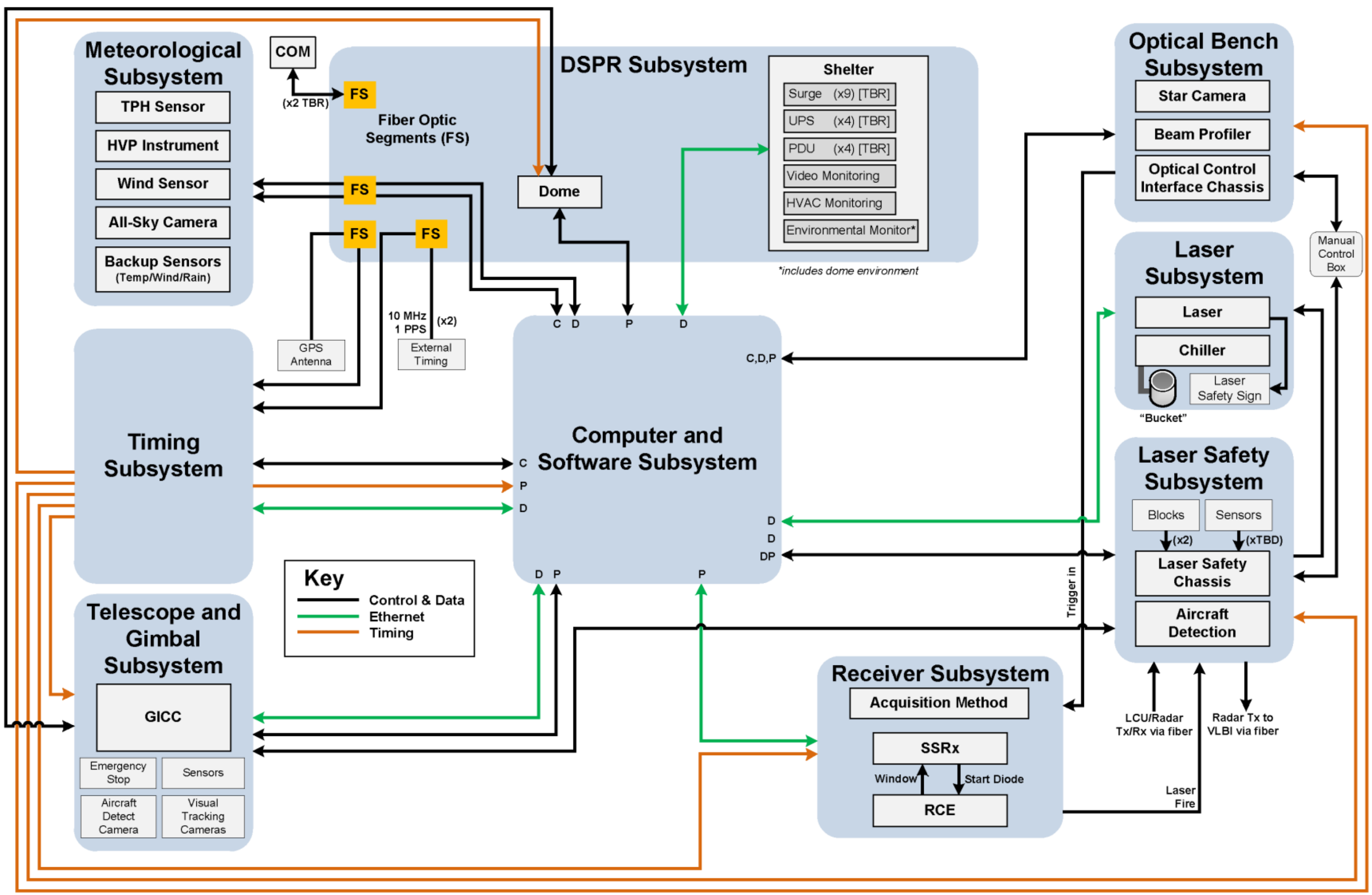
SGSLR Hardware Overview



Range Control Electronics

- Generate a laser fire command and send to the laser subsystem
- Measure the delay between the command and the actual firing of the laser (via the start diode)
- Implement range-dependent pulse repetition frequencies to prevent collisions between transmit and receive pluses
- Generate a window for the receiver based on the predicted range
- Suppress window creation (‘blank’) before and after a laser fire

Temporal Filtering

- Temporal filtering reduces the probability of false alarms (P_{FA}) for a given gate width (T)

$$P_{FA} = 1 - e^{-a_L T}$$

(McDonnel 1977)

$$a_L = \frac{n_b (n_b \tau)^{L-1}}{(L-1)!} \left[\sum_{K=0}^{L-1} \frac{(n_b \tau)^K}{K!} \right]^{-1}$$

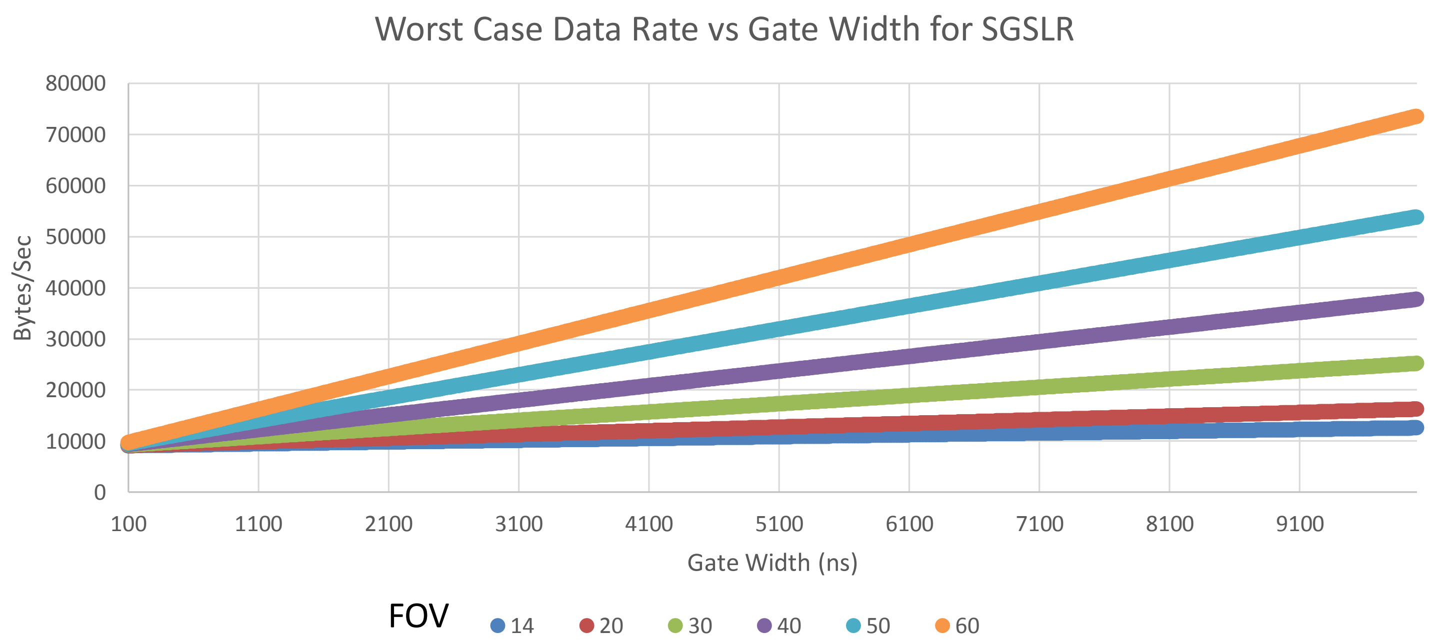
- Must build a sufficient 'temporal histogram' to distinguish noise from signal

$$P_D^{\mathrm{NofM}} = \sum_{i=N}^{M} \frac{M!}{(M-i)!\,i!} \left(P_D^{\mathrm{fr}}\right)^i \left(1 - P_D^{\mathrm{fr}}\right)^{M-i}$$

$$P_{\mathrm{FalseAcq}}^{\mathrm{NofM}} = \sum_{i=N}^{M} \frac{M!}{(M-i)!\,i!} \left(P_{\mathrm{FalseAcq}}^{\mathrm{fr}}\right)^i \left(1 - P_{\mathrm{FalseAcq}}^{\mathrm{fr}}\right)^{M-i}$$

Temporal Filtering

- Temporal filtering reduces data volume to manageable levels
- Maximum background noise rate for SGSLR at 14 arcsecond FOV is estimated to be 13 MHz (Degnan)



PRF Variation

- Pulse repetition frequency (or pulse repetition interval) is varied between a set number of values, in order to prevent collisions between transmit and receive pulses.
- Common transmit/receive optics makes this a necessity in order to maintain data volume

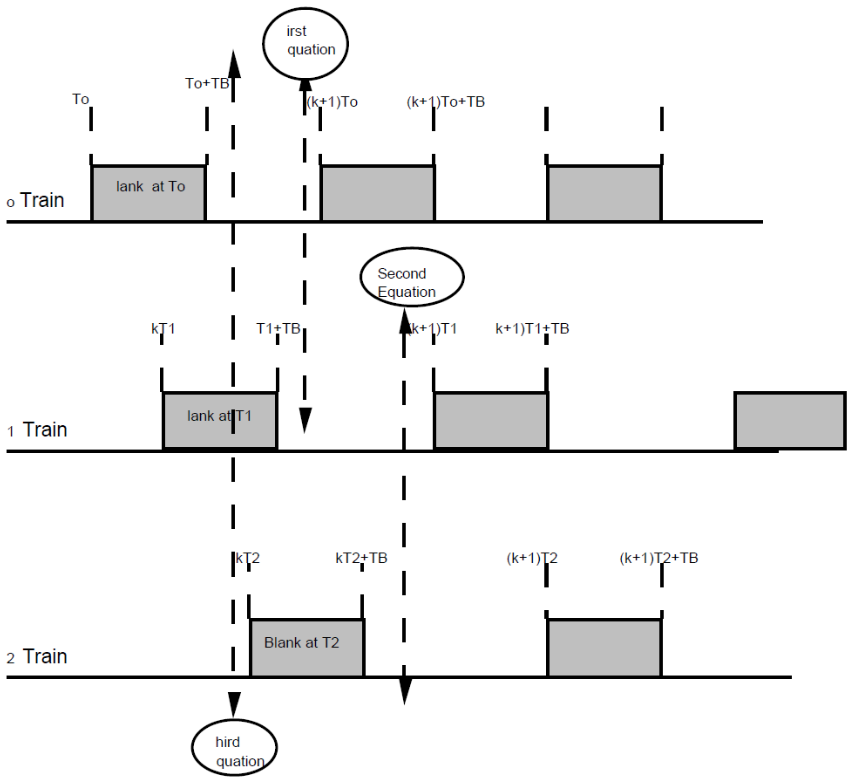


Figure 8. Three PRI clear path conditions.

$$n \geq \left(\frac{T_B}{T_0 - T_B}\right)\frac{k_{max}}{k_{min}} + 1$$

n - number of PRIs required
k - number of pulses in flight
T_B - total blanking time
T_0 - nominal PRI

(Titterton et al., ILRS Workshop Deggendorf 1998)

PRF Variation

- For SGSLR, initial calculations show that 2 PRIs are adequate for most targets. Nominal PRI for SGSLR is 500 microseconds (2 kHz)

$$\frac{T_B}{k_{min}} \leq \delta T \leq \frac{T_0 - T_B}{k_{max}}$$

δT - delta from nomial PRI (assume equal deltas between PRIs)

Satellite	Ranges (km)	PRI value (microseconds)
GEO	30000 to 50000 km	500.5
GNSS+	10000 to 30000 km	501
LAGEOS	3900 to 15000 km	502
MID	1200 to 4000 km	504
LEO	450 to 1300 km	510
GOCE	200 to 500 km	520

Hardware or Software?

"Software and Hardware are logically equivalent"

Any operation performed by software can be built into hardware

Any instruction performed by hardware can be simulated in software

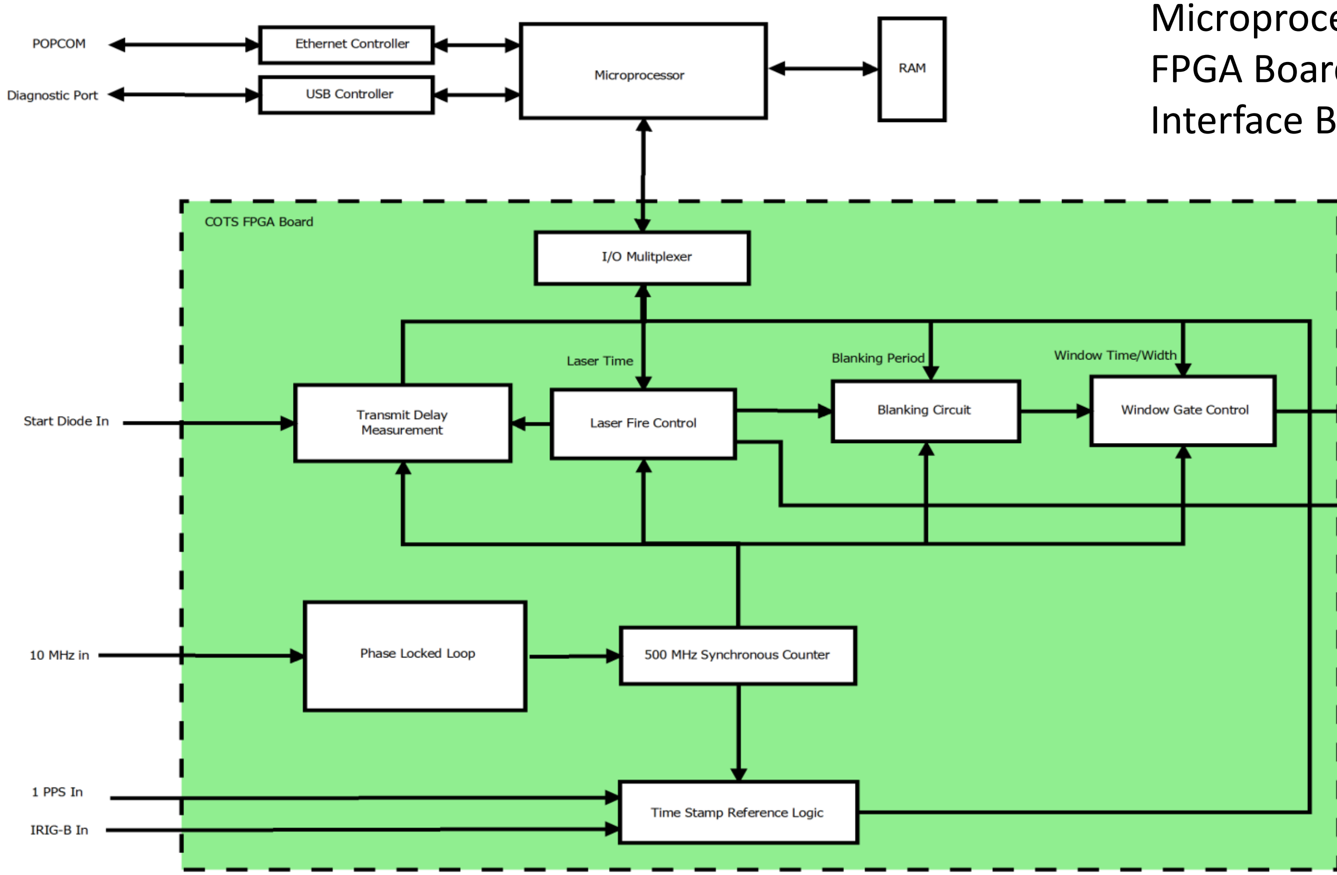
Considerations:

- Cost
- Speed/Performance
- Reliability
- Frequency of Expected Changes

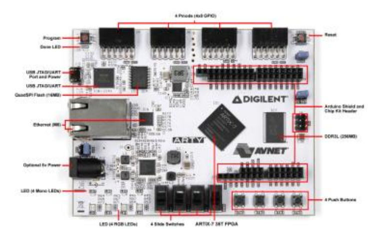
The line between the two has blurred considerably

Source: A. S. Tanenbaum, *Structured Computer Organization*. Prentice-Hall, 1976.

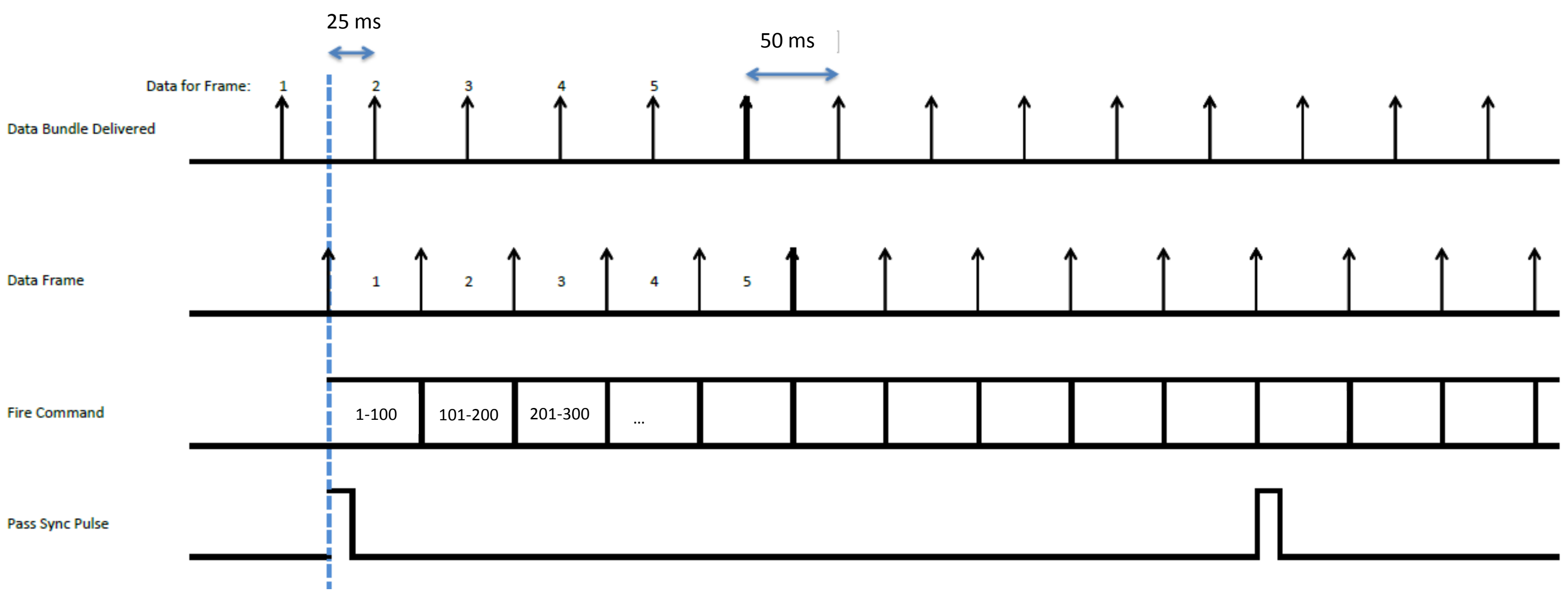
Basic Flow Diagram



Microprocessor Board (COTS)
FPGA Board (COTS)
Interface Board.. That's it!



Data Bundle Timing

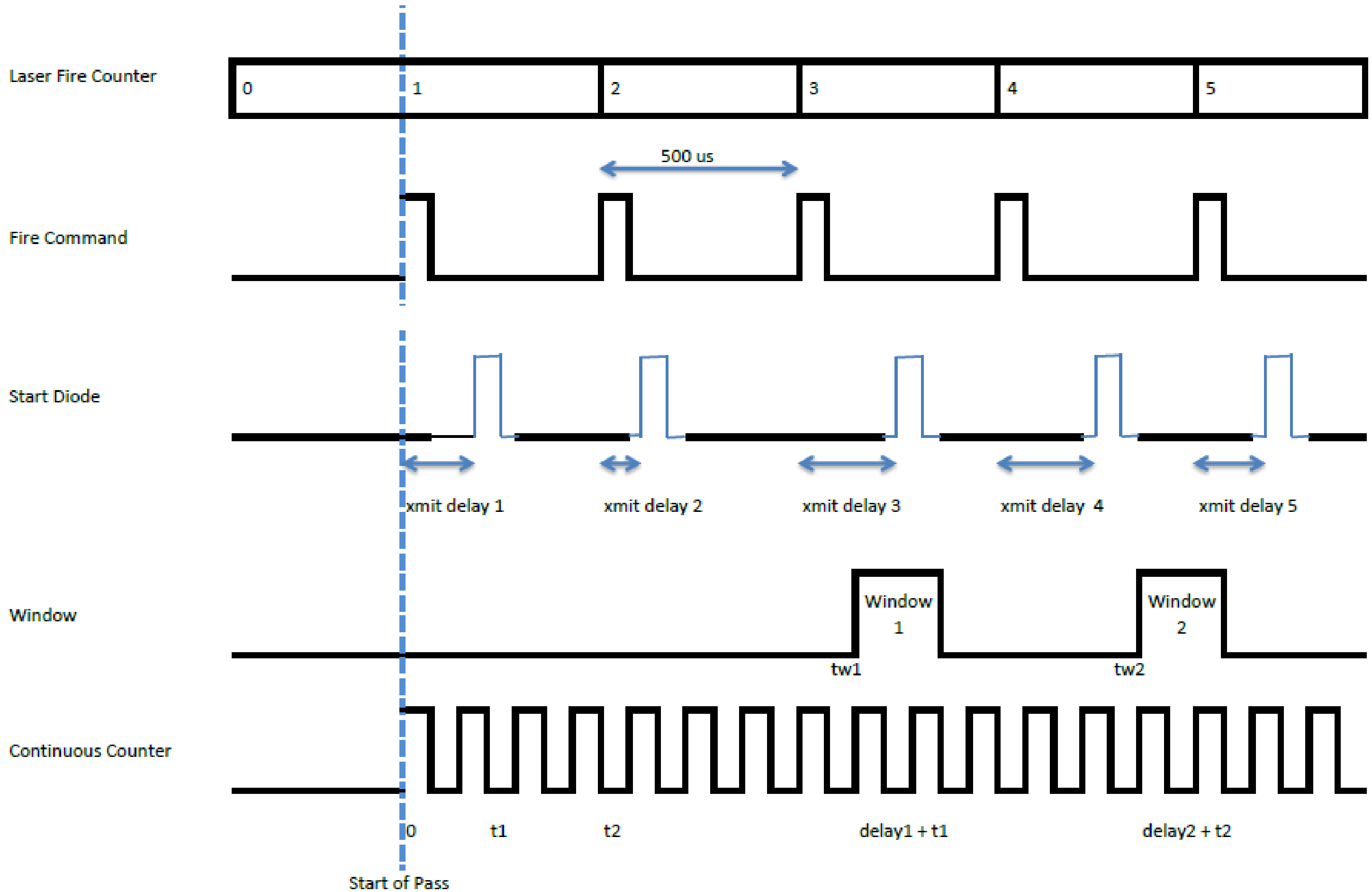


Header
Time Tag
Mode (Internal Cal/Gnd Cal/Satellite/Transponder)
Flags (start/middle/end of pass)
number of elements in bundle
originator ID (POPCOM/RCE)

Bundle rate: 20 Hz

Data (per line)
Fire Number
PRI (resolution 0.1usec)
2 way Time of Flight
Range Window Width

Pulse Timing



Each window can have a unique width (10 ns to 10 us) and timing , with a 2 ns resolution

Improvements from NGSLR

- Bundled Data packets
- Relaxed/minimum inter-computer synchronization requirement - Eliminates previous design constraints to precise real time synchronization with host computer’
  - (future features may further reduce load on the main C&S system via parallel processing)
- Greatly relaxed real-time requirement on C&S system
- Modern interfaces (fast Ethernet via RTNet)
- Updatable Logic Design with fixes/added features in the field
- Much smaller footprint (1U or 2U)
- Inexpensive COTS Components

Conclusions

- Range Control Electronics provide a snapshot into the design philosophy and direction of SGSLR
- Flexible design taking advantage of latest technologies
- Using inexpensive COTS equipment where available to significantly lower maintenance and build costs