Velodyne® LiDAR

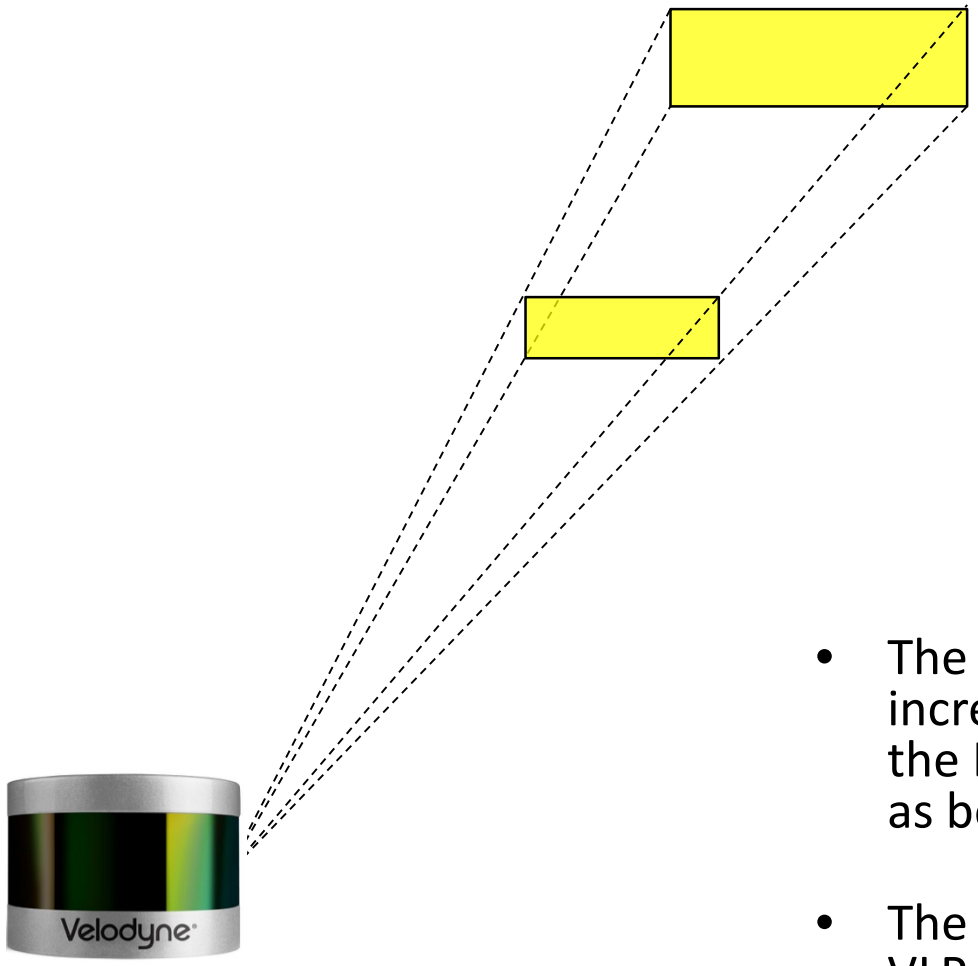
Application Note
VLP-16: Packet Structure & Timing Definition

Definitions

- **Firing Sequence**
  - The time and/or process of cycle-firing all the lasers in a VLP-16.
    - Firing sequence = 55.296 µs to fire all 16 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

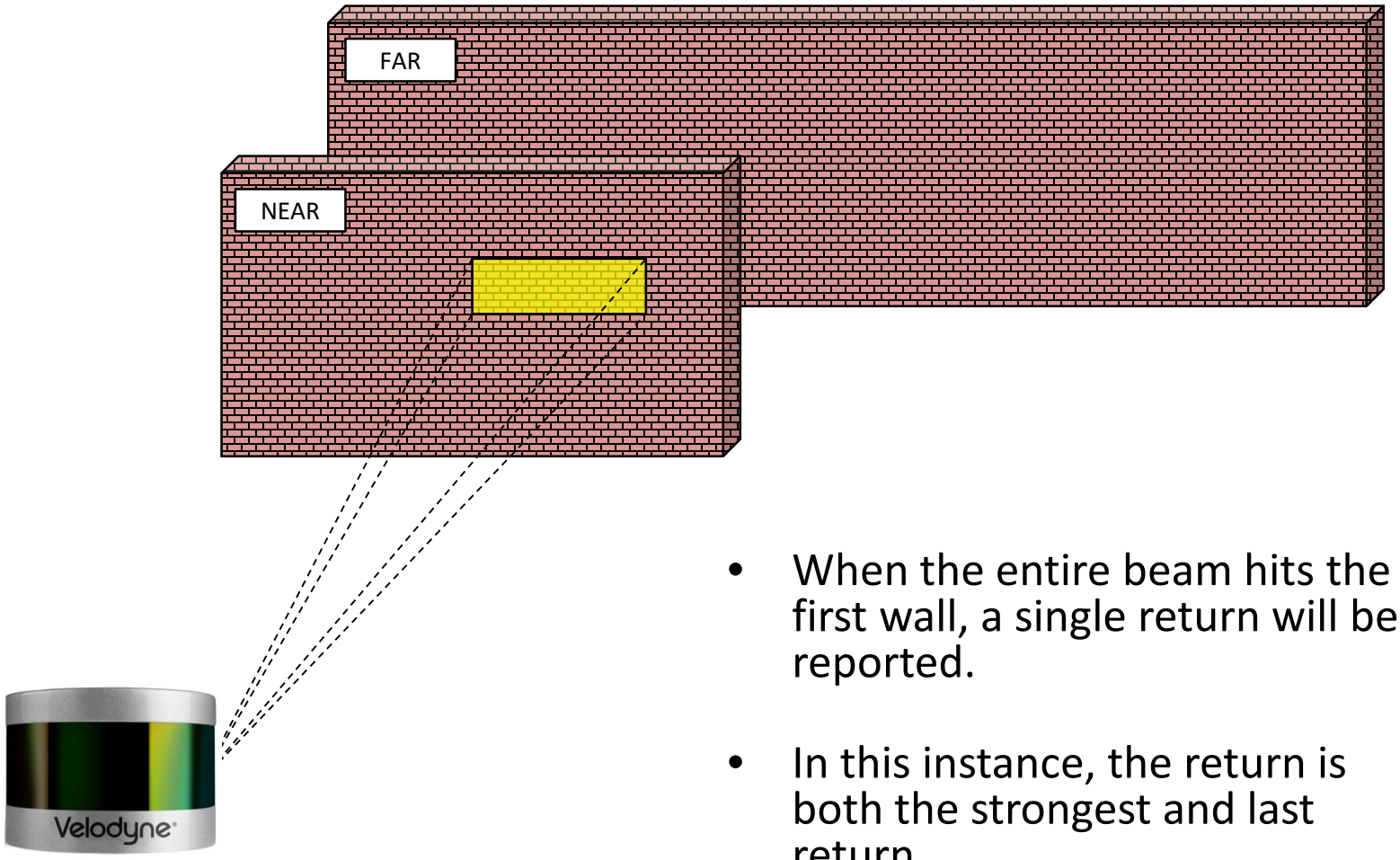
Single & Dual Returns

Multiple Returns Explained I



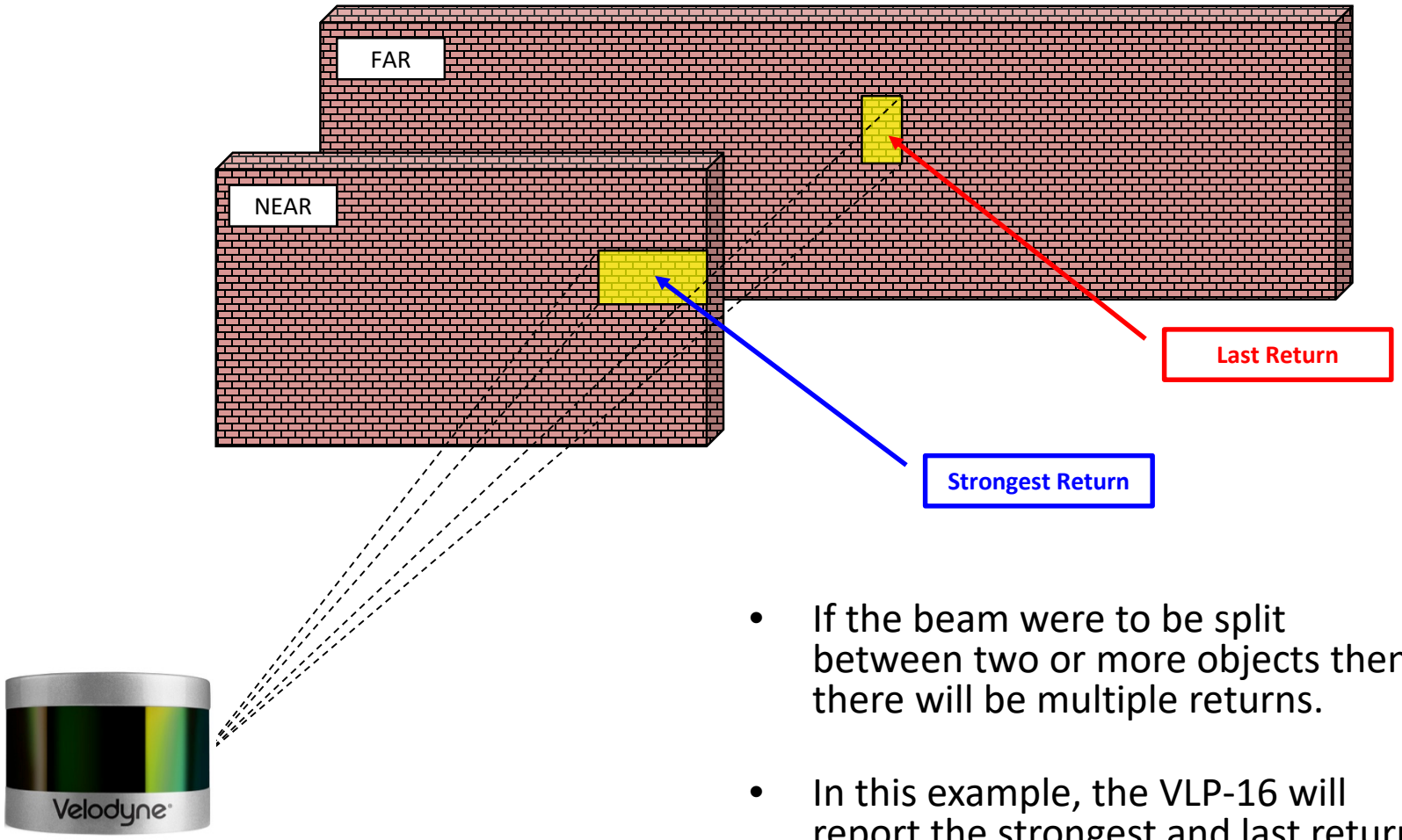
- The footprint of the laser beam increases as it gets farther from the LiDAR sensor. This is known as beam divergence.
- The beam divergence of the VLP-16 is 3 mradians.

Multiple Returns Explained II



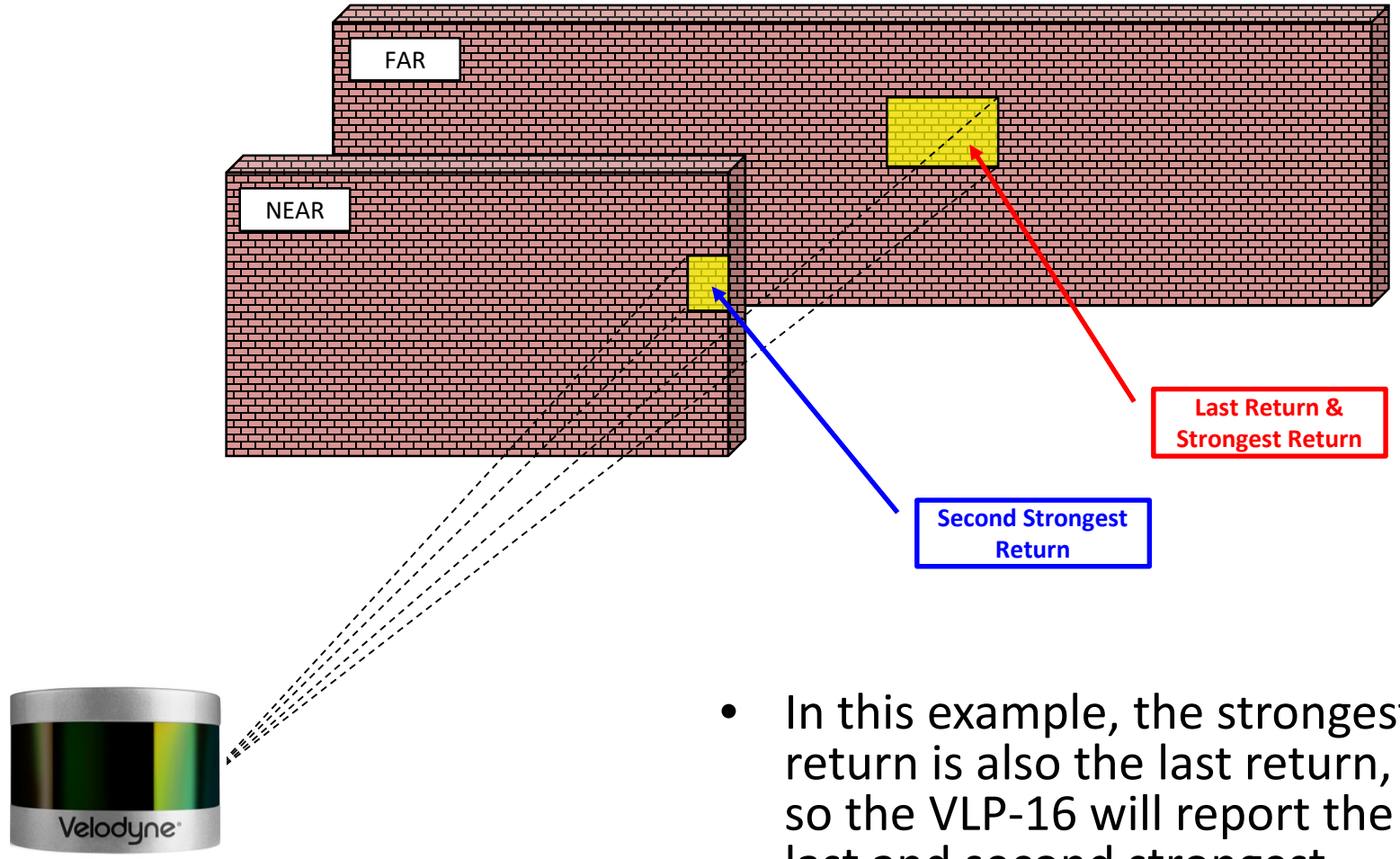
- When the entire beam hits the first wall, a single return will be reported.
- In this instance, the return is both the strongest and last return.

Multiple Returns Explained III



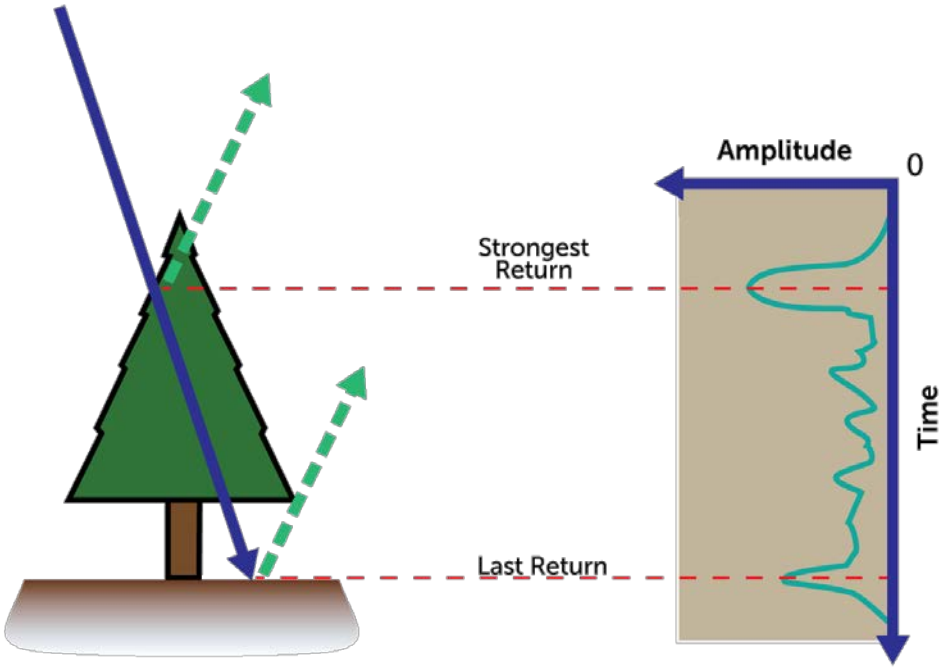
- If the beam were to be split between two or more objects then there will be multiple returns.
- In this example, the VLP-16 will report the strongest and last return.

Multiple Returns Explained IV



- In this example, the strongest return is also the last return, so the VLP-16 will report the last and second strongest return.

Multiple Returns: Forestry Application

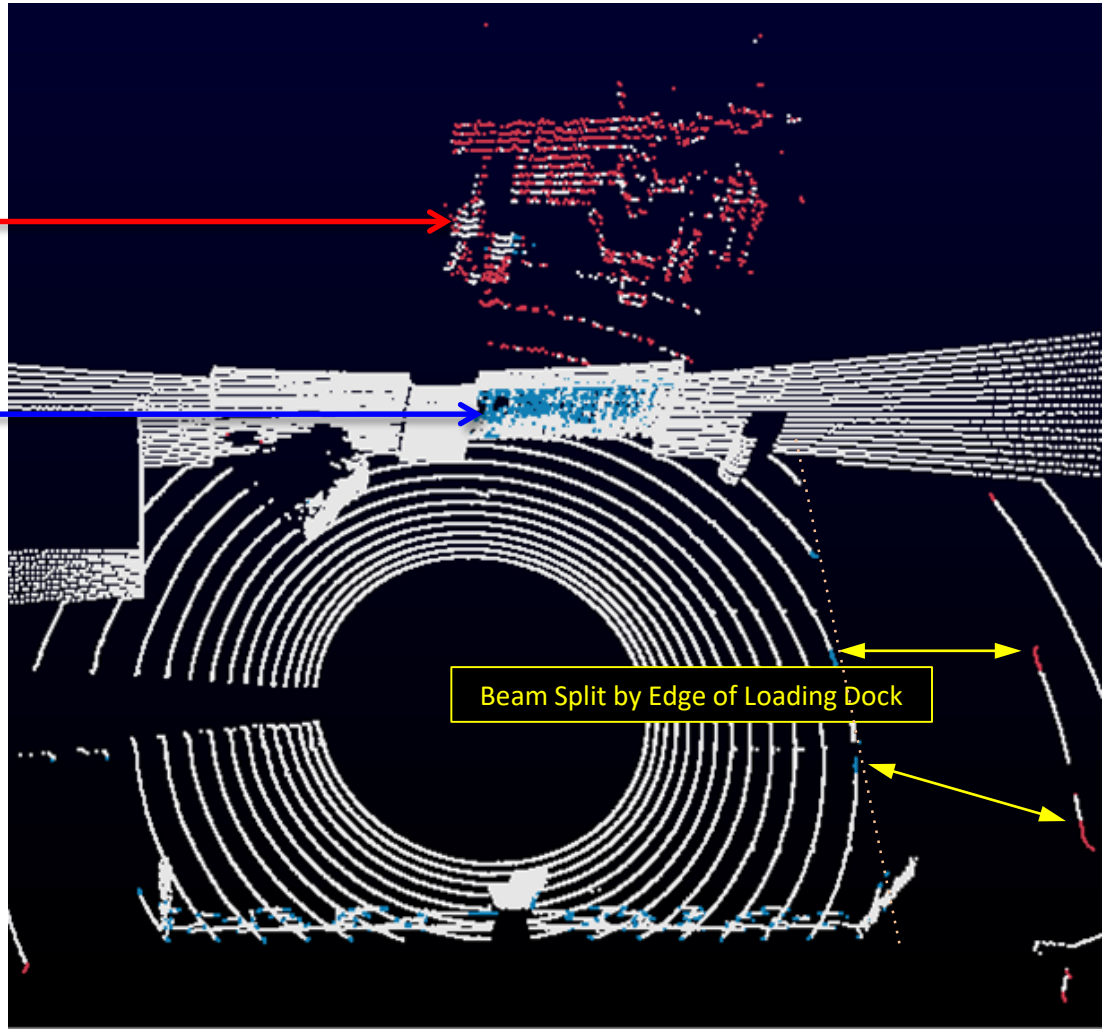


- In aerial LiDAR surveys, the last return is used to identify the ground.
- The other returns come from the tree as the beam traverses through all the tree branches.

Dual Returns in VeloView

Last Return
Solid Surface

Strongest or
2nd Strongest Return
Transparent Curtain



Actual View of VeloView Capture

Packet Structures

VLP-16 Packet Structure

- The information from 2 **Firing Sequences of 16 lasers** is contained in one (1) **Data Block**.
- Each packet contains the data from 24 **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 ~8.6 Mbps to ~17.2 Mbps.
- Each **Firing Sequence** time is 55.296 µs to fire all 16 lasers.

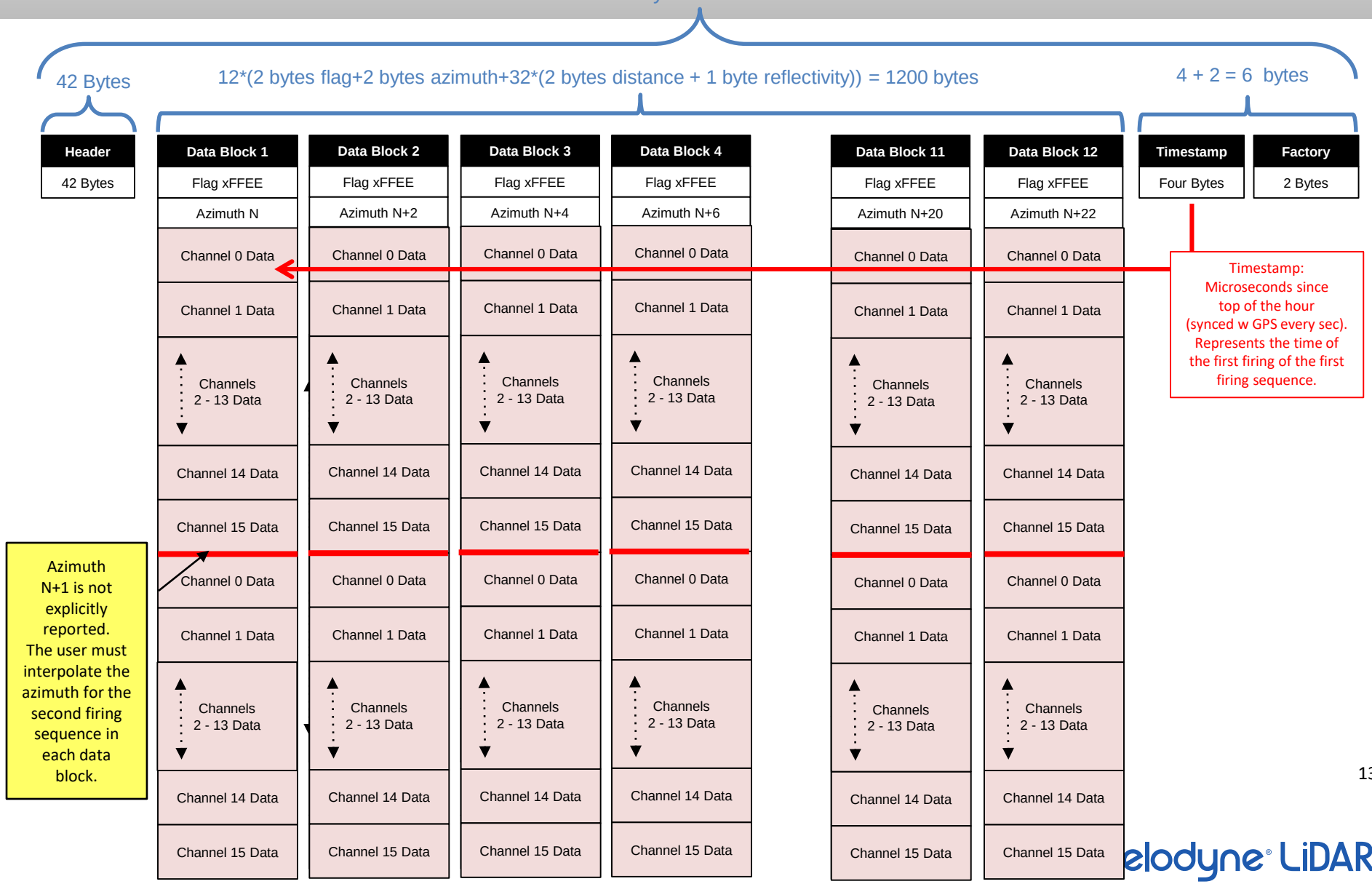
VLP-16 Vertical Angle Mapping per Laser Channel

- The channel number maps to the vertical angle in degrees relative to the horizontal plane of the VLP-16.
- 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.

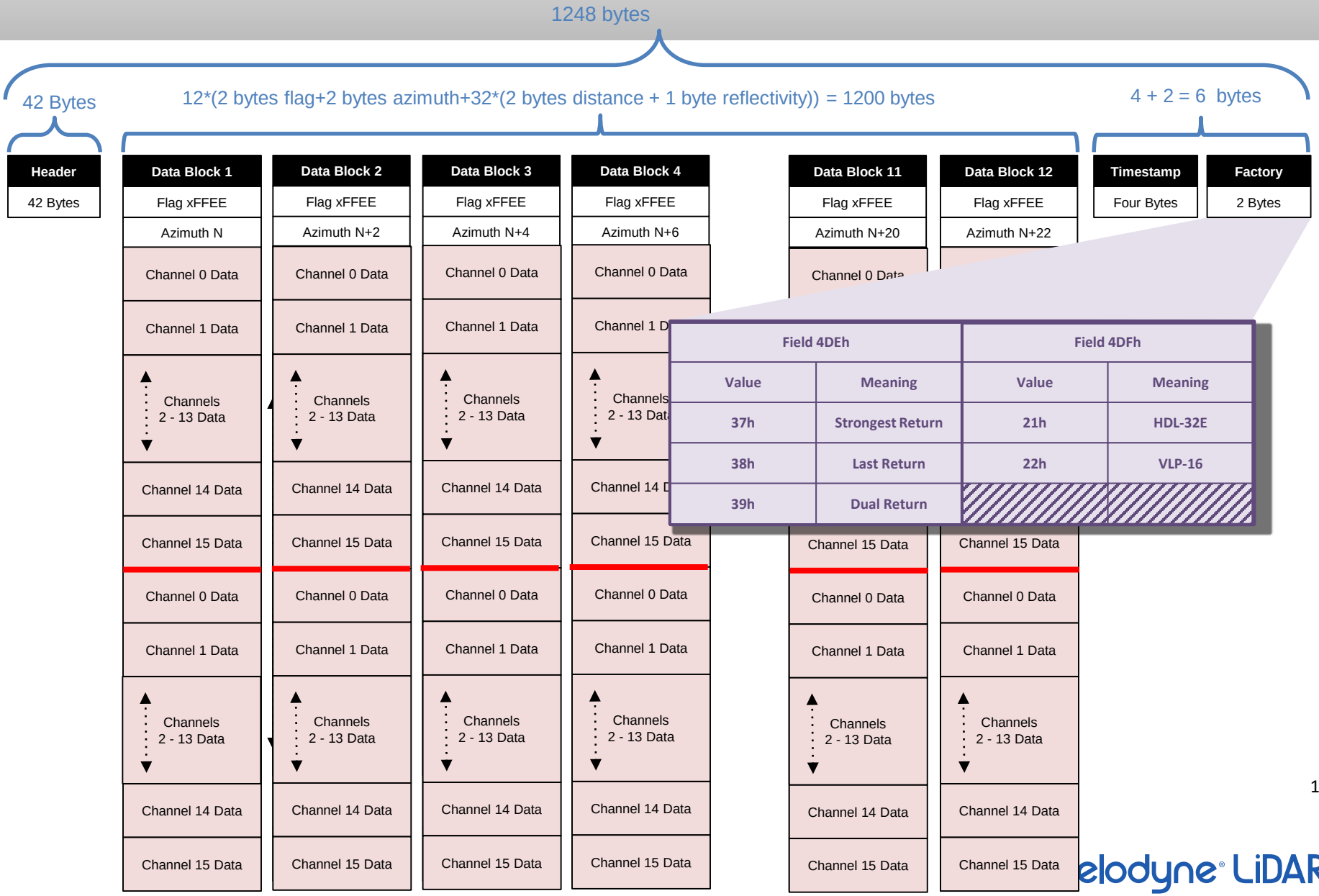
VLP-16 Channel #	VLP-16 Vert Angle (°)
0	-15°
1	1°
2	-13°
3	-3°
4	-11°
5	5°
6	-9°
7	7°
8	-7°
9	9°
10	-5°
11	11°
12	-3°
13	13°
14	-1°
15	15°

Data Block Structure in Single Return Mode

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

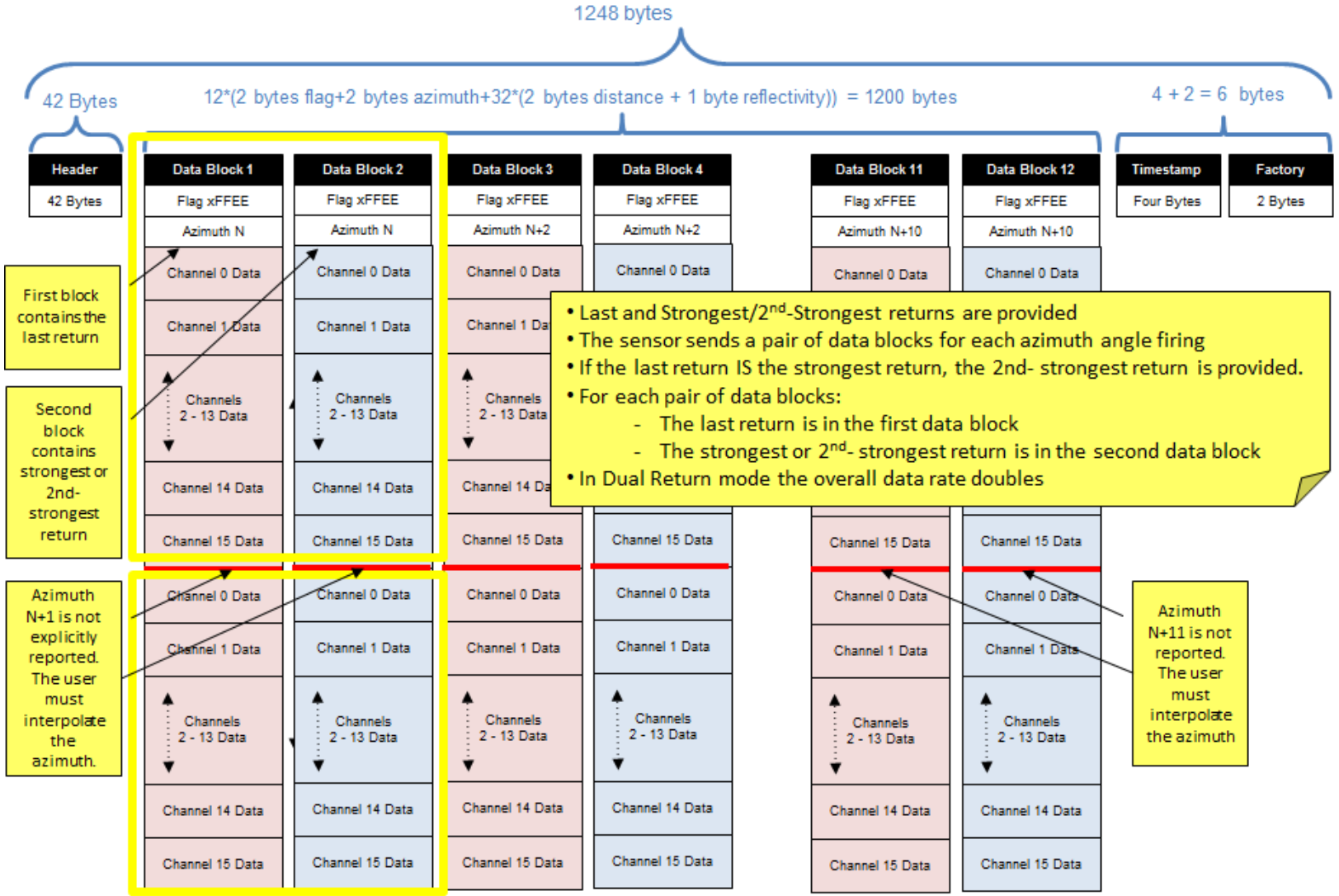


Use of Factory Bytes



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 16 lasers firing and the 1st **Firing Sequence** of the 3rd set of 16 lasers firing is ~110.6 µs.
- 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 16 laser firings is halfway between the azimuth reported with the N^{th} set of 16 laser firings and the azimuth reported with the (N+2) set of laser firings.

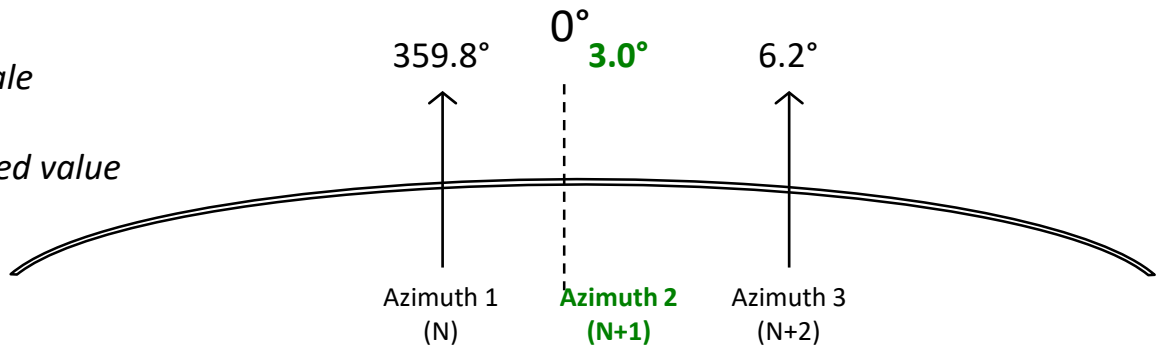
Example of Interpolation of Azimuth

- 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 VLP-16 Firing Sequence (16 lasers) = 55.296 µs.
- The 55.296 µs sequence time breaks down as:
  - $t_{SEQUENCE}$ = (16 · 2.304 µs) + 18.432 µs [recharge cycle]
- The time to accumulate one data packet is:
  - t_{DATA_PACKET} = 55.296 µs/data block · 24 data blocks/packet
    = 1.327 ms/packet

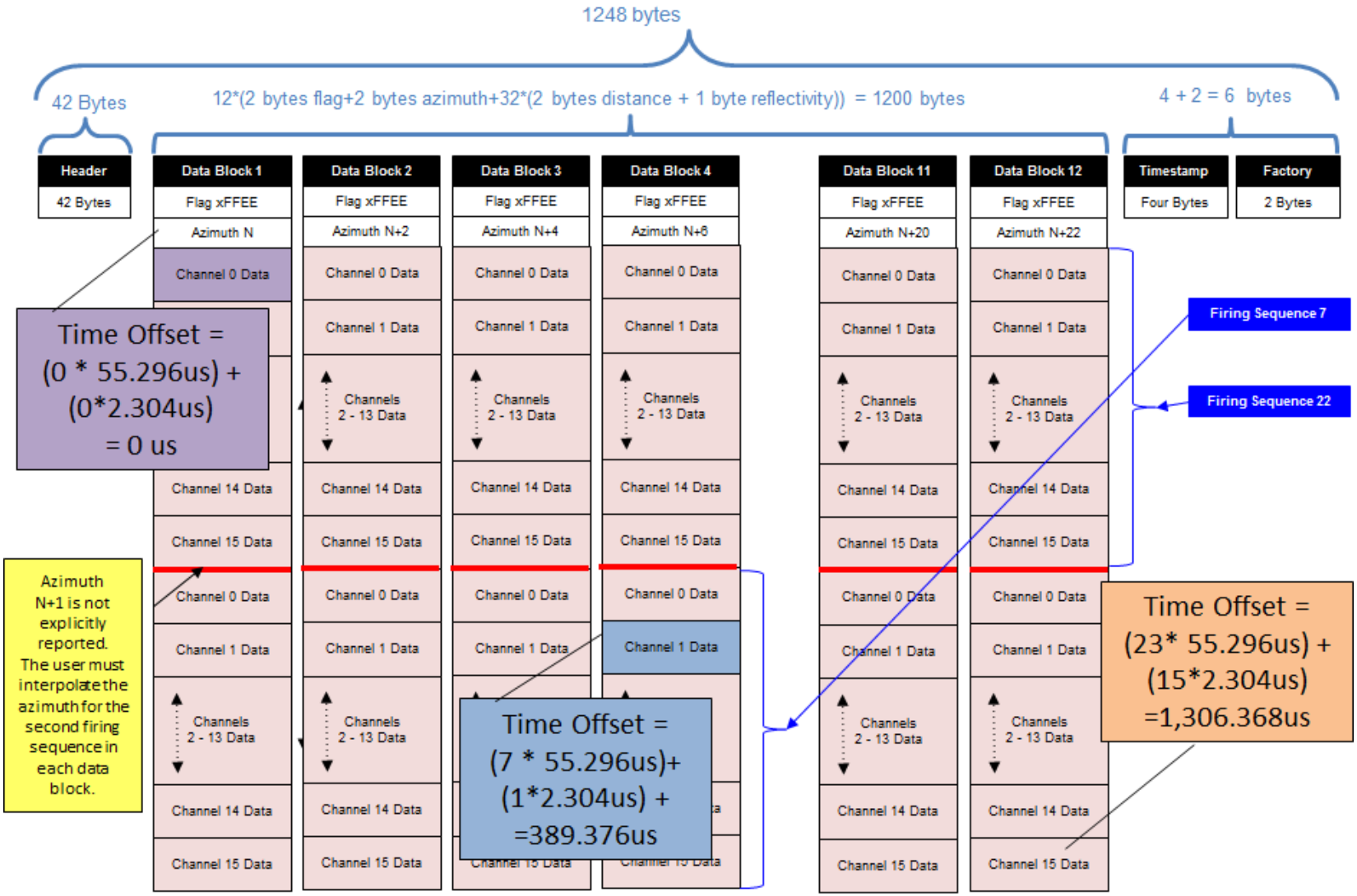
Calculating the Time Offset

- Step 1:
  - Number the data points in the firing sequence 0 to 15 (Data Point Index).
  - Remember:
    - There are 2 **Firing Sequences** per Data Block.
    - 24 **Firing Sequences** per packet.
  - Number the **Firing Sequences** 0 to 23 (Sequence Index)

- Time Offset = (55.296 µs · Sequence Index) + (2.304 µs · Data Point Index)

- Example:
  - Time Offset = (55.296 µs · 23) + (2.304 µs · 15)
    = 1,306.37 µs

Timing Offset Calculation in VLP-16



Thank You!

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