

Velodyne® LiDAR



Application Note HDL-32E: Packet Structure & Timing Definition

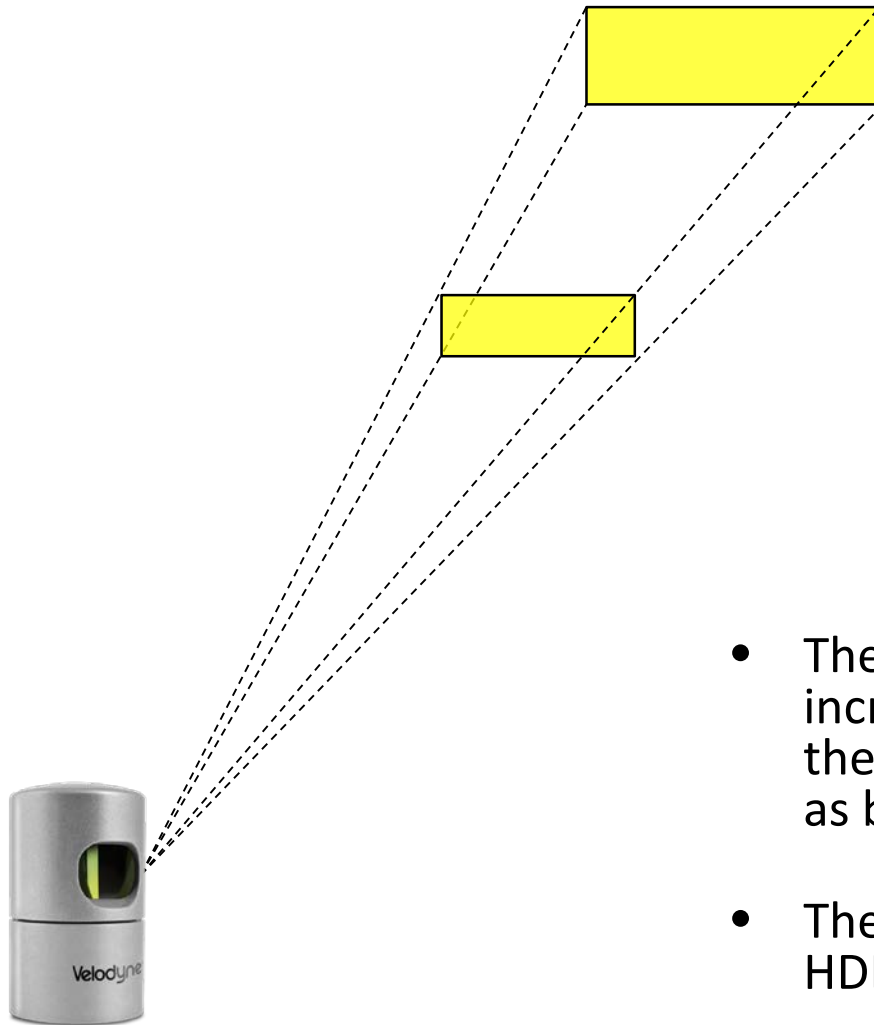
Definitions

- **Firing Sequence**
 - The time and/or process of cycle-firing all the lasers in a HDL-32E.
 - Firing sequence = 46.080 μ s to fire all 32 lasers
- **Laser Channel**
 - A single 905 nm laser emitter and detector pair.
 - Each laser is fixed at a particular elevation angle relative to the horizontal plane of the sensor.
 - The elevation angle of a particular laser channel is given by its location in the data packet.
- **Data Point** (3 bytes) from a single firing from a laser
 - Two (2) bytes of distance.
 - One (1) byte of calibrated reflectivity.
- **Data Block** (100 bytes)
 - Two-byte flag (xFFEE)
 - Two-byte azimuth
 - 32 Data Points (96 bytes)
- **Data Packet**
 - 42 bytes of header
 - 12x Data Blocks
 - Four-byte timestamp
 - Two-byte factory field
- **Return Modes**
 - Strongest (Default) = The strongest (by light energy) return is reported
 - Last = The last (temporally) return detected is reported
 - Dual = Both the **Strongest** and **Last** returns are reported

Single & Dual Returns

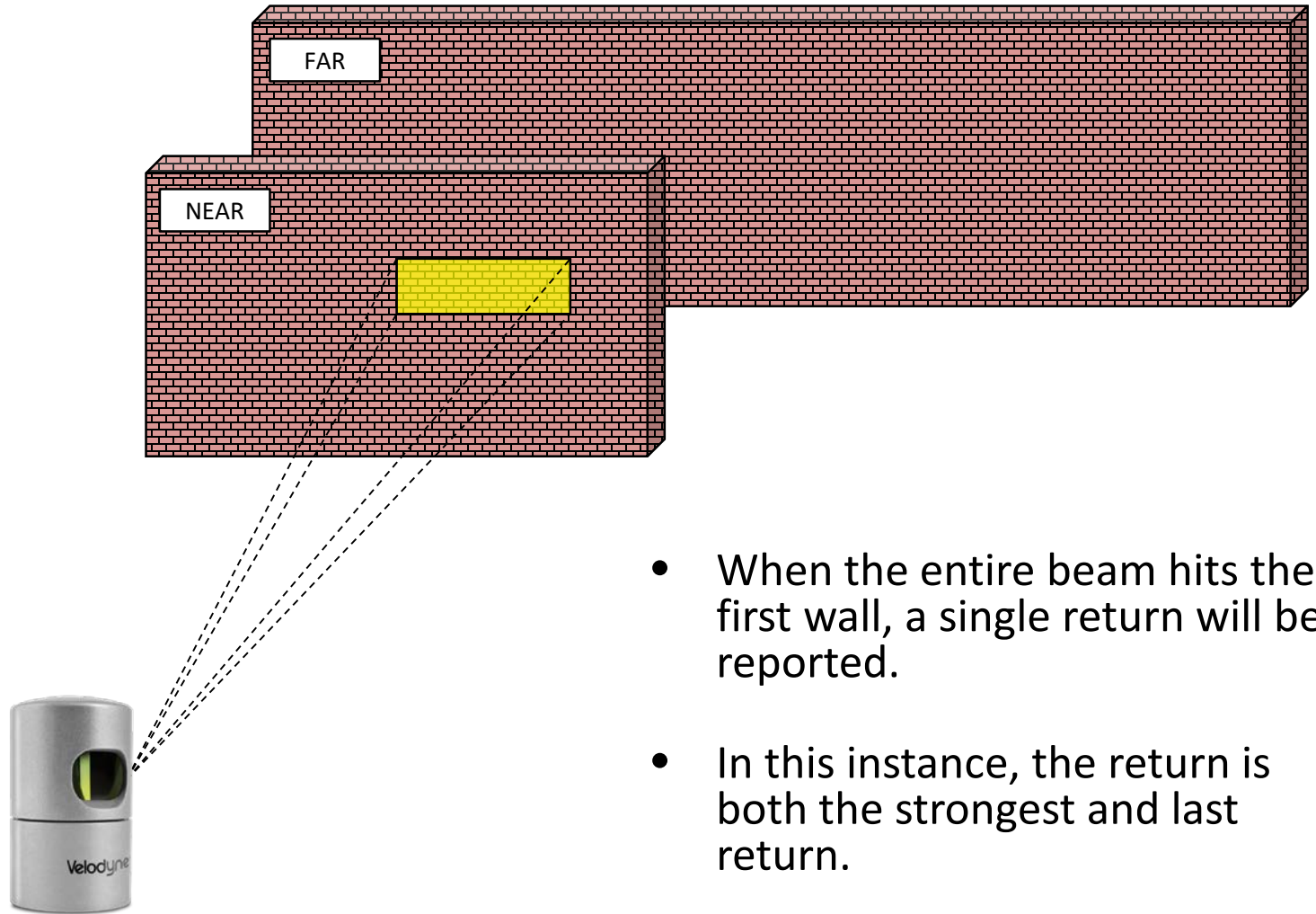


Multiple Returns Explained I



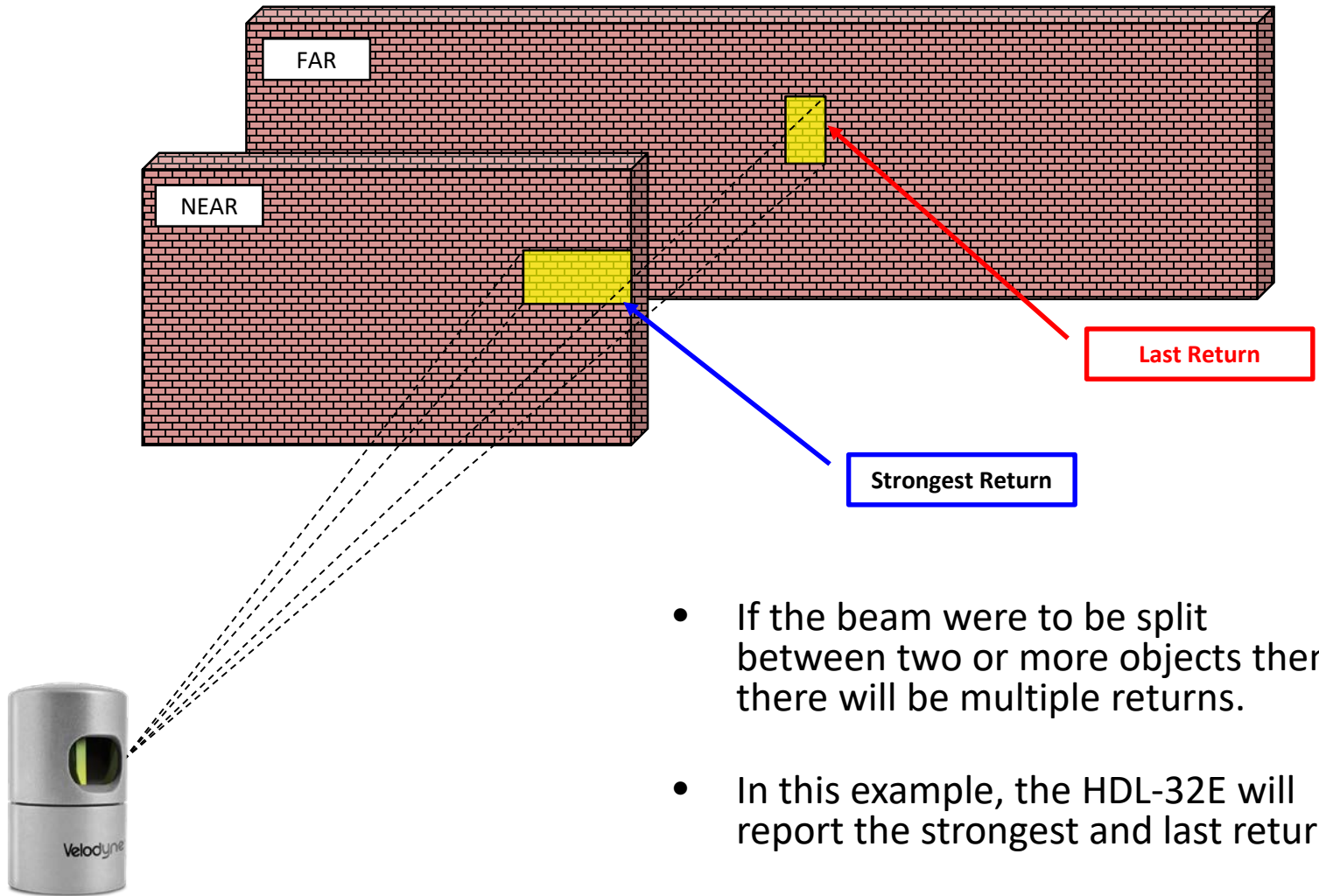
- The footprint of the laser beam increases as it gets farther from the LiDAR sensor. This is known as beam divergence.
- The beam divergence of the HDL-32E is 3 mrad.

Multiple Returns Explained II

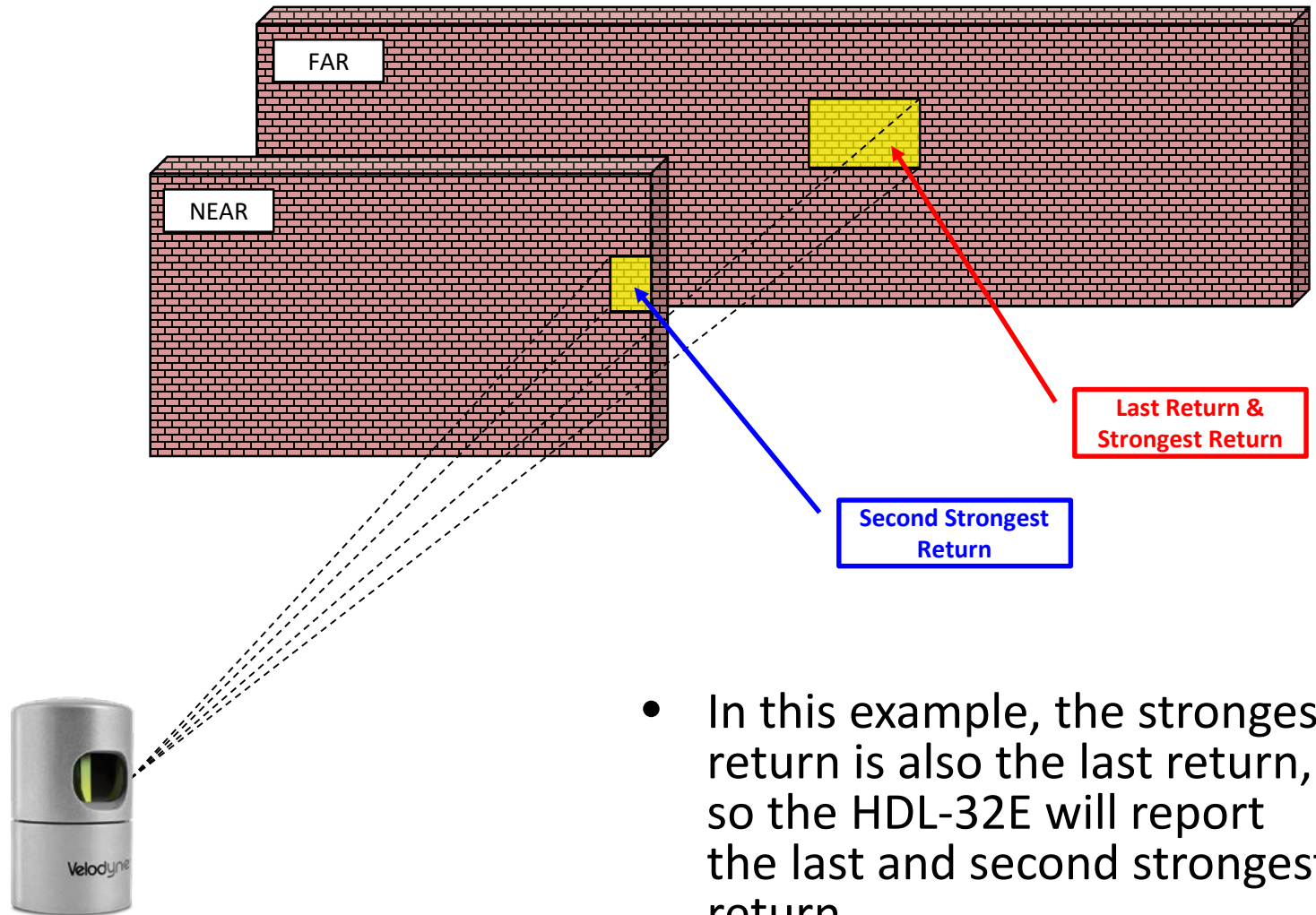


- When the entire beam hits the first wall, a single return will be reported.
- In this instance, the return is both the strongest and last return.

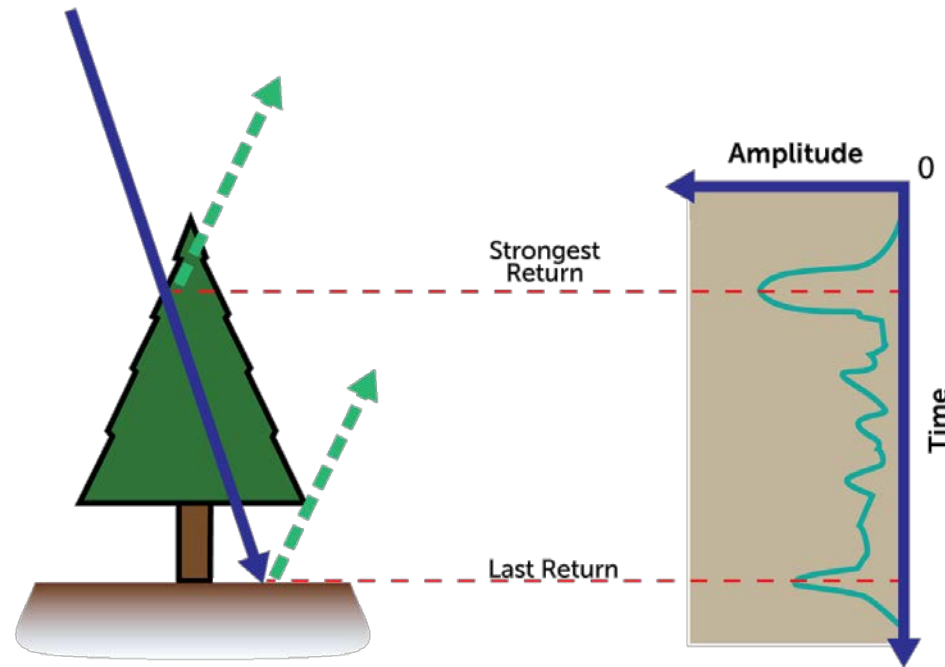
Multiple Returns Explained III



Multiple Returns Explained IV



Multiple Returns: Forestry Application



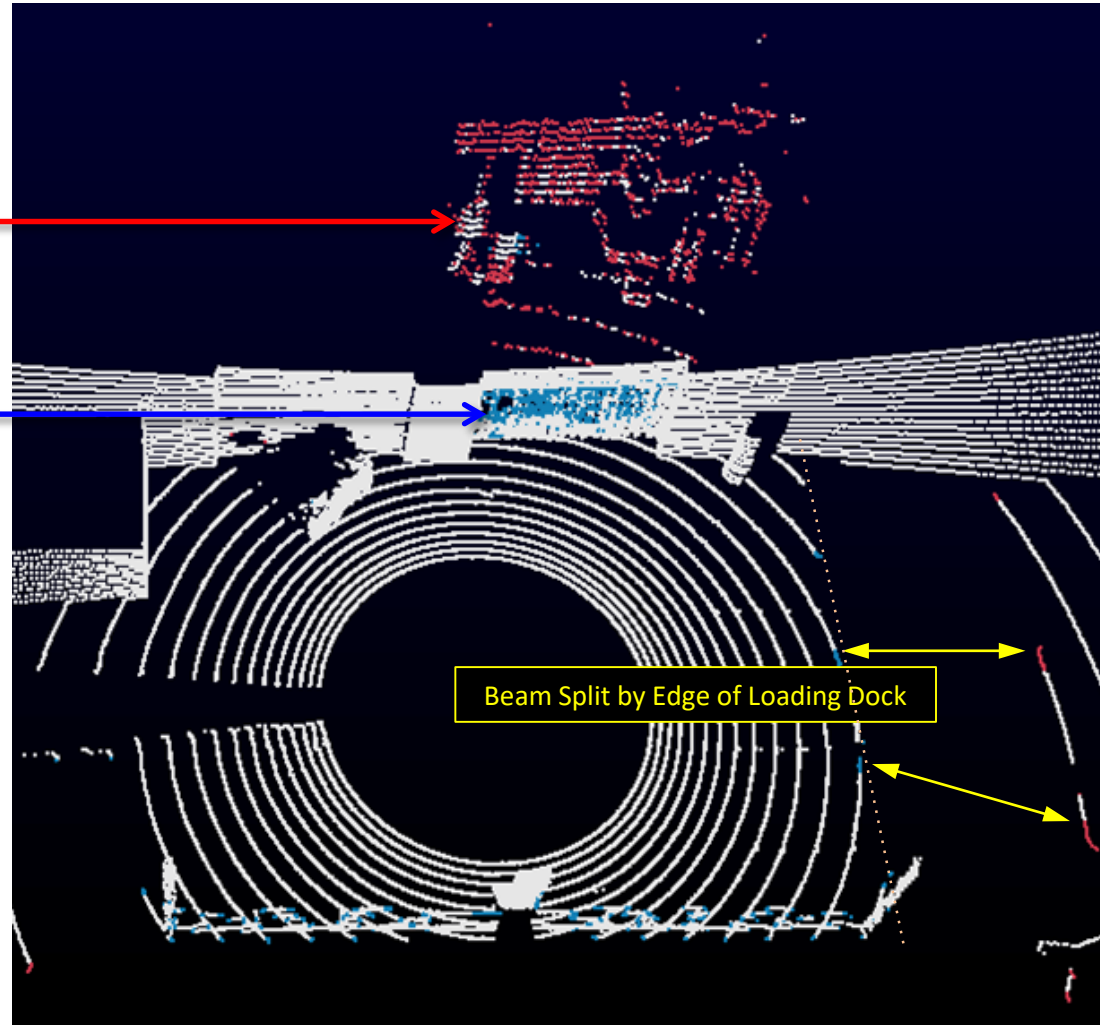
- In aerial LiDAR surveys, the last return is used to identify the ground.
- The other returns come from the tree as the beam traverses through all the tree branches.

Dual Returns in VeloView

Last Return
Solid Surface

**Strongest or
2nd Strongest Return**
Transparent Curtain

Actual View of VeloView Capture



Packet Structures



HDL-32E Packet Structure

- The information from a single **Firing Sequences of 32 lasers** is contained in one (1) **Data Block**.
- Each packet contains the data from 12 **Firing Sequences**.
- Only a single azimuth is returned per Data Block.
- If **Dual Return** mode is enabled, twice as many packets are returned.
 - Throughput increases from ~20 Mbps to ~40 Mbps.
- Each **Firing Sequence** time is 46.1 μs to fire all 32 lasers.

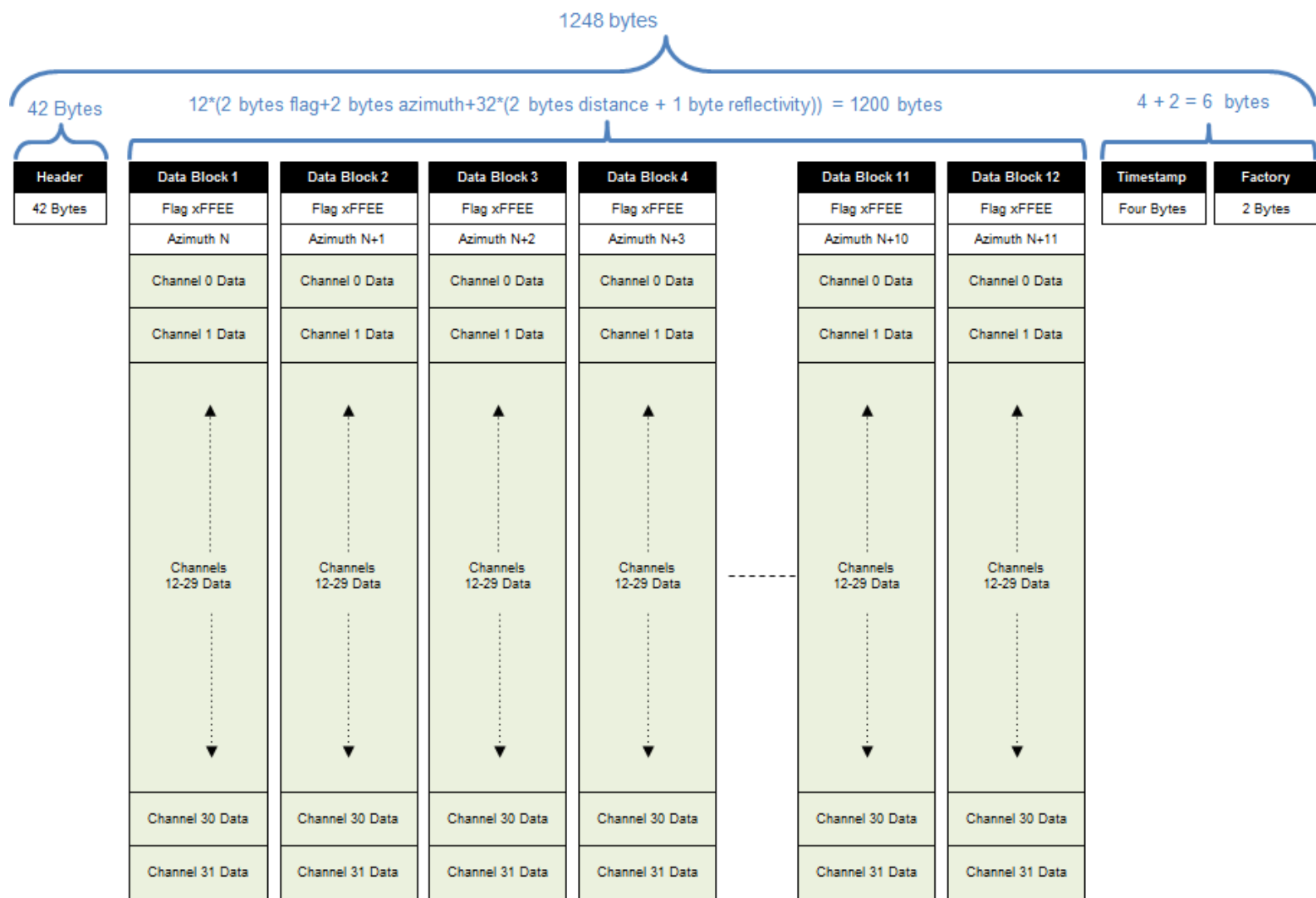
HDL-32E Vertical Angle Mapping per Laser Channel

- The channel number maps to the vertical angle in degrees relative to the horizontal plane of the HDL-32E.
- To find the elevation point of a specific laser, your software should use the channel number as an index into the lookup table to the right.

HDL-32E Channel #	HDL-32E Vert Angle (°)
0	-30.67
1	-9.33
2	-29.33
3	-8.00
4	-28.00
5	-6.67
6	-26.67
7	-5.33
8	-25.33
9	-4.00
10	-24.00
11	-2.67
12	-22.67
13	-1.33
14	-21.33
15	0.00
16	-20.00
17	1.33
18	-18.67
19	2.67
20	-17.33
21	4.00
22	-16.00
23	5.33
24	-14.67
25	6.67
26	-13.33
27	8.00
28	-12.00
29	9.33
30	-10.67
31	10.67

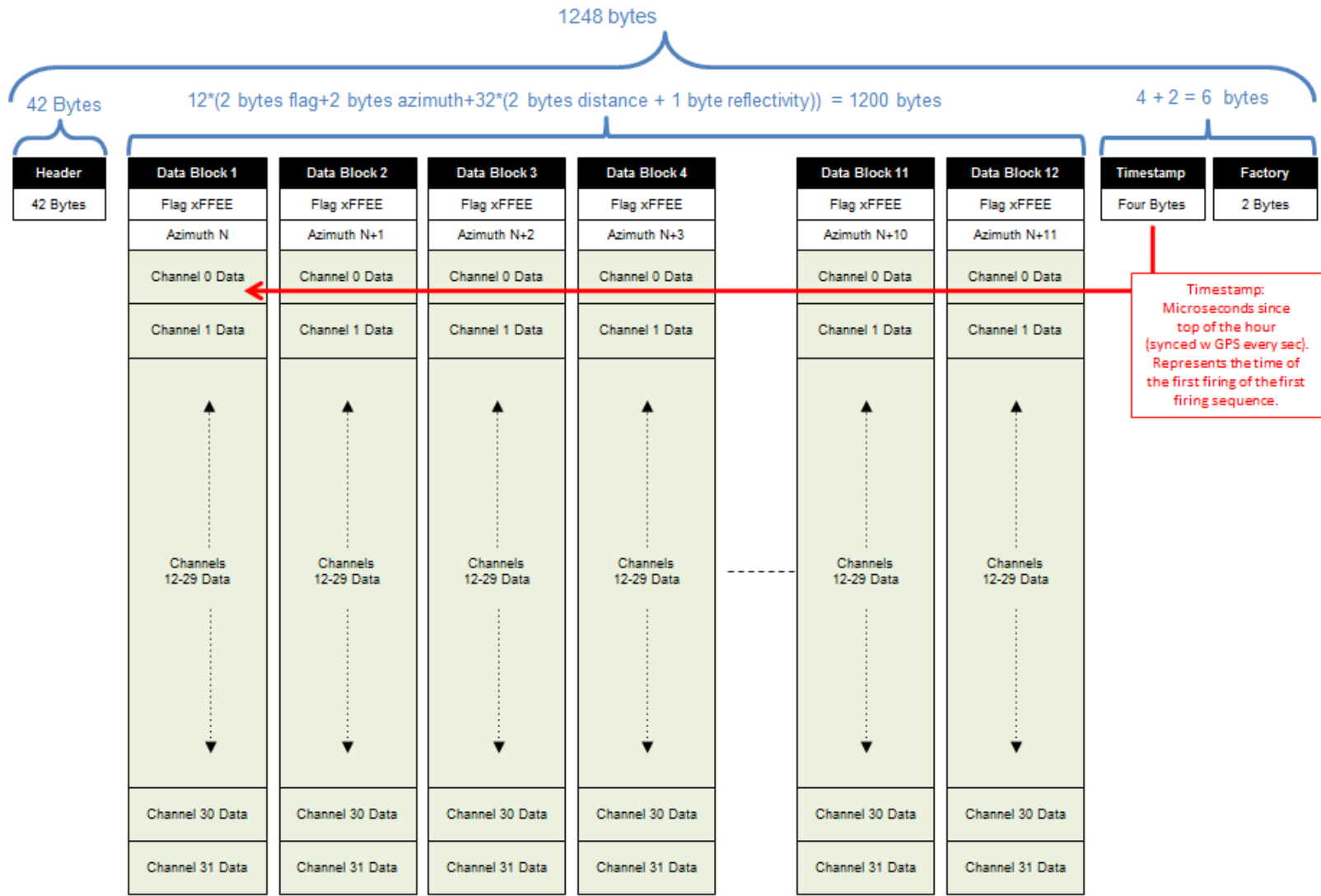
Data Block Structure in Single Return Mode

User can select **Strongest** or **Last Return**



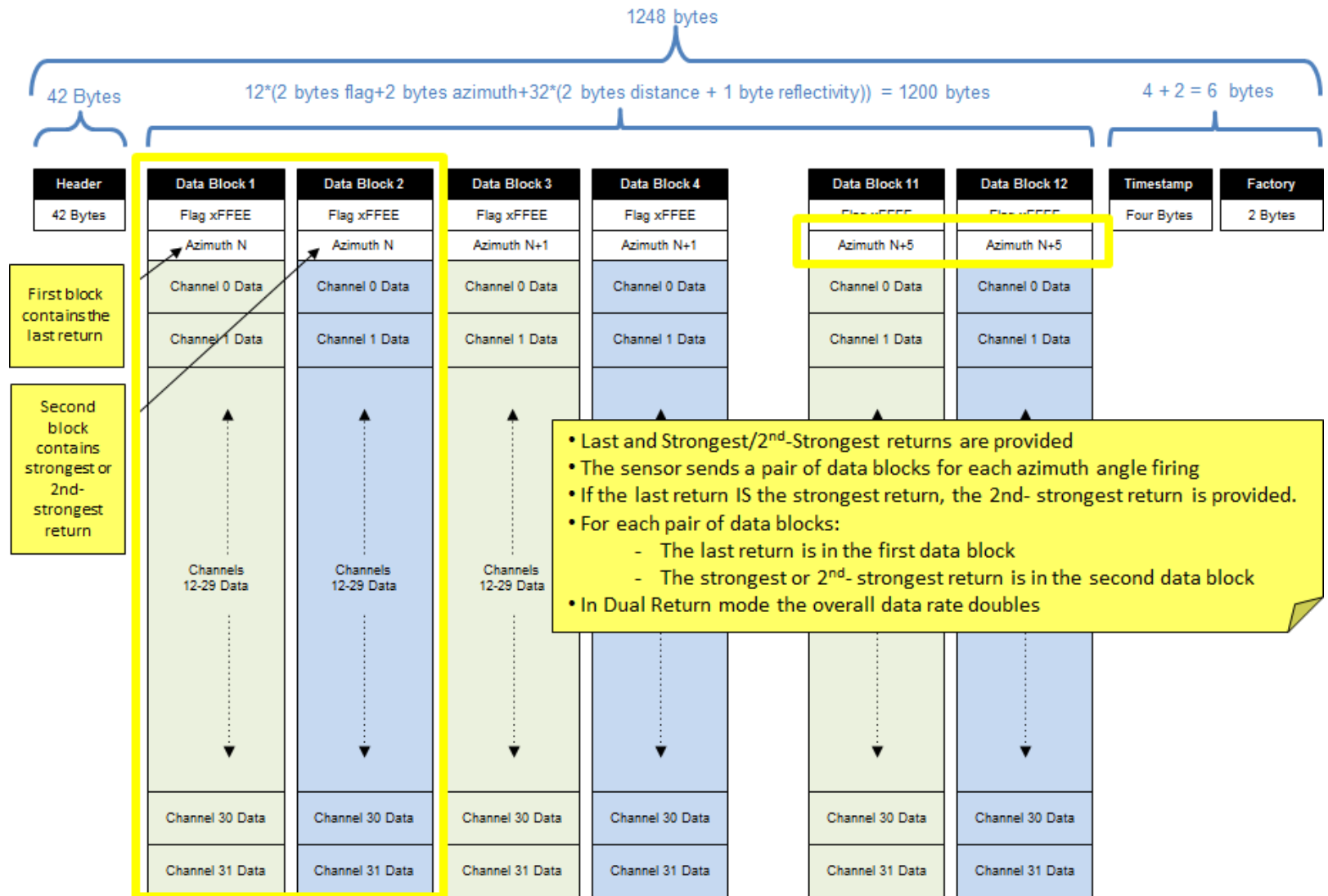
Data Block Structure in Single Return Mode

User can select **Strongest** or **Last Return**



Data Block Structure in Dual Return Mode

Data Blocks Alternate Between **Last** and **Strongest** (or 2nd Strongest) Return



Interpolation of Azimuths

- Consider a single data packet.
- The time between the 1st **Firing Sequence** of the 1st set of 32 lasers firing and the 1st **Firing Sequence** of the 3rd set of 32 lasers firing is $\sim 96.2 \mu\text{s}$.
- If you assume the rotation speed over that short time interval is constant, then you can assume the azimuth of the (N+1) set of 32 laser firings is halfway between the azimuth reported with the Nth set of 32 laser firings and the azimuth reported with the (N+2) set of laser firings.

Example of Interpolation of Azimuth

- Below is pseudo code that performs the interpolation.
- The code checks to see if the azimuth rolled over from the 359.9° to 0° between firing sets N and N+2. In the example below, N = 1.

```

If (Azimuth[3] < Azimuth[1])
    Then Azimuth[3]:= Azimuth[3]+360°; // Adjust for a rollover from 359.99° to 0
Endif;

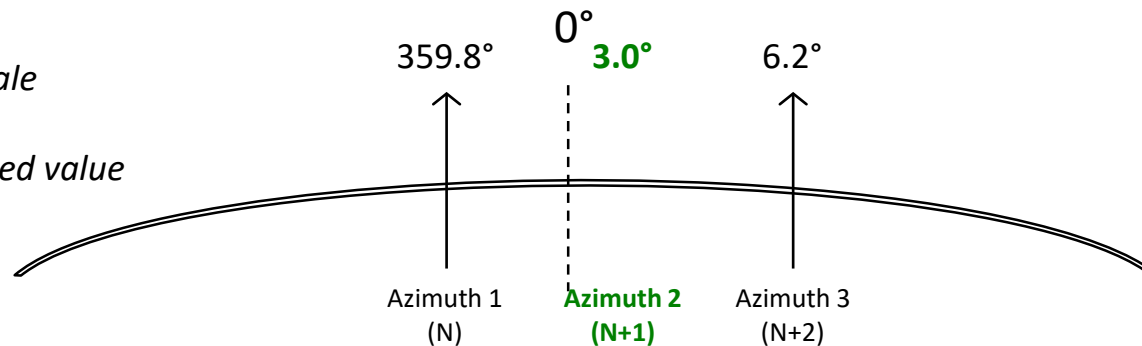
Azimuth[2]:=Azimuth[1]+( (Azimuth[3]-Azimuth[1])/2 ); // Interpolation

If (Azimuth[2]>360)
    Then Azimuth[2]:= Azimuth[2]-360°; // Correct for any rollover over from 359.99° to 0
Endif

Round(Azimuth[2], 2 decimal places); // User might to round or truncate the computed azimuth
  
```

Example:

*Figure not to scale
N+1, in green,
is the interpolated value*



Precise Data Point Timing



Precision Data Point Timing

- Each packet has one timestamp representing the first firing of the packet.
- For increased accuracy, you can calculate a timestamp for each individual laser firing.
- Remember, the data points in each block are recorded in the order which the lasers are fired.
- In Dual Return Mode, the computed timestamps for the corresponding strongest and last returns are equal.

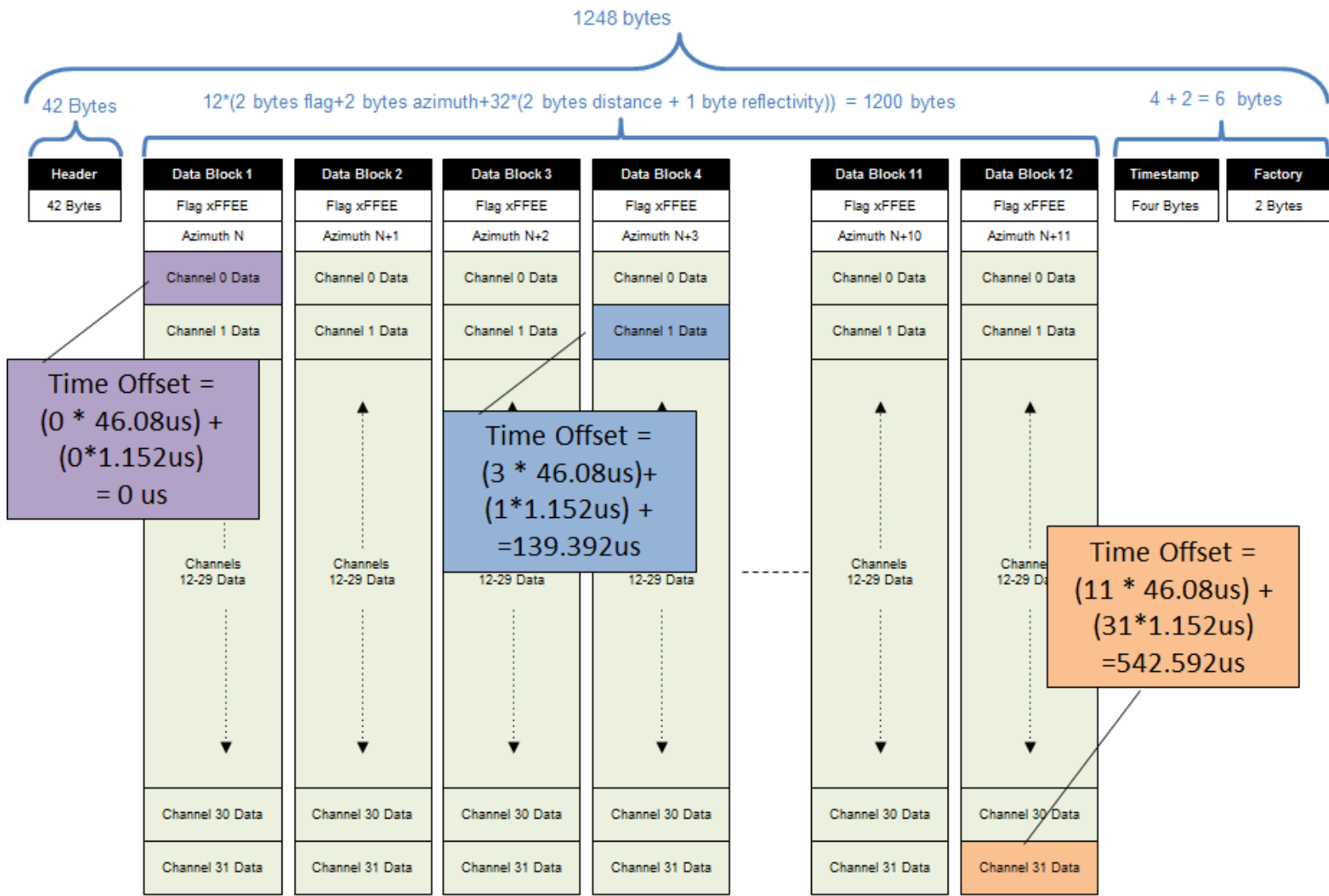
Data Timing Breakdown

- Single HDL-32E Firing Sequence (32 lasers) = 46.080 μ s.
- The 46.080 μ s sequence time breaks down as:
 - $t_{\text{SEQUENCE}} = (32 \cdot 1.152 \mu\text{s}) + 9.216 \mu\text{s}$ [recharge cycle]
- The time to accumulate one data packet is:
 - $t_{\text{DATA_PACKET}} = 46.080 \mu\text{s}/\text{data block} \cdot 12 \text{ data blocks}/\text{packet}$
 $= 552.960 \mu\text{s}/\text{packet}$

Calculating the Time Offset

- Step 1:
 - Number the data points in the firing sequence 0 to 31 (Data Point Index).
 - Number the **Firing Sequences** 0 to 11 (Sequence Index)
- Time Offset = $(46.080 \mu\text{s} \cdot \text{Sequence Index}) + (1.152 \mu\text{s} \cdot \text{Data Point Index})$
- Example:
 - Time Offset = $(46.080 \mu\text{s} \cdot 11) + (1.152 \mu\text{s} \cdot 31)$
= $542.592 \mu\text{s}$

Timing Offset Calculation in HDL-32E



Thank You!



345 Digital Drive, Morgan Hill, CA 95037
63-9277 Rev D

Tel: 408.465.2800 (Main Office)

Tel: 408.465.2819 (LiDAR Sales)