NIF Cross timing overview

NIF User Forum

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Cross Timing RI

September 18, 2017

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Overview

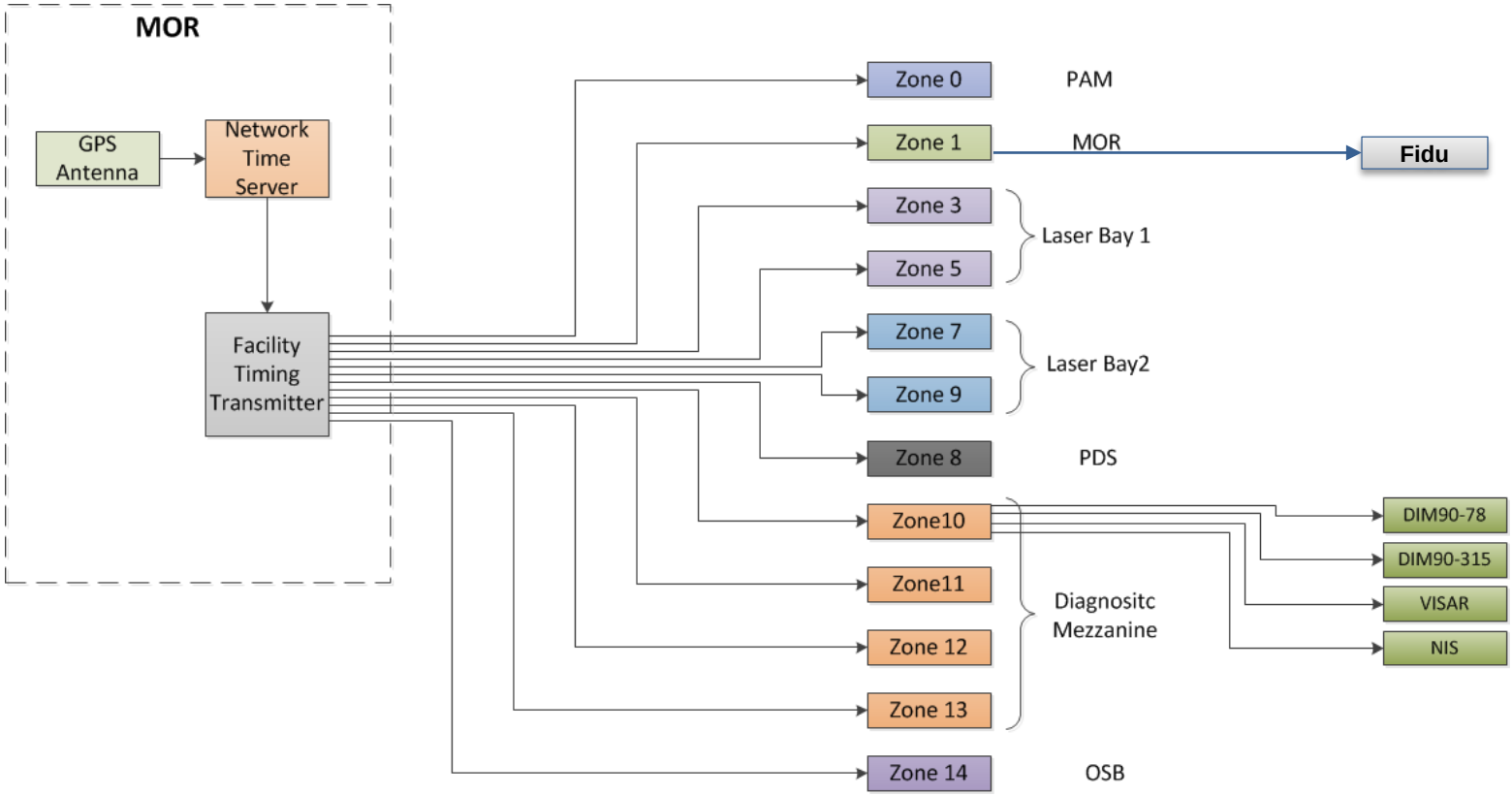
- Integrated Timing System (ITS) overview
  - Hardware, software & archive
- Fidu
  - Hardware
- Diagnostic timing commissioning process

What is Integrated Timing System (ITS)

- ITS is a combination of hardware and software products which provides triggers for the for the entire NIF facility.
- ITS is a distributive system which originates in the NIF MOR and provides triggers to local zones in key locations in the facility such as MOR, Laser bays, Switchyards, OSB and Diagnostic mezzanines.
- Depending on shot type and instrument various software products provide input for trigger setup, including CMT/SST, AppMan, LoCos, LPOM & multiple ICCS products.

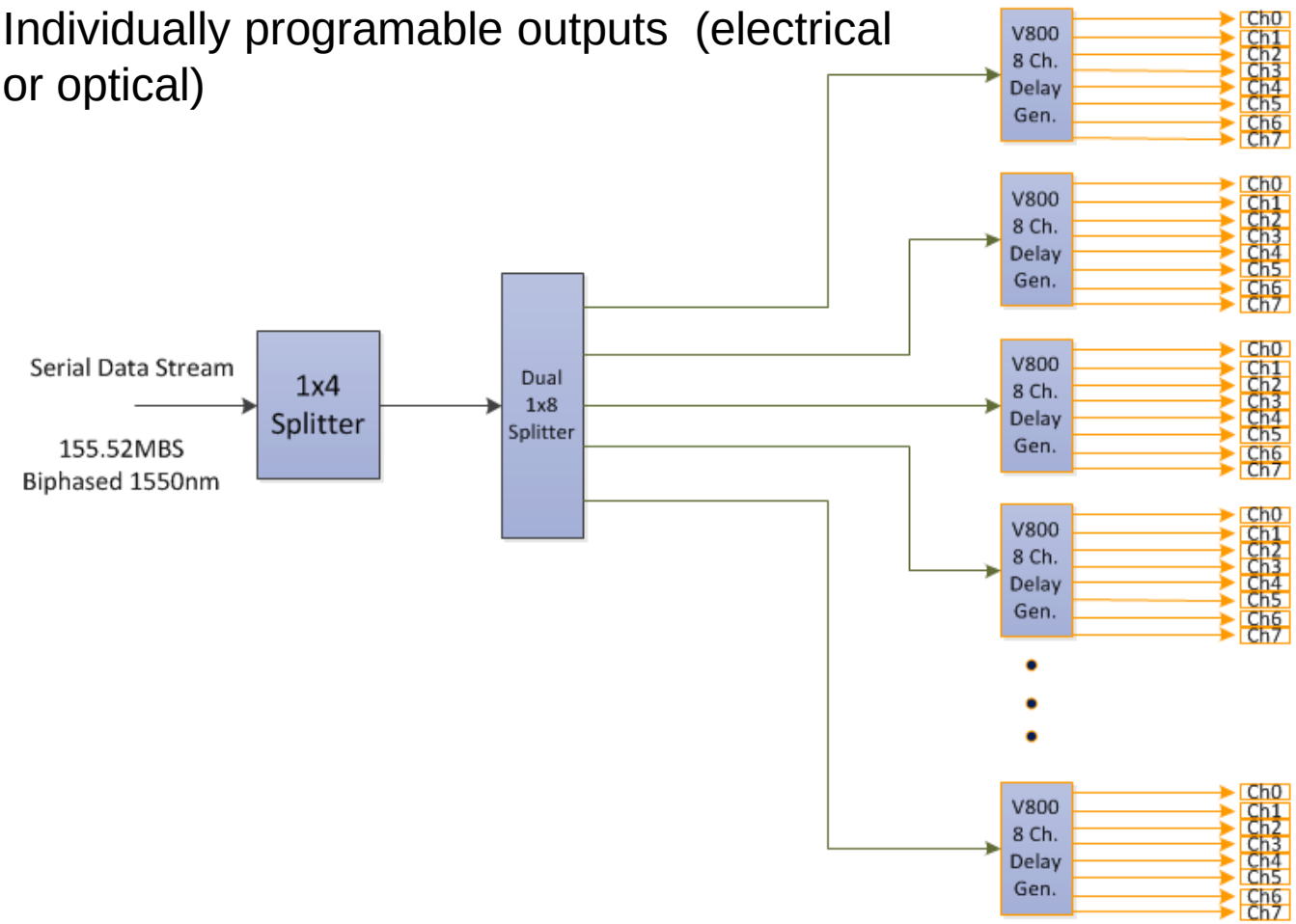
ITS Top Level View

The Facility Timing Transmitter sends the trigger message to the delay generators located in each timing zone. When a message is sent with a trigger key, the delay generated will start the process of issuing a trigger based on data from the FTT message



ITS Zone Layout

Each zone is capable of supporting multiple delay generators (V880). A V880 has 8 Individually programable outputs (electrical or optical)



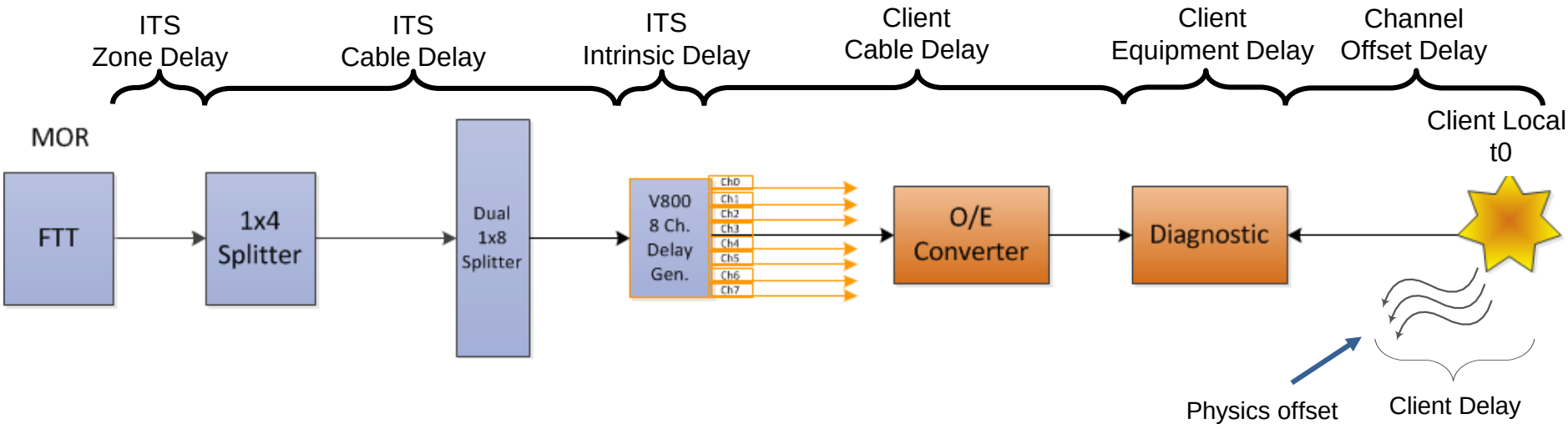
Pulse Width	200ns
Wavelength	850nm
Rep. Rate (Hz)	0.2, 1,10,30,60,960

The arrival time of a hardware trigger at a diagnostic is determined by the values associated with several delay fields

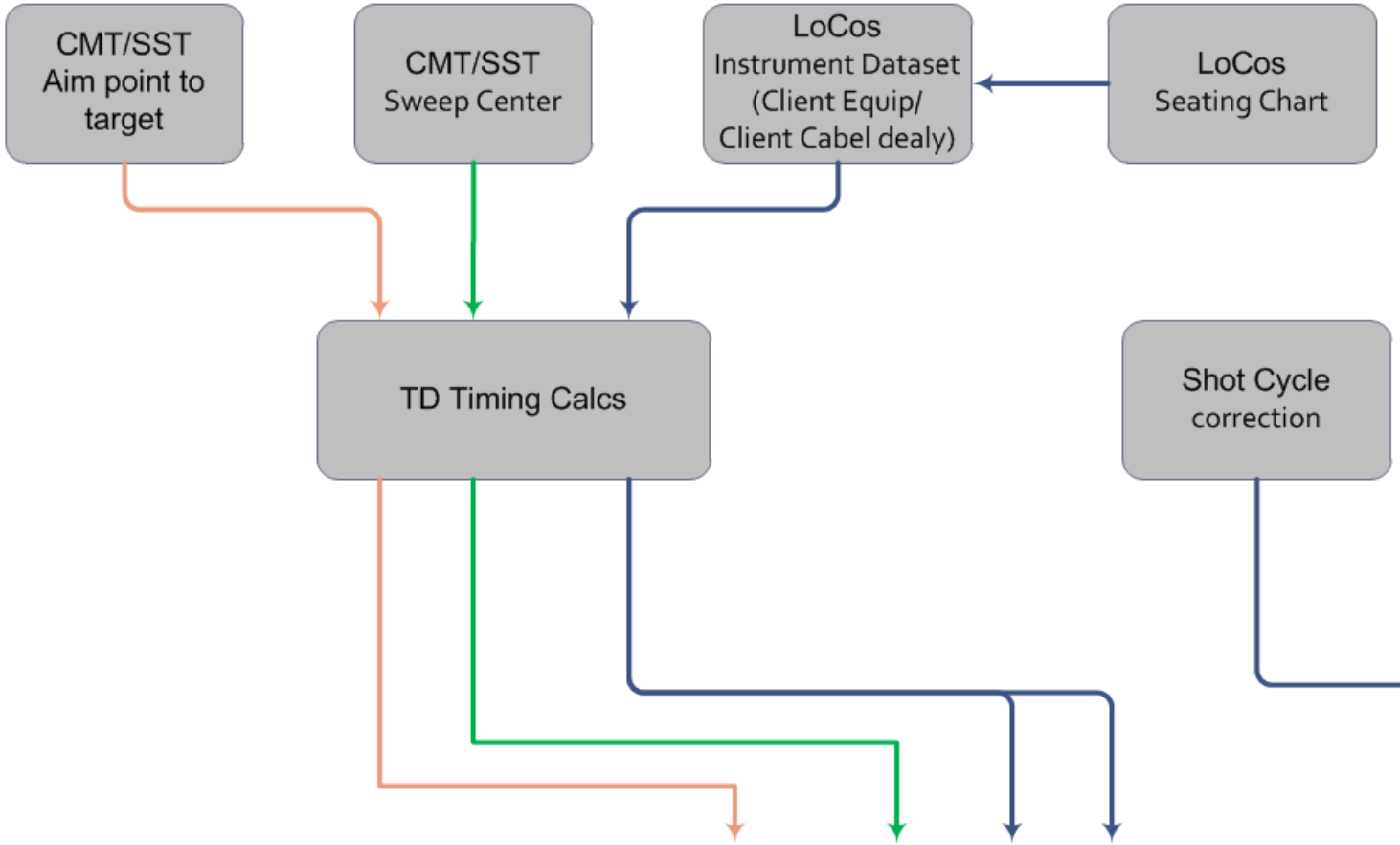
SHOT_ID	N170719-003-999
TAXON	TIMING|TC090-078|DIM|TRIG3-HTRIG
SUBSYSTEM	TIMING
LOCATION	TC090-078
UNIT	DIM
IDENTIFIER	TRIG3-HTRIG
SAMPLE_NUM	0
SAMPLE_ID	SHOT
ITS_ZONE_DELAY	948629
ITS_CABLE_DELAY	49596
ITS_INTRINSIC_DELAY	96000
CHANNEL_OFFSET_DELAY	3087
CLIENT_DELAY	3000
CLIENT_CABLE_DELAY	0
CLIENT_EQUIPMENT_DELAY	453283
CLIENT_LOCAL_T0	757500397
CHANNEL_DELAY_SETTING	755959001
OFFSET_CORRECTION	25

Trigger delay fields

- Each Zone has physical delay elements such as
  - Serial Data Stream Path (ITS Zone Delay)
  - Optical Fibers (ITS Cable Delay)
  - V880 Delay Generator (Intrinsic Delay)
  - Fiber path to custom locations (Client Cable Delay)
  - O/Es to connect optical signals to electrical systems (Client Cable Delay)
  - Diagnostic internal trigger delays (Client Equipment Delay)
  - Detector distance from Target (Channel Offset) [Signal Path]



Example of how each timing field is populated.

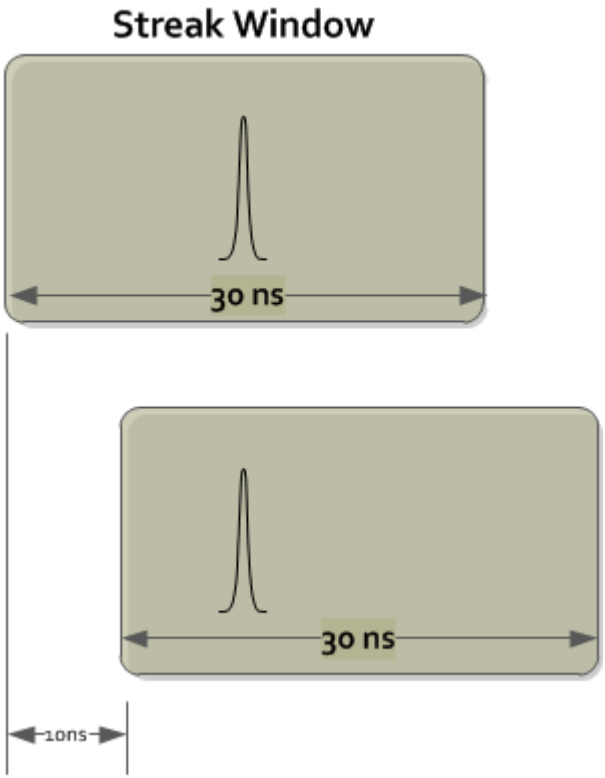


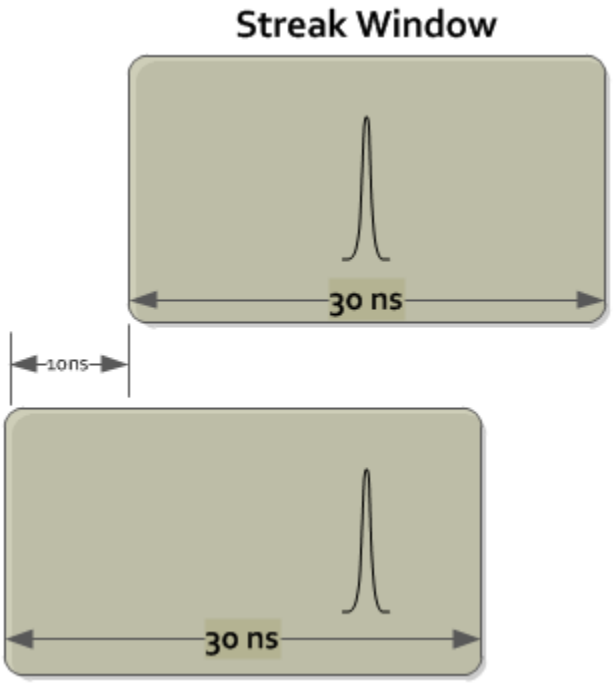
SHOT_ID	TAXON	ITS ZONE DELAY	ITS CABLE DELAY	ITS INTRINSIC DELAY	CHANNEL OFFSET DELAY	CLIENT DELAY	CLIENT CABLE DELAY	CLIENT EQUIPMENT DELAY	CLIENT LOCAL T0	CHANNEL DELAY SETTING	OFFSET CORRECTION
N170719-003-999	TIMING|TC090-078|DIM|TRIG3-HTRIG	948629	49596	96000	3087	3000	0	453283	757500397	755959001	25

Defined during commisioning

Values entered in Timing Trigger fields have different effects to the actual trigger arrival time

Instrument Sweep Trigger





If +10ns is added to **Client delay, Channel Offset or Offset Correction**, the signal will appear earlier in the record.

If +10ns is added to **Client cable or Client Equipment delay**, the signal will appear later in the record.

Trigger archive can be used for all commissioned diagnostics to review each trigger delay field

NIFIT>Data Visualization>Launch QuickLooks>Database>Database Report>Timing Triggers

TIMING_TRIGGERS

Max Rows Returned	Report Type	Action	
100000	EXCEL-ROW_HORZ	Report	New Table

Select Columns			Query Constraints	Order By
SHOT_ID	?	☑ VARCHAR2	N1708%999	
TAXON	?	☑ VARCHAR2		
SUBSYSTEM	?	☐ VARCHAR2		
LOCATION	?	☐ VARCHAR2	TC090-078	
UNIT	?	☐ VARCHAR2	DIM	
IDENTIFIER	?	☐ VARCHAR2	TRIG3%	
SAMPLE_NUM	?	☐ NUMBER		
SAMPLE_ID	?	☐ VARCHAR2		
ITS_ZONE_DELAY	?	☑ NUMBER		
ITS_CABLE_DELAY	?	☑ NUMBER		
ITS_INTRINSIC_DELAY	?	☑ NUMBER		
CHANNEL_OFFSET_DELAY	?	☑ NUMBER		
CLIENT_DELAY	?	☑ NUMBER		
CLIENT_CABLE_DELAY	?	☑ NUMBER		
CLIENT_EQUIPMENT_DELAY	?	☑ NUMBER		
CLIENT_LOCAL_T0	?	☑ NUMBER		
CHANNEL_DELAY_SETTING	?	☑ NUMBER		
ACQ_TIME	?	☐ DATE		
ACQ_TIME_USECS	?	☐ NUMBER		
SERIAL_NUMBER	?	☐ NUMBER		
CHANNEL_NUMBER	?	☐ NUMBER		
PC_BOARD_TEMP	?	☐ NUMBER		
RECEIVED_OPTICAL_POWER	?	☐ NUMBER		
VCXO_CONTROL_VOLTAGE	?	☐ NUMBER		
CAL_ERROR	?	☐ NUMBER		
CRC_ERROR	?	☐ NUMBER		
JITTER_ERROR	?	☐ NUMBER		
NOLOCK	?	☐ NUMBER		
SIGNAL_LOSS_ALARM	?	☐ NUMBER		
HIGH_PRECISION	?	☐ NUMBER		
ALT_TABLE	?	☐ NUMBER		
MARGINAL_LOCK	?	☐ NUMBER		
PFAIL	?	☐ NUMBER		
EPOCH	?	☑ VARCHAR2		
SHOT_KEY	?	☐ NUMBER		
TRIGGER_KEY	?	☐ NUMBER		
PERMISSIVE_KEY	?	☐ NUMBER		
REQUEST_ID	?	☐ NUMBER		
OFFSET_CORRECTION	?	☑ NUMBER		

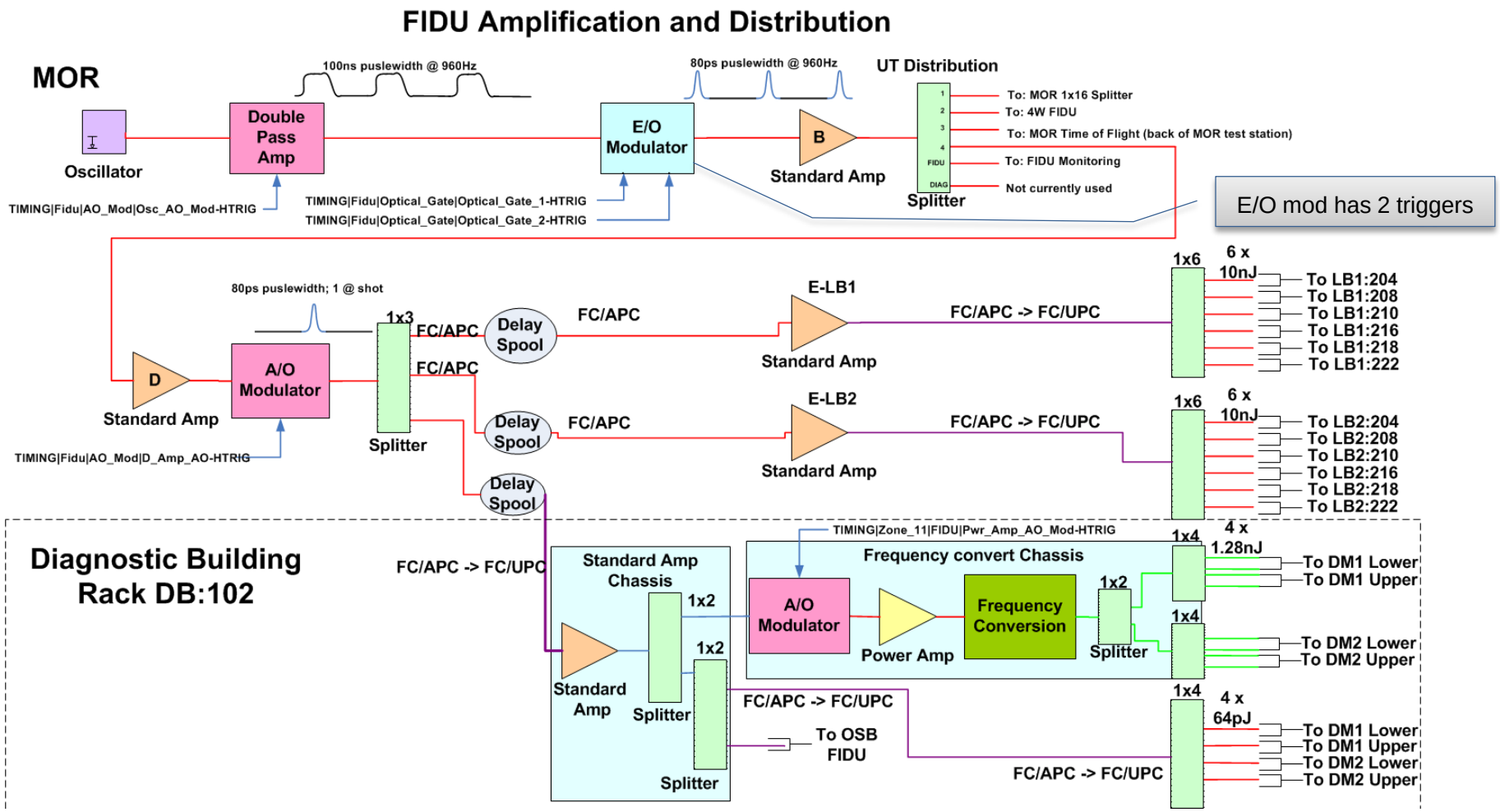
Reset | Select All columns | Deselect All columns

SHOT_ID	TAXON	ITS_ZONE_DE	ITS_CABLE_D	ITS_INTRINSIC_D	CHANNEL_OFFSET_	CLIENT_DEI	CLIENT_CABLE_I	CLIENT_EQUIPMENT_I	CLIENT_LOCA	CHANNEL_DELAY_SI	EPOCH	OFFSET_CORRECTION
N170806-004-9	TIMING|TC090-078|DIM|TRIG3	948629	49596	96000	2640	3750	0	456867	757500397	755956030	EPOCH	335
N170813-001-99	TIMING|TC090-078|DIM|TRIG3	948629	49596	96000	0	0	0	0	757500397	756406172	EPOCH	0

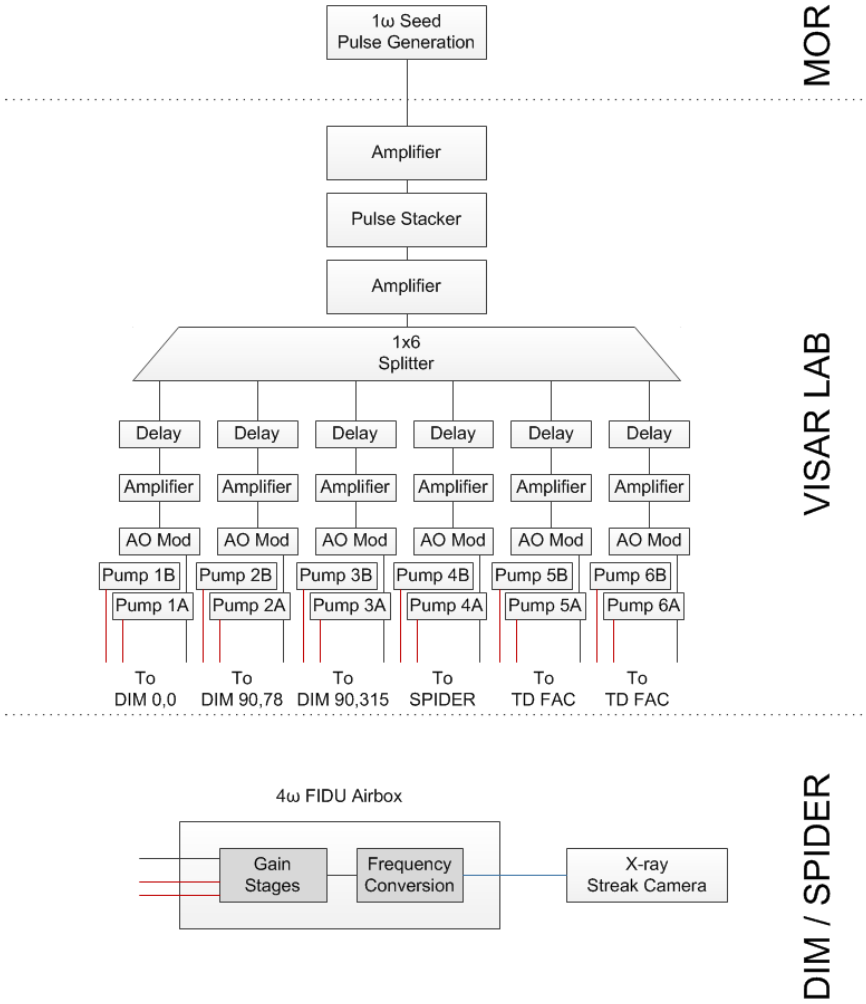
Fidu System description

- Fiducials provide temporal relationships between time bases of different instruments in the facility.
- Fiducials appear on multiple diagnostics and provide a shot to shot reference.
- Fiducials are optical based timing markers which are injected on required diagnostics.
- The source Fidu signal is generated in the MOR and distributed to the laser bays, diagnostics mezzanines and target area.
- Three Fidu wavelengths are generated, 1ω (1053nm), 2ω (527 nm) & 4w (263 nm).

Top level Fidu 1ω & 2ω system



4w Fidu system block diagram



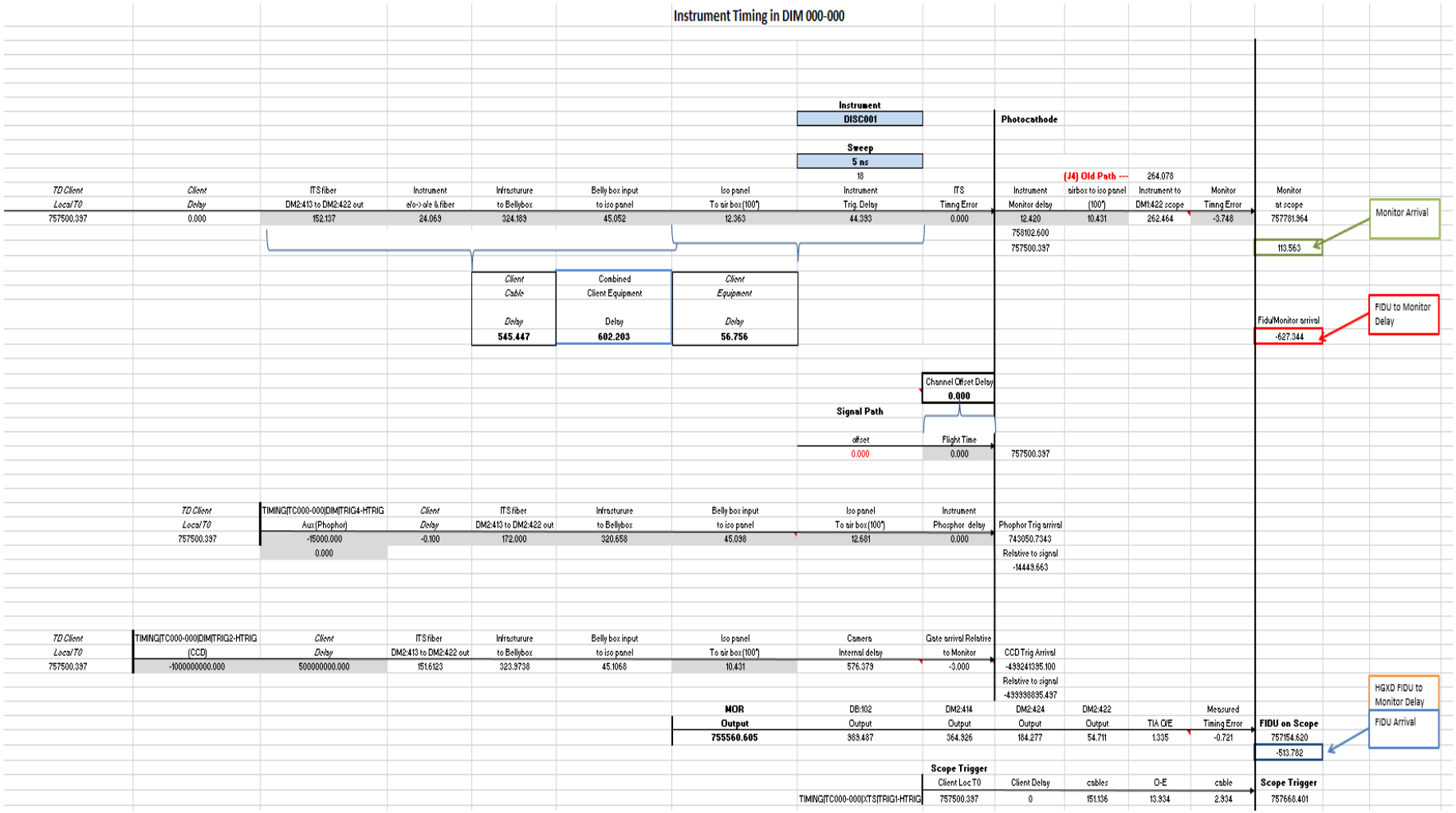
Cross Timing new diagnostic commissioning

- IPRB requirements
  - Collaborate with RI/RS for proper Timing & Fidu hardware interfaces
  - Provide ICCS Software team Htrig taxon mapping to V880
  - Procure hardware
  - Update drawings
  - Temporal measurements of cabling & infrastructure hardware
  - Collect instrument delay, standoff distances and time of flight information
  - Build Timing Diagram: compare predicted vs measured data
  - Populate datasets, setpoints
  - Update data based on post shot analysis

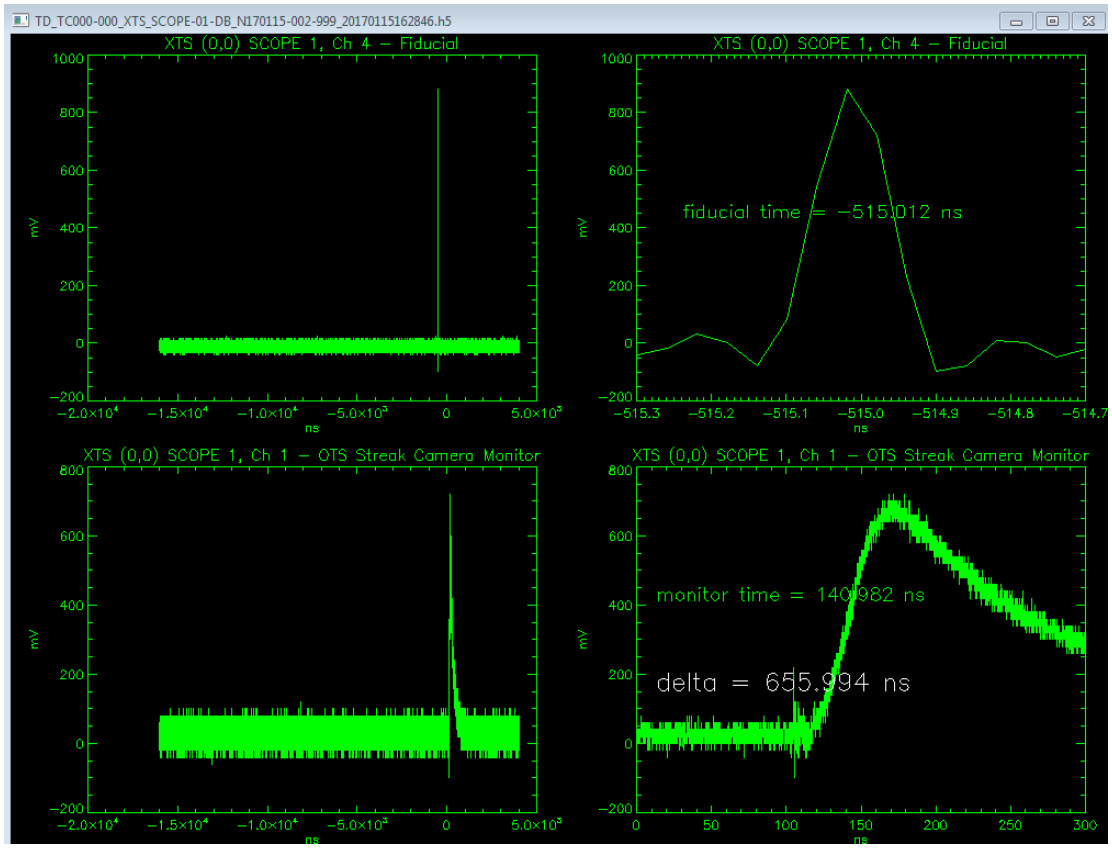
What is a timing diagram

- Purpose of a timing diagram to determine the necessary trigger delay settings needed for the physic signal to appear at the appropriate location on an instrument record.
  - In some instances it is also necessary to predict additional delay such that fidu can simultaneous appear in the record with the signal.
- All fibers, cables , o/e delays are measured for the Fidu, Trigger & signal path
  - Optical Time Domain reflectometer (fiber optic infrastructure)
  - Time Domain reflectometer (copper infrastructure)
- Signal time of flight is provided by the diagnostic RS/RI
- Instrument trigger & monitor delays are provided by instrument RS/RI
  - Measurements are provided with respect of temporal reference position
    - Streak camera reference- center of sweep
    - Gated imager- center of 1st strip
- Operations team will verify timing of an instrument with the Fidu to Monitor time.
  - Absolute arrival times of the fidu, monitor, and are useful during troubleshooting

Timing diagrams describe arrival times of signals at key locations in a diagnostic



DIM 0,0 fidu & OTS monitor signal (TDO software tool)



Fidu arrival time uses Midpoint analysis
Monitor arrival time is defined as the 50% of Leading edge

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Timing of Diagnostics and Related Issues

NIF User Forum

Shahab Khan
X-ray Diagnostic Campaign co-lead
X-ray Streak Camera Responsible Scientist

September 18, 2017

LLNL-PRES-739311 This work was performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory under contract DE-AC52-07NA27344. Lawrence Livermore National Security, LLC

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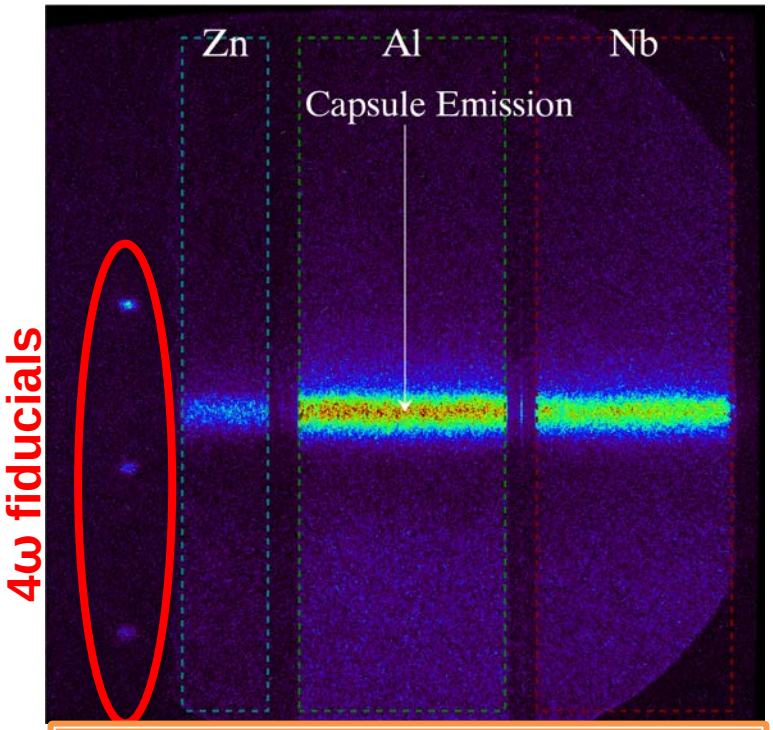
Shot RI's must correctly set the timing of a suite of diagnostics in order to obtain the desired data

- X-ray Framing cameras (GXD, HGXD, DIXI) have the shortest time windows and are thus the most critical to timing errors
- Streak Cameras (SPIDER, DISC, VISAR) can be setup with larger measurement windows at the cost of temporal resolution
- The other diagnostics (GLEH, SPBT) that require timing input have their own setup guides and will not be discussed here
  - They are timed using NIF impulses on Timing shots

SPIDER* is used as the constant time reference for other diagnostic timing

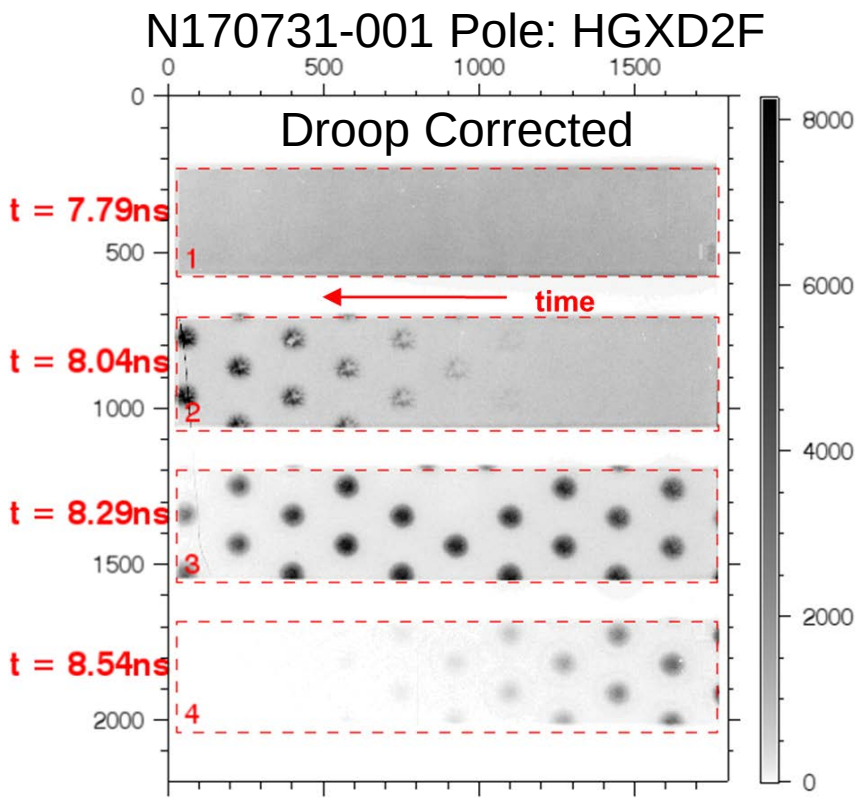
- Facility experiments dedicated to timing are rare so we cross-time the framing cameras and DISC with SPIDER
- SPIDER uses the 4ω fiducials generated at the MOR along with measured delay spools to determine its time base
- SPIDER/4ω fiducials are timed using Facility shots with a gold foil or gold coated sphere – Repeat shots show timing within 10ps



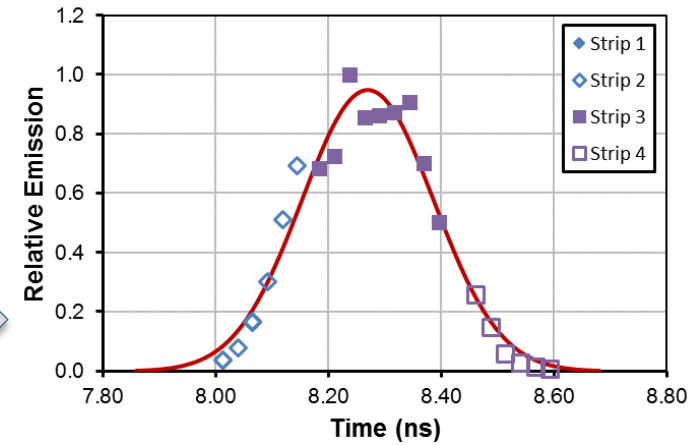
Streak speed/duration determined shot to shot by fitting the three fiducials assuming constant speed

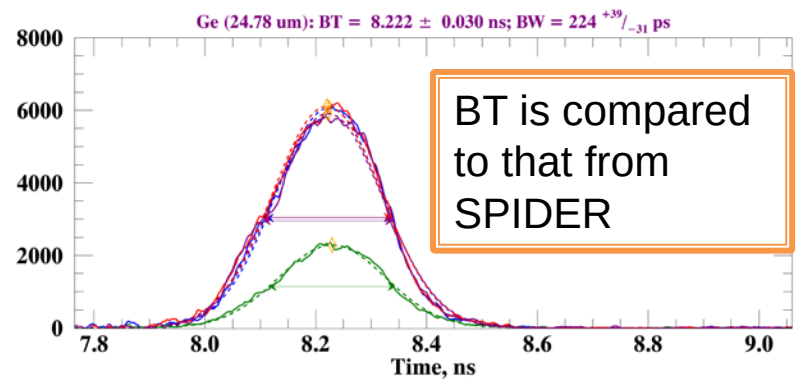
*Streaked Polar Instrumentation for Diagnosing Energetic Radiation
For more information see SPIDER setup guide obtainable through CMT

To time framing cameras, we cross-time implosion emission profiles with SPIDER's signal



Integrated relative emission from each image fit to a Gaussian





BT is compared to that from SPIDER

The problems with this method include the assumptions that the NSTEC* measured strip-strip timings are correct, droop correction is valid here, emission profile is Gaussian
The cross-timing values among a set of shots show a variation of ~75ps

*National Security Technology located in Livermore
Calibrates our gated cameras, streak cameras and others

Strip to strip timings and gate velocity measured at NSTEC using UV pulse

HGXD-002-AUG15 GATE PROFILE ANALYSIS, GATE PROFILE 2A
Imager in Gated Operation, 50V Bias, 200ps PFM's
Interstrip Delays, Chan.1: 0 ps, Chan.2: OFF , Chan.3: OFF , Chan.4: OFF
Page 2/9

Example Data and Fits

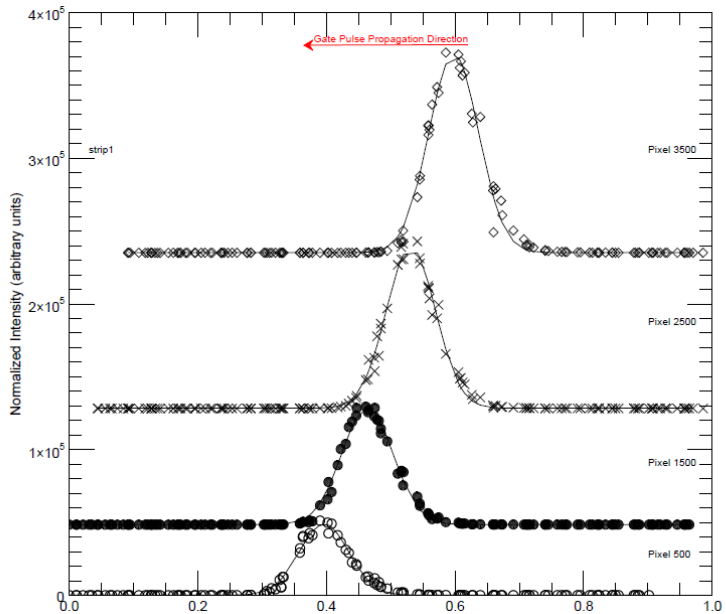


Figure 1: Plot shows (4) Gate Profiles for each strip. Each Profile shows measured data points and a Gaussian fit to these points. Each data point shows the relative intensity at a given pixel location as a function of Gated Imager trigger delay. The amplitude, width, and peak location in subsequent analysis are determined by the Gaussian fit.

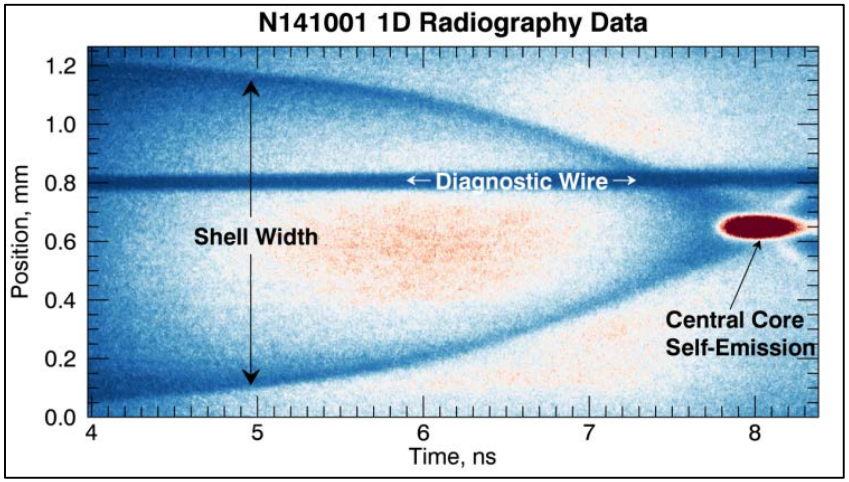
- Relative strip timing and strip velocities found by time-stepping the camera and measuring where the UV pulse is detected
- Uncertainty in measurement arises from camera jitter, strip gain variations, UV vs X-ray gain difference
- Only a subset of strip configurations are measured
- One example: HGXD2F Observed delays with 0/250/500/750 settings 0/250/514/743@ 200V bias
- HGXD6F not recommended to be operated at strip intervals below 250ps

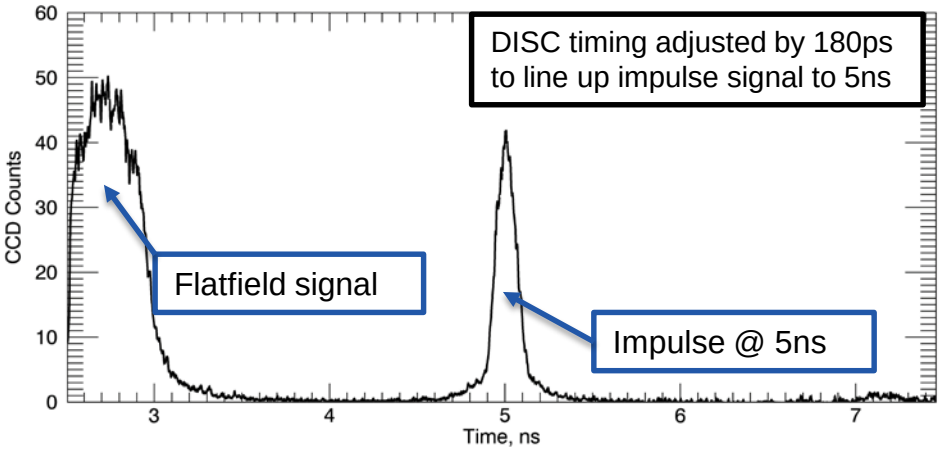
Check Framing camera guide or ask RS* if thinking of using an usual strip configuration

*Responsible Scientist: Joe Holder

DISCs* also use shot data to cross time with SPIDER

- Self emission signal from 1D Radiography experiments are cross-timed to SPIDER's measurement
- In rare occasions, timing shot impulses are used to time the instrument with
- Timing for other streak speeds and other DIM locations can be determined by adding offsets to a cross-timed configuration
- DIM timing deltas come from offsets tabulated for other DISC units or Framing camera units (some found with timing shots and cross timing)





*DIM Insertable/Imaging Streak Camera

DISC/SPIDER sweep windows calibrated at NSTEC using pulses with known time spacing

- Due to imaging system within streak cameras, there is some non-linear warping of the signal when it hits the imager
- A warp correction is generated to linearize the signal in space/time; warp correction also sets the sweep window
- Etalon with known spacing is used to create a train of pulses
- A spatial resolution mask is used to determine warping in space

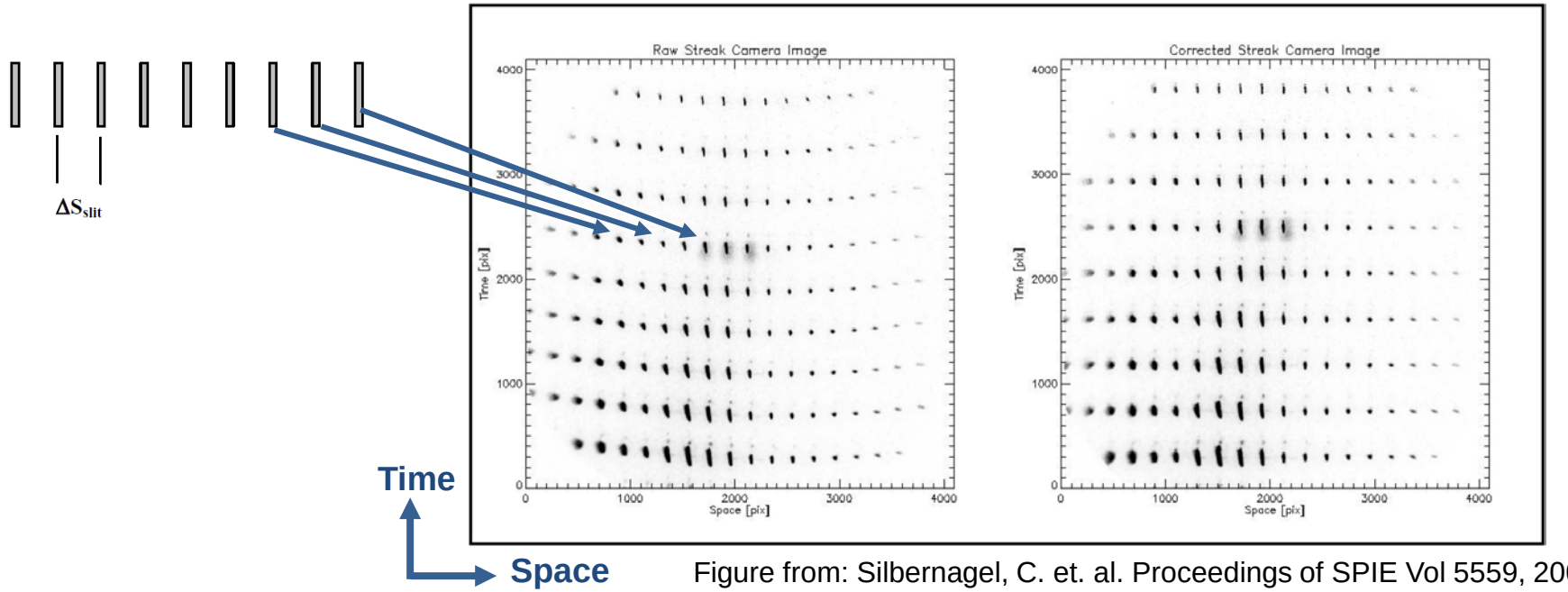


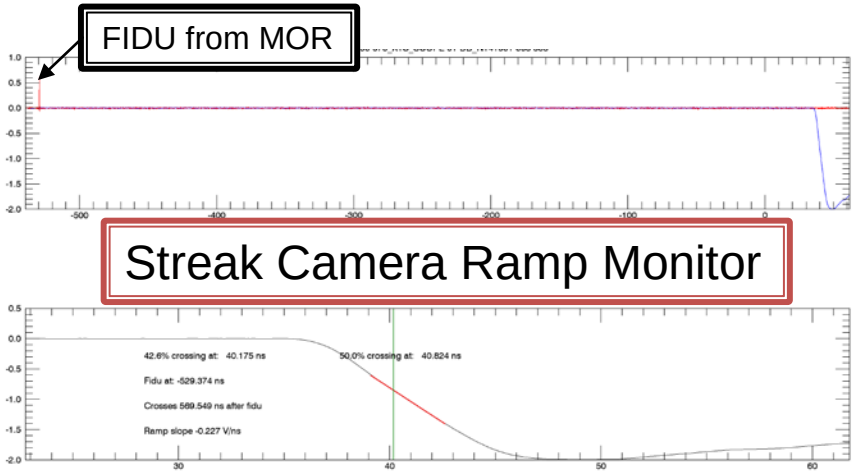
Figure from: Silbernagel, C. et. al. Proceedings of SPIE Vol 5559, 2004

Instrument Jitter adds uncertainty to timing

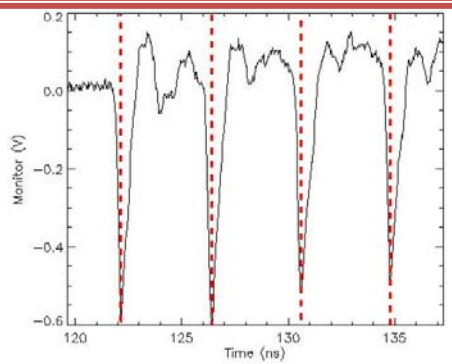
- The sweep speeds and timing of streak cameras as well as the strip intervals and timing of gated cameras fluctuates shot to shot due to the inherent design as well as constantly changing physical conditions
- Electronic jitter is adds an uncertainty to absolute timing of about 50ps
- Using SPIDER's 4w fidu, the range of measured sweep duration observed is about 4% from nominal; i.e. the 10ns sweep can actually be 9.8-10.2ns

When we determine/adjust timing for a diagnostic we update two different datasets

- First dataset is the feedback monitor – This is a signal from the diagnostic which specifies when it actually triggered
  - Streak cameras: Trace of voltage across sweep plates
  - Gated cameras: Representation of gate pulse through each strip
- Second dataset is the Client Equipment Delay (part of ITS) which offsets when the instrument triggers relative to NIF time zero
- When Shot RI's specify a time to trigger an instrument in CMT/SST, the actual time it fires is determined by ITS. However, the TDO's can make adjustments during the shot based on when the feedback monitor signal is expected (dataset RS's provide)



Gated Camera Monitor



Note, only first pulse is utilized since subsequent pulses are affected by cross-talk, etc

Summary

- SPIDER is the time reference instrument on NIF for X-rays since it is the most accurate and repeatable diagnostic
- Both gated framing cameras and DISC use timing shots and implosion data cross-timed with SPIDER to determine their time base
- Gated camera strip intervals and Streak camera sweep speeds determined at NSTEC (SPIDER uses 4ω 4idu for shot to shot sweep speed)
- There is added uncertainty in timing due to electronic jitter
- Two quantities are updated when timing an instrument: Expected monitor time and Client Equipment Delay (affects trigger)

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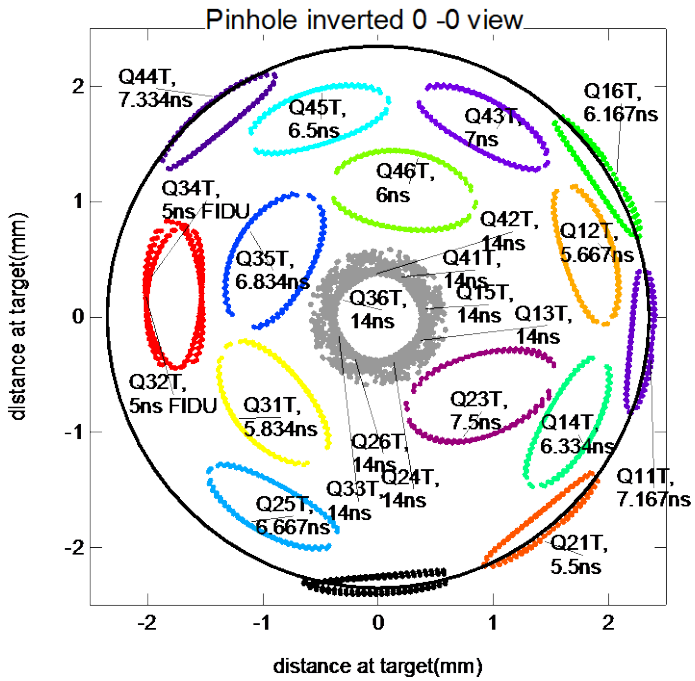
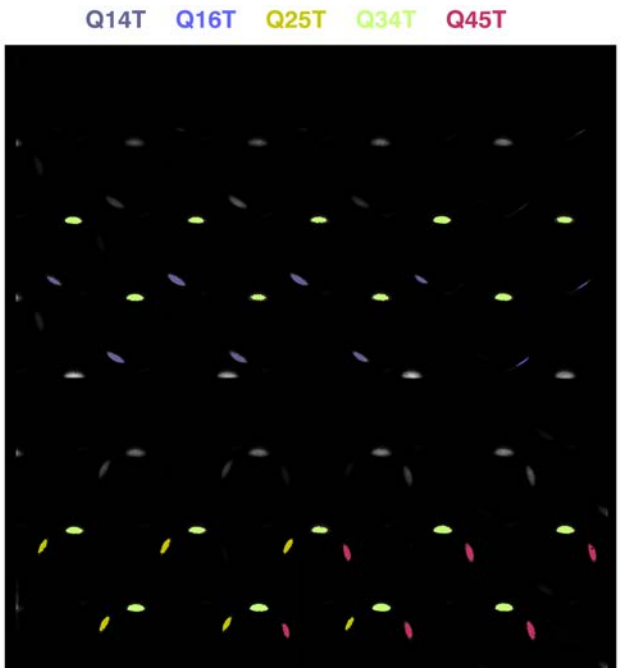
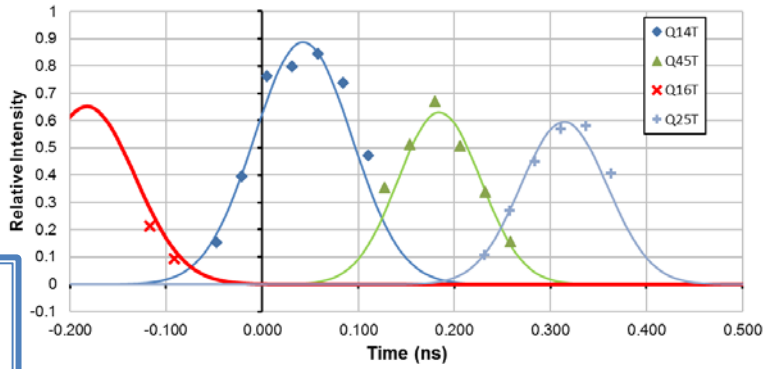
Au Sphere Timing shots can provide absolute timing as well as strip to strip intervals

We hit a Au coated sphere at many locations with 100ps pulses with known times







Plot of intensities of spot gives us independent timing of strips