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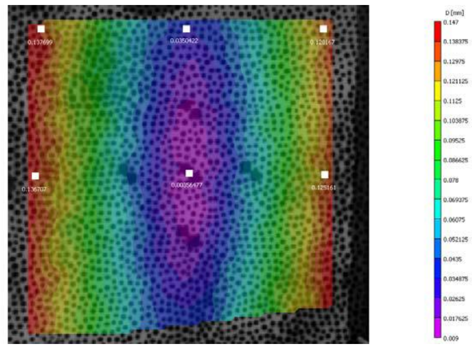

Synchronization Concerns In Range Measurements

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Sensing & Imaging Technologies

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U.S. DEPARTMENT OF ENERGY

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Reality Sets In

There is good understanding and handling of synchronization error at Sandia and similar groups with long experience in range measurements. But the errors they had work to diminish can creep back into measurements with the advent of:

- Entrant or evolved technologies: i.e. the priority is set in the number of pixels in the CCD/FPA, the interconnectivity, or their memory size, while not focusing in the clock speed and synchronization protocols.
- Test devices working at higher match numbers may increase insignificant errors to substantial ones.
- Longer range testing (>50Km ?), ditto.
- New software that provides new functionality but diminish or varies clock times

What do we care for?

At the end, it all boils down to a question: what is the meaning of that time stamp on your data?

- Is it UTC?
- Is it the event you are trying to measure?
- Is it some master clock?
- Is it the clock in your instrument?

The **first two** you can rely, on the **last two** can get you in trouble

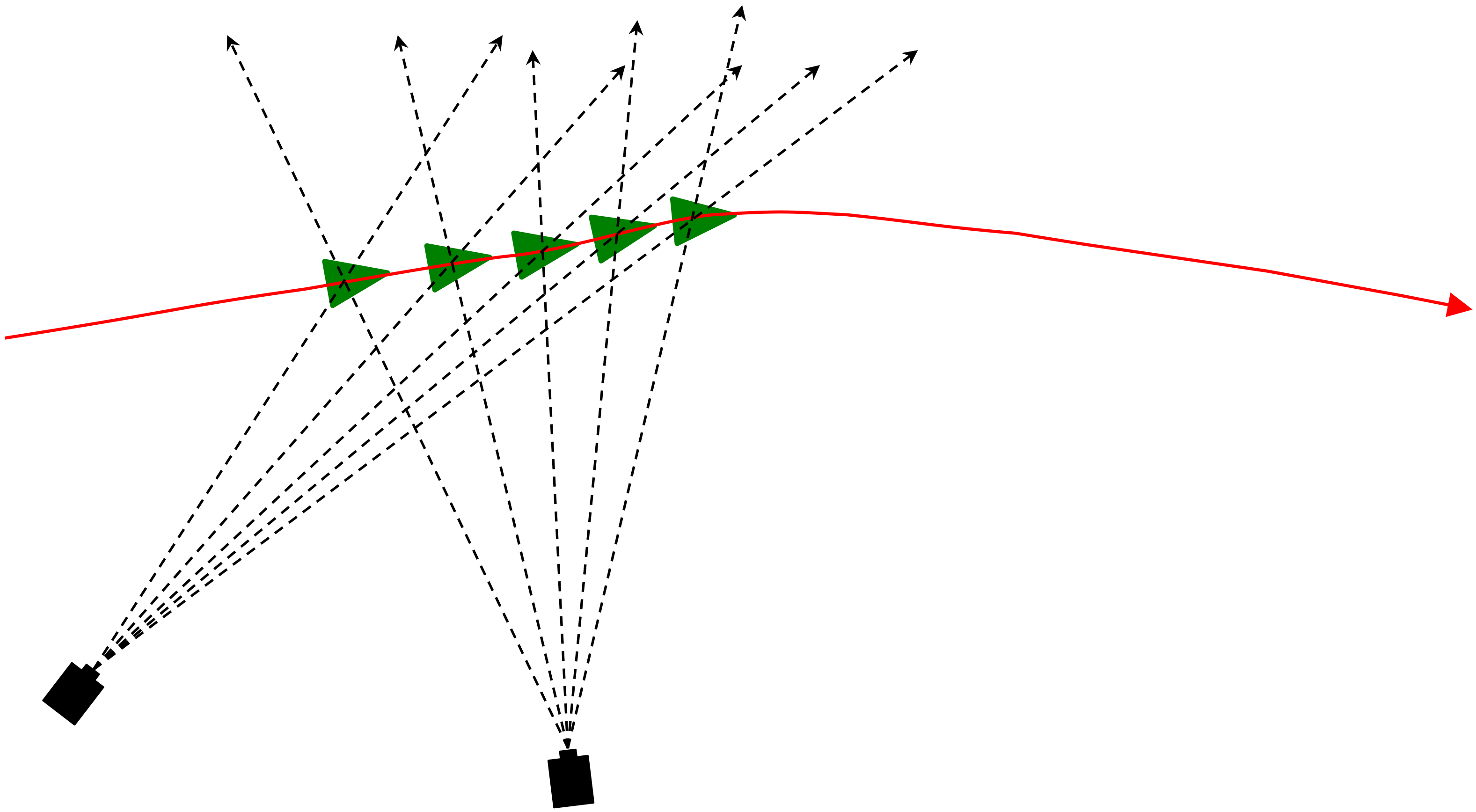
Questions to be Made

- What are your error sources?
    - Processing times
    - Clock and time stamps
    - Shutter times
    - Distances to the event
    - How is the data stored (film or ccd)
- What is your accuracy?
    - How do you specify it: absolute or 6σ?
    - Don't check clock accuracy for all conditions
    - Don't check clock accuracy before, during and after
- What is your customer requirements?
    - Client → x, y, z, t / We → r, φ, θ, t

Example 1

Original work by Eric Hussman and Kevin Norwood Work at Newtec

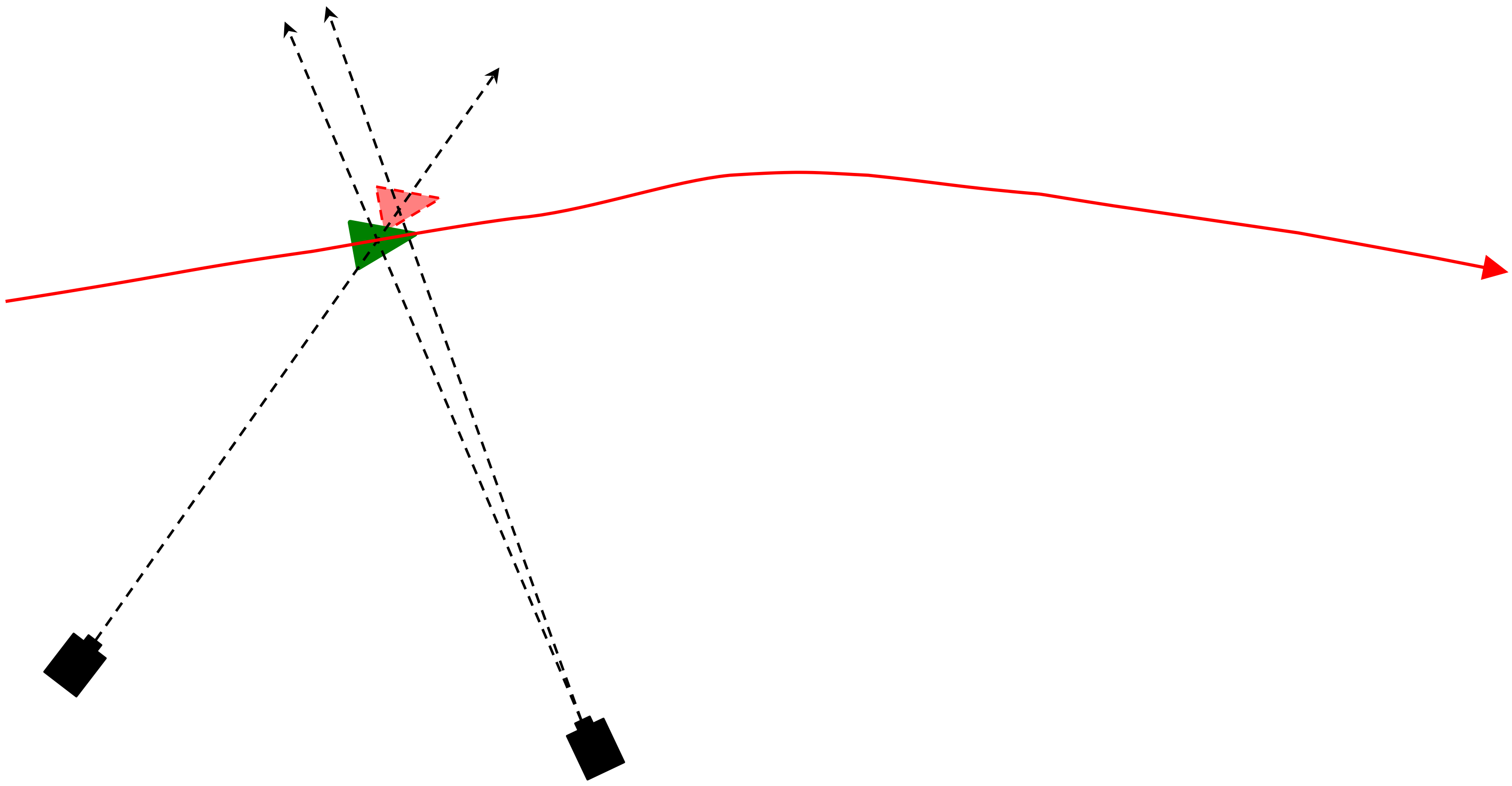
Tracking systems follows trajectory and sample points from a measurement at Mach 1



Example 1 – Cont.

Original work by Eric Hussman and Kevin Norwood Work at Newtec

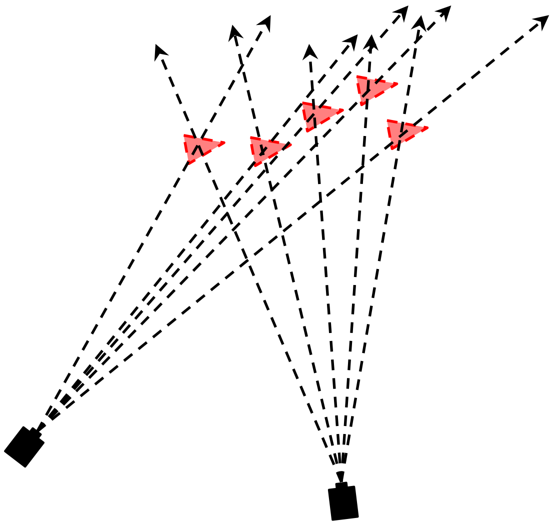
But angular error looks a lot like time error



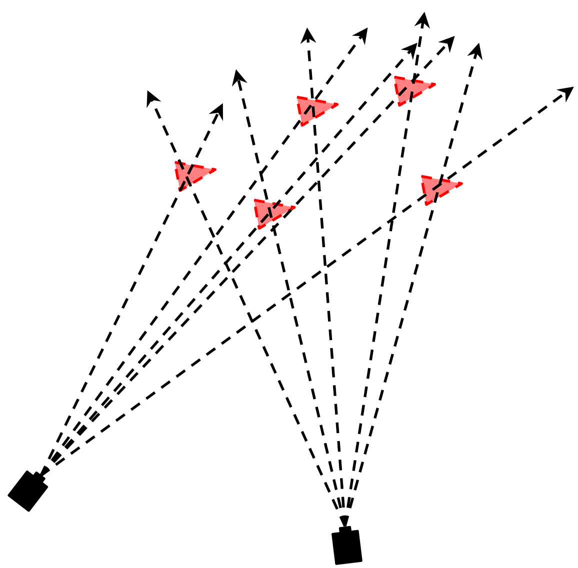
Example 1 – Cont.

Original work by Eric Hussman and Kevin Norwood Work at Newtec

What is the trajectory again for Mach 1?

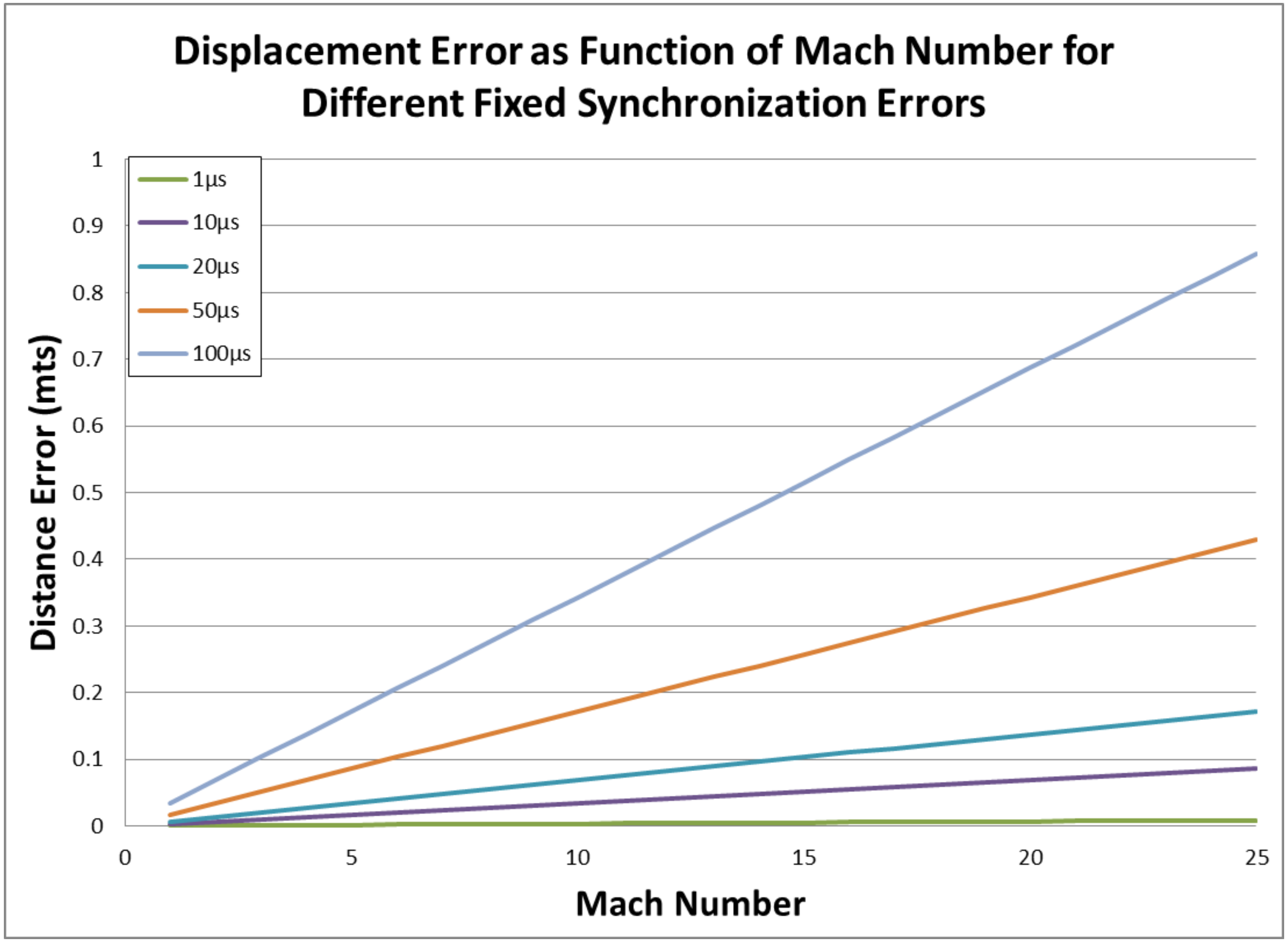


What about Mach 5?



Example 1 – Cont.

A simpler way to see this error is by looking at the displacement errors in the imaging measurement as a function of Mach number for different constant synchronization differences.



Example 2

Sandia[1] tested the synchronization of two types of cameras in a Digital Image Correlation (DIC) experiment:

- Phantom v12 with a 56 MHz clock for a time granularity of 17.875 ns
- Shimadzu with a 16 MHz clock for a time granularity of 62.5 ns
- Used in Master-Slave configuration
- Tested using 10 x 10 LED array with rate of 1µs
- Synchronization tested with a Tektronix 2-GHz digital oscilloscope
- The synchronization was done with FSYNC and IRIG modes
- The fundamental error is caused by one camera taking a picture slightly after the other, capturing the object after it translated a small amount.

Note: DIC results are functioning at a sub-pixel resolution (1/100th)

[1]P. L. Reu and T. J. Miller, "Synchronization Errors in High-Speed Digital Image Correlation"

Example 2 – Cont.

Phantom v12 Synchronization Errors Measured:

Table 1. Phantom V12 timing results (Note that IRIG frame rates are limited to being both divisible by 4 and 10).

Frame Rate (Hz)	Sync Mode	Camera Exposure (μs)	IRIG Error (ns)	Strobe Error (ns)	Corrected Error (ns)
64,000	FSYNC	1	640	28	18
64,000	IRIG	1	10	330	18
66,037	FSYNC	0.3	1150	26	18
175,000	FSYNC	0.3	7400	50	18
175,000	IRIG	0.3	10	356	18
320,000	FSYNC	0.3	82,000	55	18
320,000	IRIG	0.3	10	276	18

Shimadzu Synchronization Errors Measured:

- Cameras were synchronized with an oscilloscope to within 7-ns using a 3-m network cable.
- A ~20-m cable was also used resulting in a 50-ns synchronization error.
- Cable quality as demonstrated by a 50-ns delay which was measured using an extremely short “home-made” network cable.

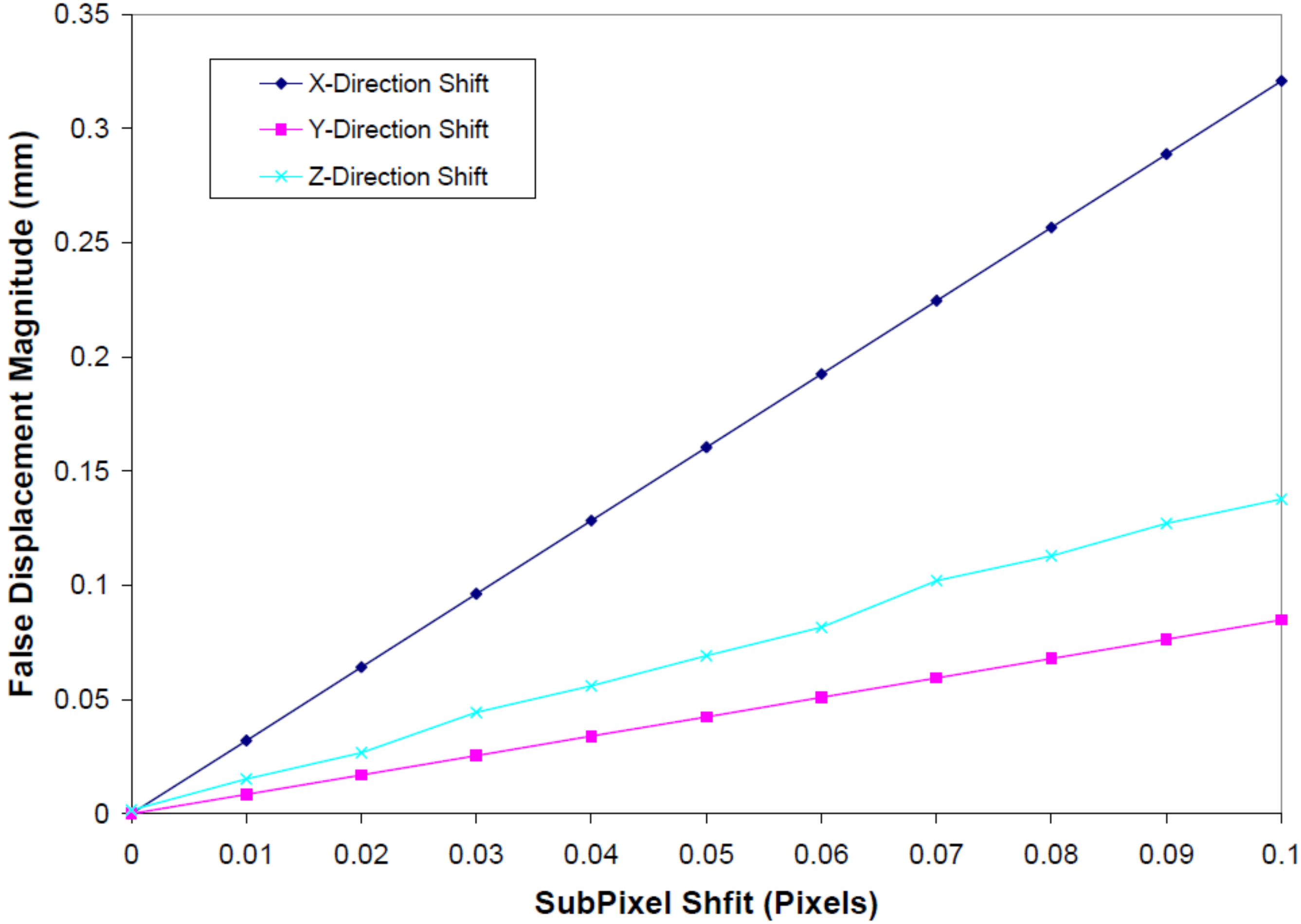
Example 2 – Cont.

Pixel Shift Example

- Data was taken with a V12 camera
- Resolution set to 400×416 pixels
- Frame rate of 36,000 frames/second
- Feld-of-view of 48 inches
    - Resolution of 3.0 mm/pixel
- Typical velocity measured for this experiment was 396 m/s.
- Worst case synchronization of 350 ns
    - 0.03 pixel shift can be calculated between the master and slave camera.
- The results are for shifts of between 0 and 0.1 pixels as a worst case scenario.

Example 2 – Cont.

Expected DIC errors due to pixel shift as a product of the two cameras taking the images out of sequence between 0 and 350 ns



Summary

- Understand what is the time stamp in your data
    - Know your error sources
    - Understand how the errors propagate
    - Know your accuracy

- What is your customers requirements
    - Don’t Overkill