NIF Target Diagnostic Automated Analysis: Operations & Calibrations

Presentation to

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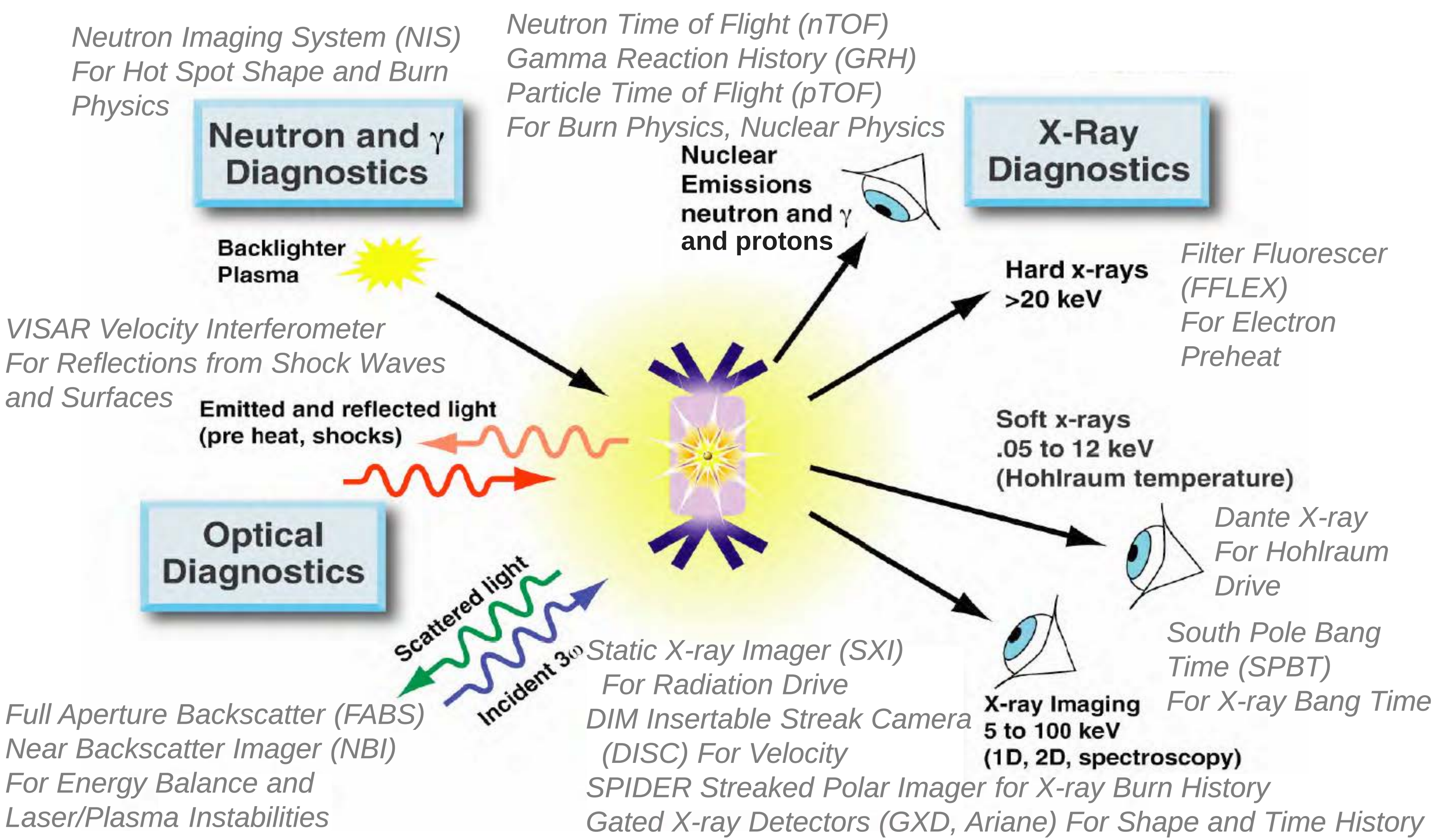
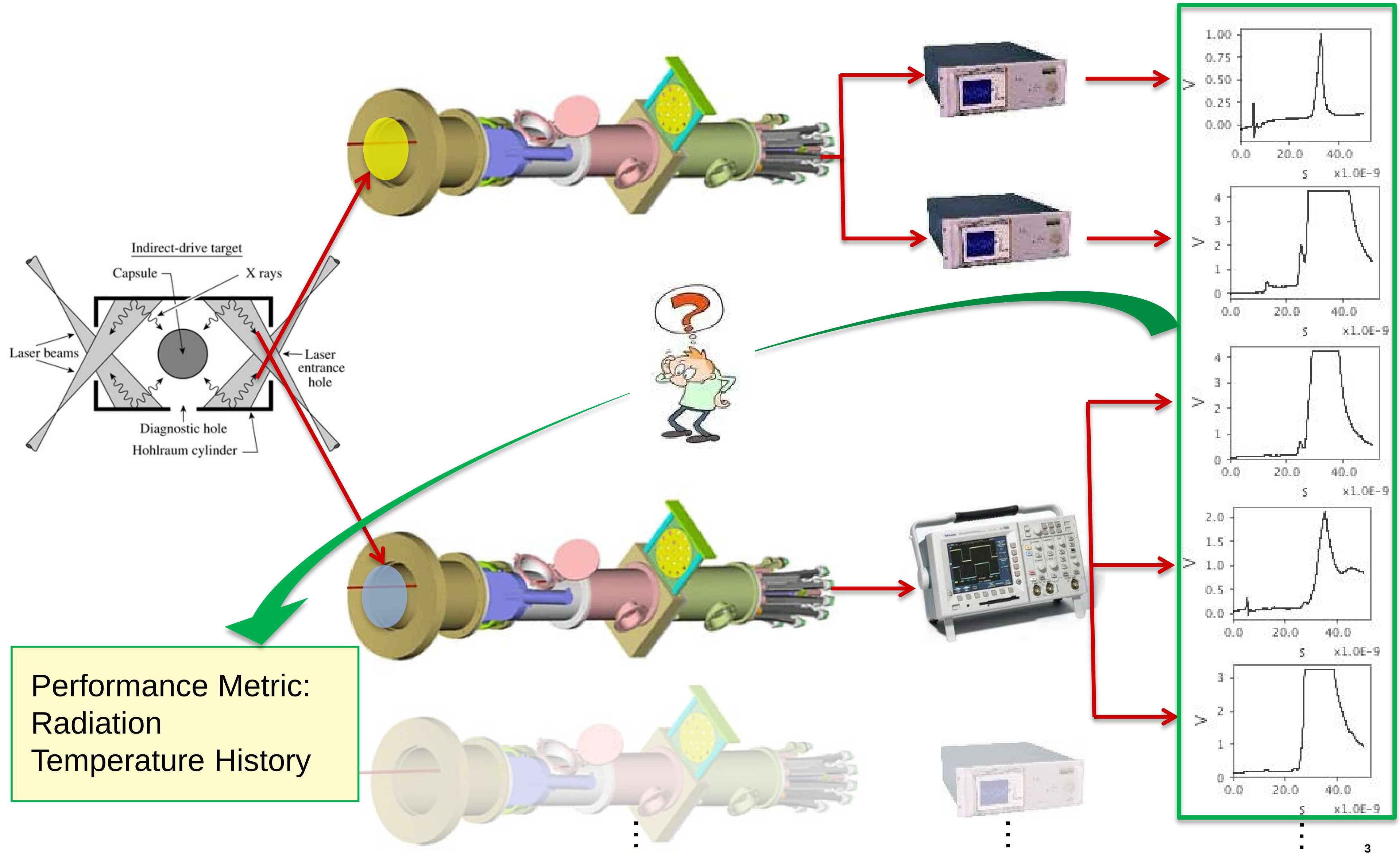
After a NIF laser shot, analysis is automatically run on data from more than 20 target diagnostic systems



Novel signal & image processing is needed to turn raw diagnostic data into the key performance metrics



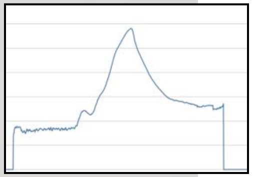
Performance Metric:
Radiation
Temperature History

Automated diagnostic analysis is used to estimate key performance metrics and enable NIF optimization

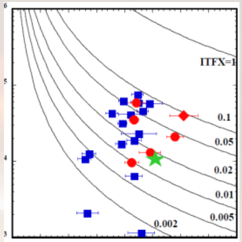
Key performance metrics

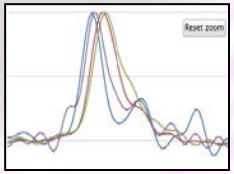
- **Temperature**:
  - Hot spot temperature
  - Hohlraum radiation temperature
- **Density** – areal density of hot spot
- **Yield** of fusion reaction– total production of neutrons or gammas
- **Velocity** – measure of capsule radius over time
- **Shape** – symmetry of the implosion
- **Timing**
  - Shock timing
  - Bang time – time of peak fusion reaction
- **Preheat** of the ablator

Dante analysis estimates radiation temperature

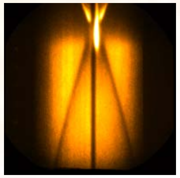


nTOF analysis reports hot spot temp, neutron yield and density metrics



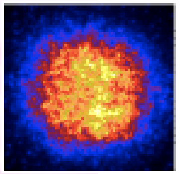


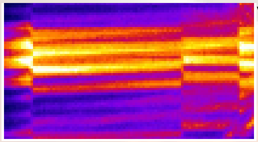
Gamma yield depends on **GRH** analysis



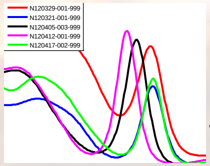
DISC uses camera corrected images

Shape metrics rely on **GXD, Ariane, NIS** timing and image analyses



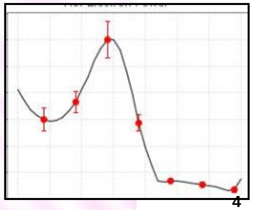


VISAR interferometry analysis enables shock timing



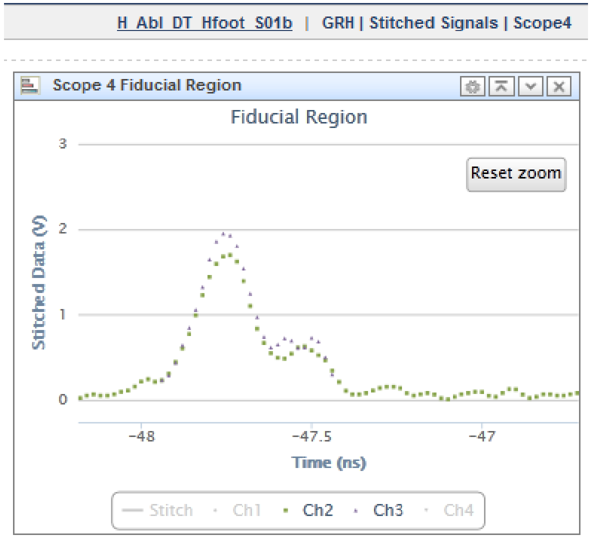
SPBT & GRH analyses report bang time

FFLEX analysis reports hot electrons & preheat

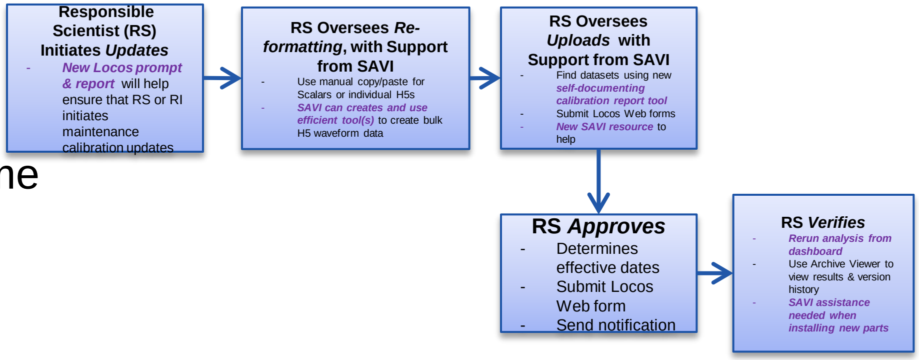


Two critical components of automated analysis are supporting NIF operations and maintaining calibration data

- **Handling operational off-normal data**
  — Diagnostic raw data may be different than expected due to hardware redesigns, detector malfunctions, abnormal shot types, noise, etc.
  — Review one example: Gamma Reaction History (GRH) peak suppression discrepancies between channels.



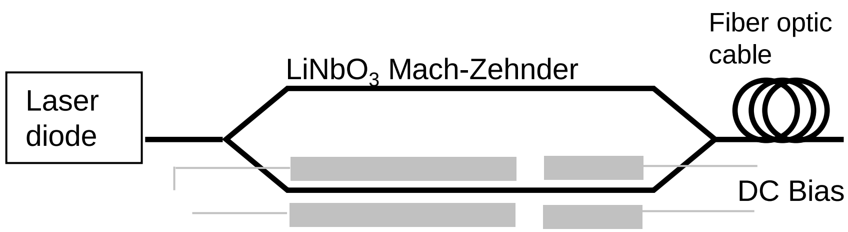
- **Calibration maintenance design**
  — Analysis relies on a gargantuan amount of calibration data
  — Review example of oscilloscope time base calibration for DANTE
  — Review scope of the maintenance feat



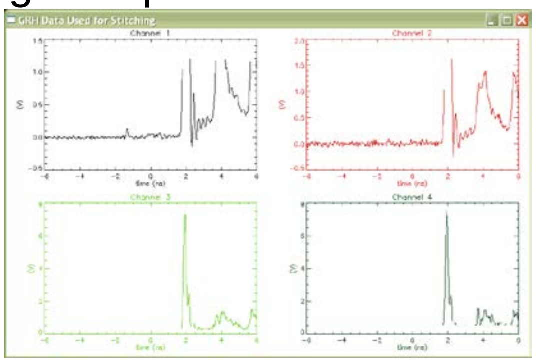
GRH automated analysis reports gamma bang time and burn width with tens of ps accuracy – fielded in 2011

GRH Inverse Problems Include:

- Demodulating amplitude modulated signal from Mach-Zehnder hardware



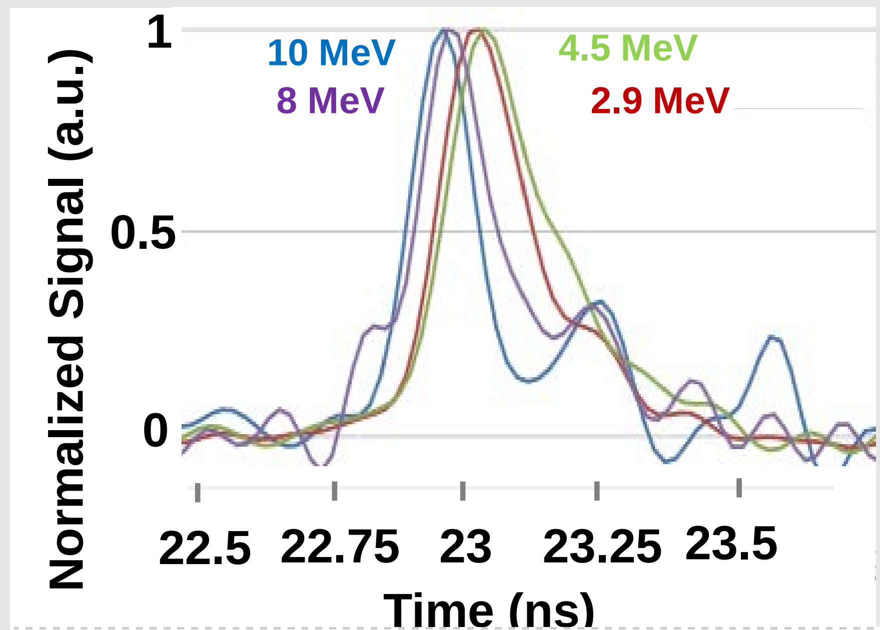
- Stitching multiple channel data



- Deconvolving system responses of PMT and Cherenkov Gas cells using constrained least squares filtering in the frequency domain

$$H(f)^{-1} = X(f) \,.\, \frac{Conj(Y(f)}{(Y(f)^2 + G))}$$

Deconvolved Cherenkov Peaks



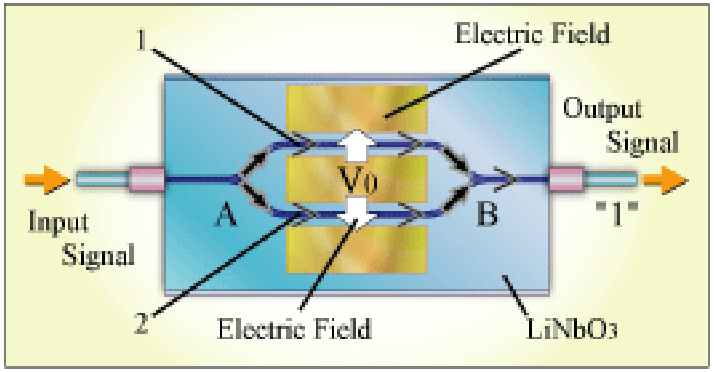
GRH Summary

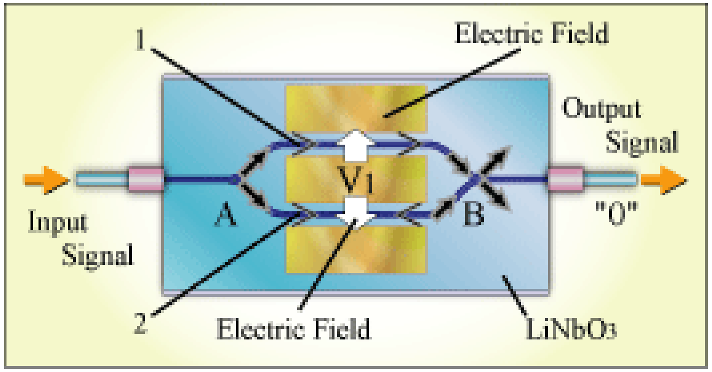
Scope	Peak Time (ns)	Peak Width (ps)	Peak Area	Gas Thresh (MeV)
SCOPE-1	22.956	141.581	4358.268	10
SCOPE-2	23.020	190.374	3.601E6	2.9
SCOPE-3	23.039	216.940	3.577E5	4.5
SCOPE-4	22.974	159.349	6422.004	8

GRH data on one detector scope system showed the two Mach Zehnders reporting conflicting peak levels

N130311 **N130331** **N130501** **N130505**

Investigating causes of peak suppression in Mach Zehnder (MZ) results: MZ introduction

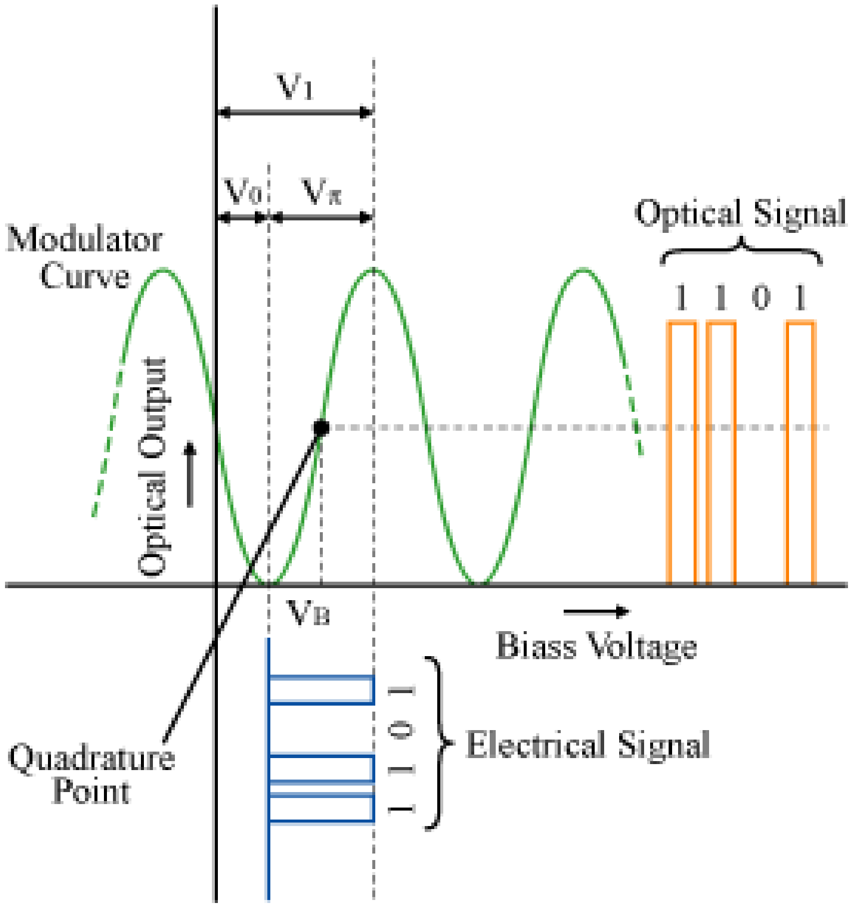




- MZ is used to create a continuous signal light output from a continuous voltage input signal (usually to send down a fiber optic cable)
  - Can produce continuous light signal at high speed and with accuracy.
- To do this the MZ modulates the light intensity of a constant laser source
  - Some materials can change the phase of light passing through them based on voltage level applied to the material – LiNbO3 is often used
  - Light source is split, half is phase modulated, then recombined in order to amplitude modulate the light signal, similar to an interferometer.

Investigating causes of peak suppression in MZ results: Dither signal used for active bias control

- Bias point drifts with changes in temperature and environment
- Active Control of the bias point can be achieved by applying a low-frequency dither signal to the control system.
  - Second harmonic of the dither signal is minimized
  - Output data includes presence of the dither signal



Peak suppression solution: use recorded dither signal to incorporate dither input correction into MZ demodulation equations

$$I_{out}(t) = \frac{I_{MaxIn}}{2}\left[1+\sin\left(\frac{\pi V_{pmt}(t)}{V_{pmt}^{\pi}} + \frac{\pi \Delta V_{bias}}{V_{bias}^{\pi}}\right)\right]$$

Light intensity through MZ transfer function

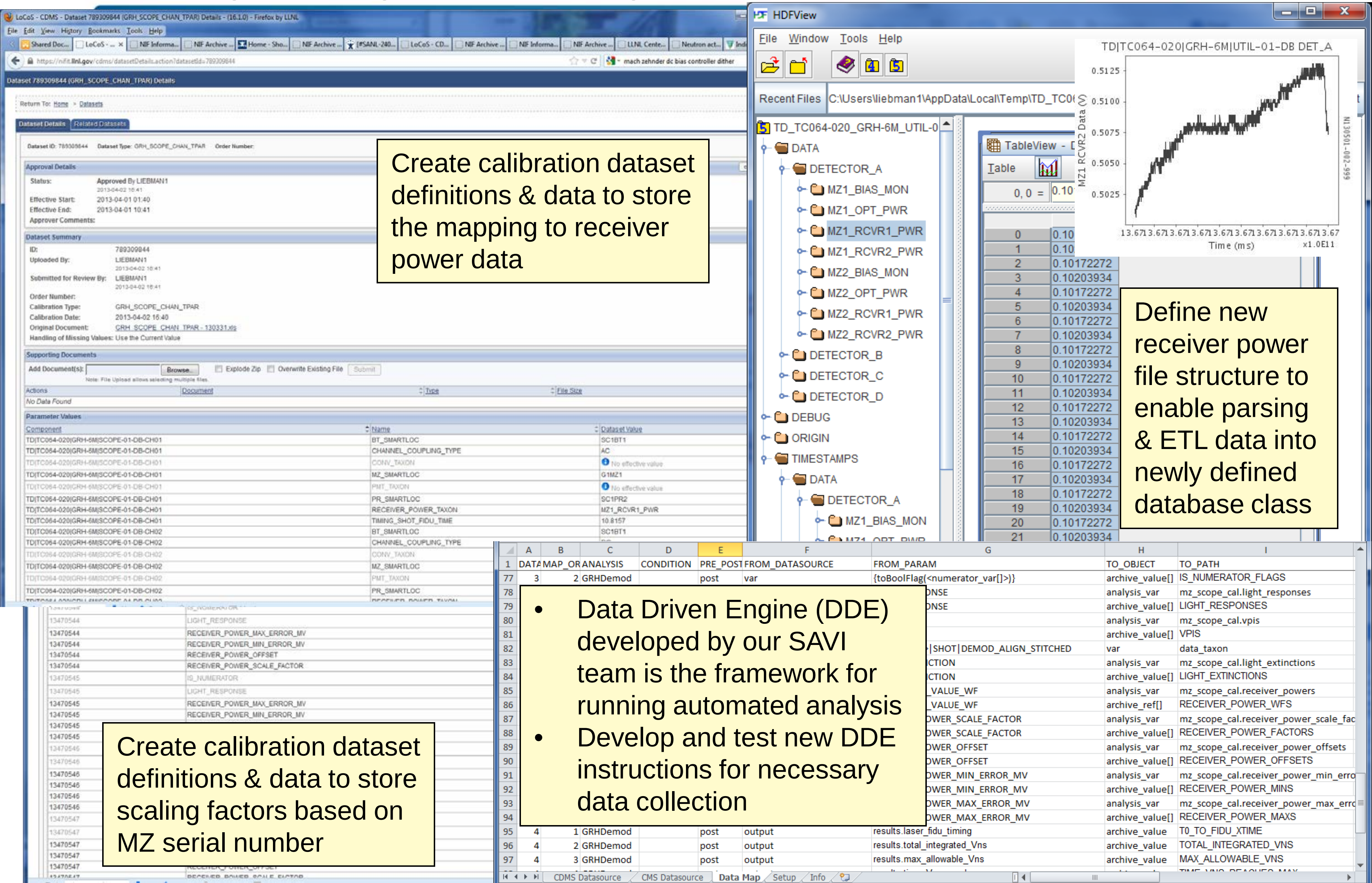
Solve for voltage entering MZ, substitute measured vars

$$V_{pmt}(t) = \frac{V_{pmt}^{\pi}}{\pi}\left[\sin^{-1}\left(\frac{V_{dig} - V_{lightExt}^{0}}{abs(V_{Dig}^{0@Q_-} - V_{lightExt}^{0})} + 1\right) - \sin^{-1}\left(\frac{V_{Dig}^{0shot} - V_{lightExt}^{0}}{abs(V_{Dig}^{0@Q_-} - V_{lightExt}^{0})} + 1\right)\right]$$

$V_{Dig}^{0@Q_-}$ is the recorded dither signal

$$V_{pmt}(t) = \frac{V_{pmt}^{\pi}}{\pi}\left[\sin^{-1}\left[\frac{V_{Dig_{ac}}(t) - baseline}{c_{ac/dc}\, abs(V_{Dig_{dc}}^{0@Q_-} - V_{lightExt}^{0})} + \left(\frac{V_{Dig_{DC}}^{0shot} - V_{lightExt}^{0}}{abs(V_{Dig_{DC}}^{0@Q_-} - V_{lightExt}^{0})} + 1\right)\right] - \sin^{-1}\left[\frac{V_{Dig_{DC}}^{0shot} - V_{lightExt}^{0}}{abs(V_{Dig_{DC}}^{0@Q_-} - V_{lightExt}^{0})} + 1\right]\right]$$

Majority of effort to develop dither correction solution is defining, storing and querying necessary data



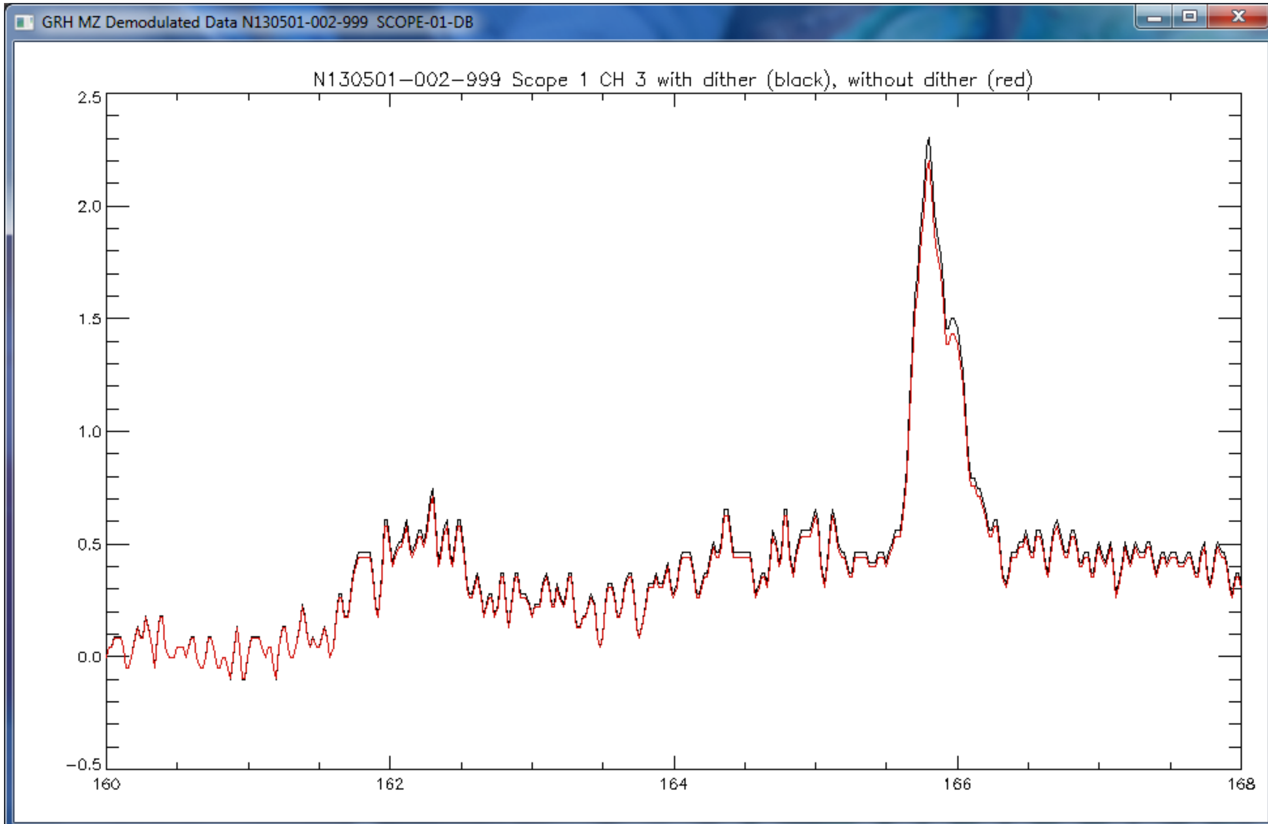
Create calibration dataset definitions & data to store the mapping to receiver power data

Define new receiver power file structure to enable parsing & ETL data into newly defined database class

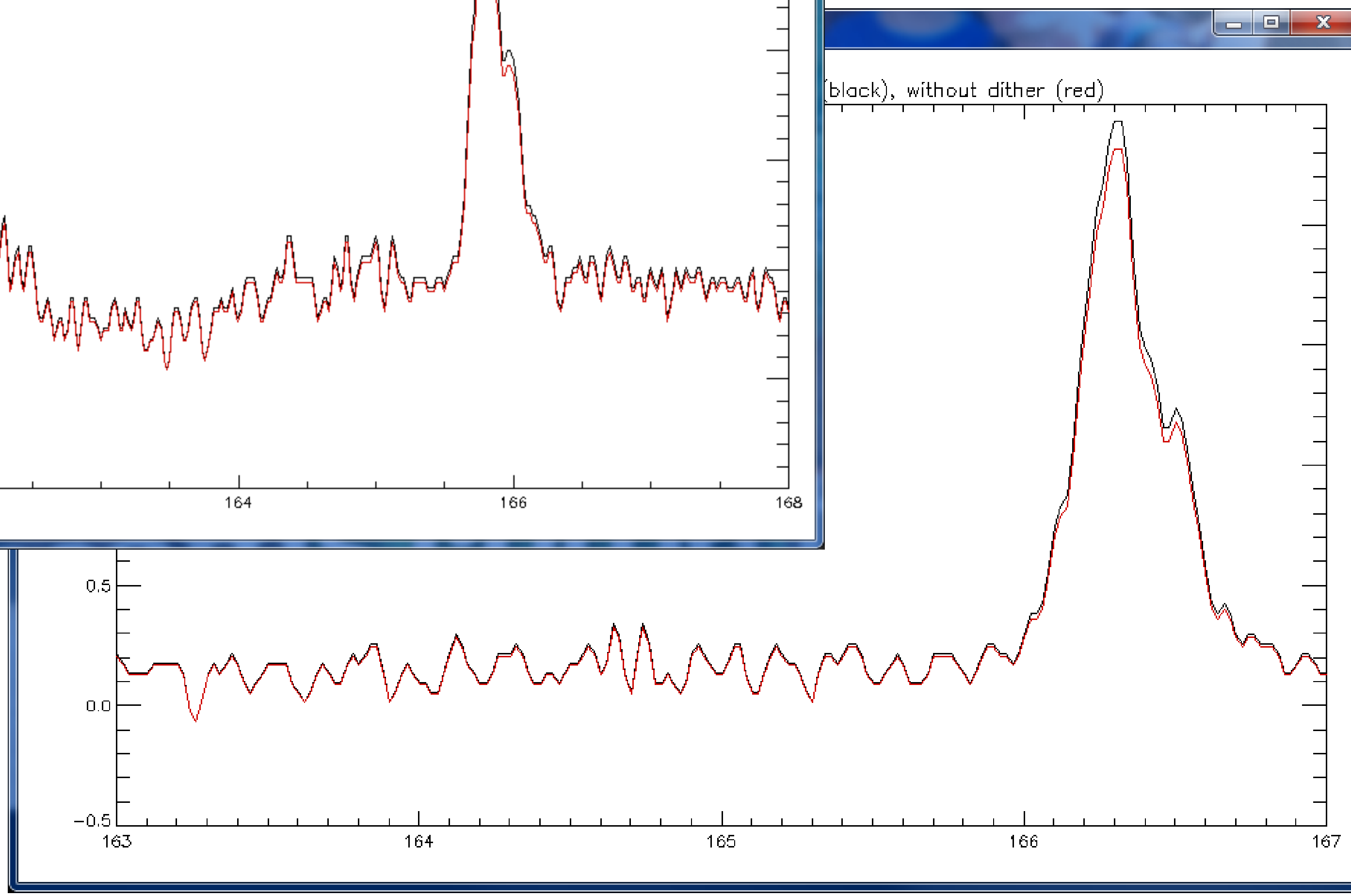
- Data Driven Engine (DDE) developed by our SAVI team is the framework for running automated analysis
- Develop and test new DDE instructions for necessary data collection

Create calibration dataset definitions & data to store scaling factors based on MZ serial number

Dither corrected demodulation results show the effects of bias control dither related peak suppression

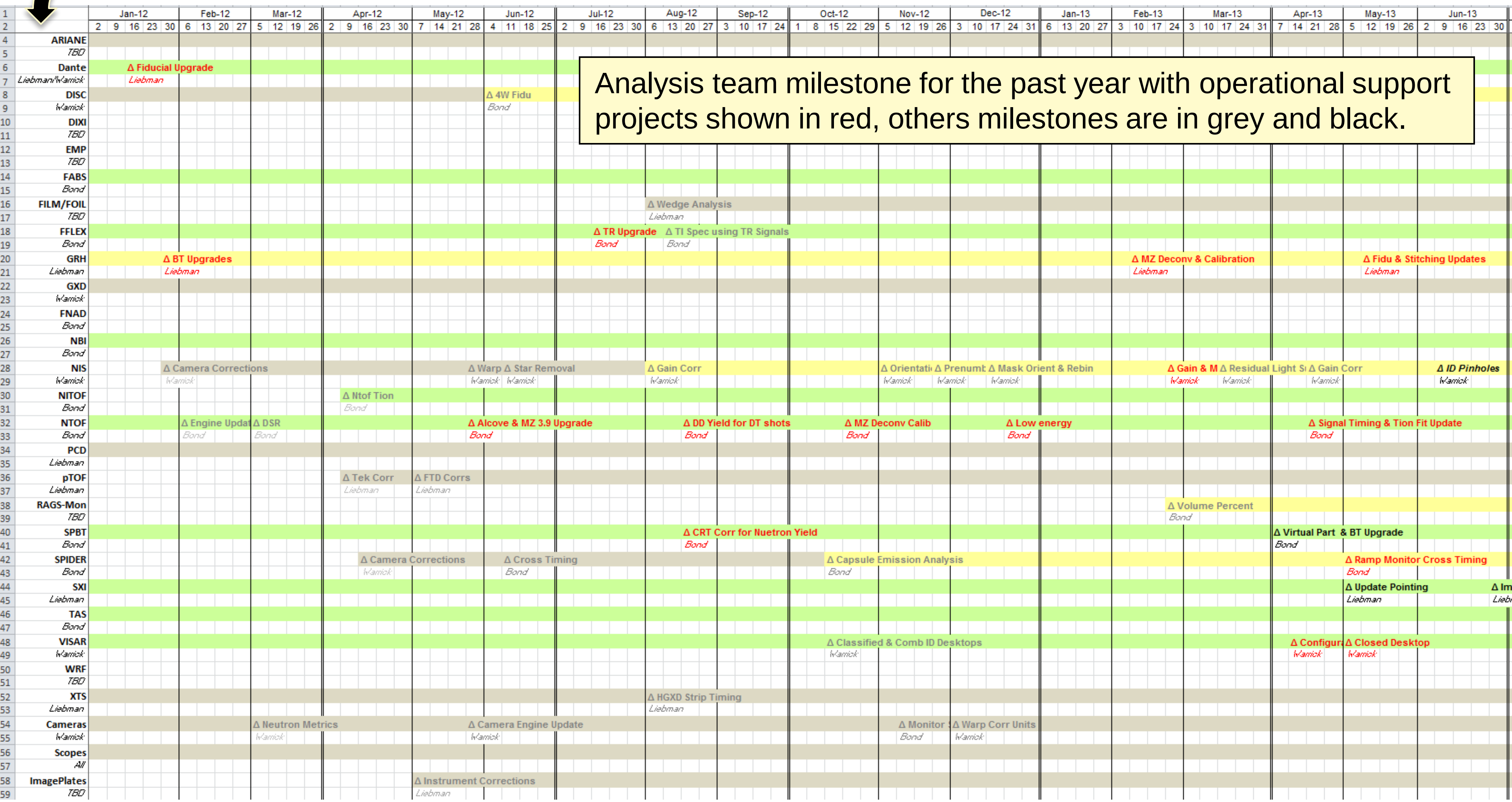


Bias point control dither manifests as a scaling factor that disproportionately effects the most relevant data points



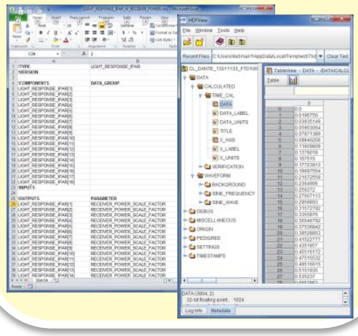
Operational support projects account for one third of target diagnostic analysis team milestones

List of 22 diagnostics supported with automated analyses



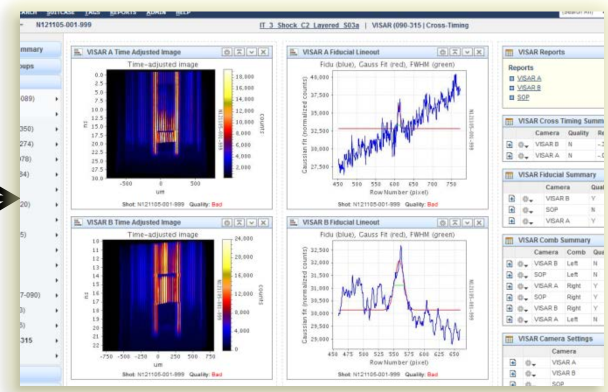
Quality automated results require expected target diagnostic data, tested analysis software, and *accurate calibration data*

Calibration Data



Target Diagnostic Raw Data

SAVI Automated Analysis
- Custom utilities
- Re-useable algorithms
- Specialized diagnostic analysis

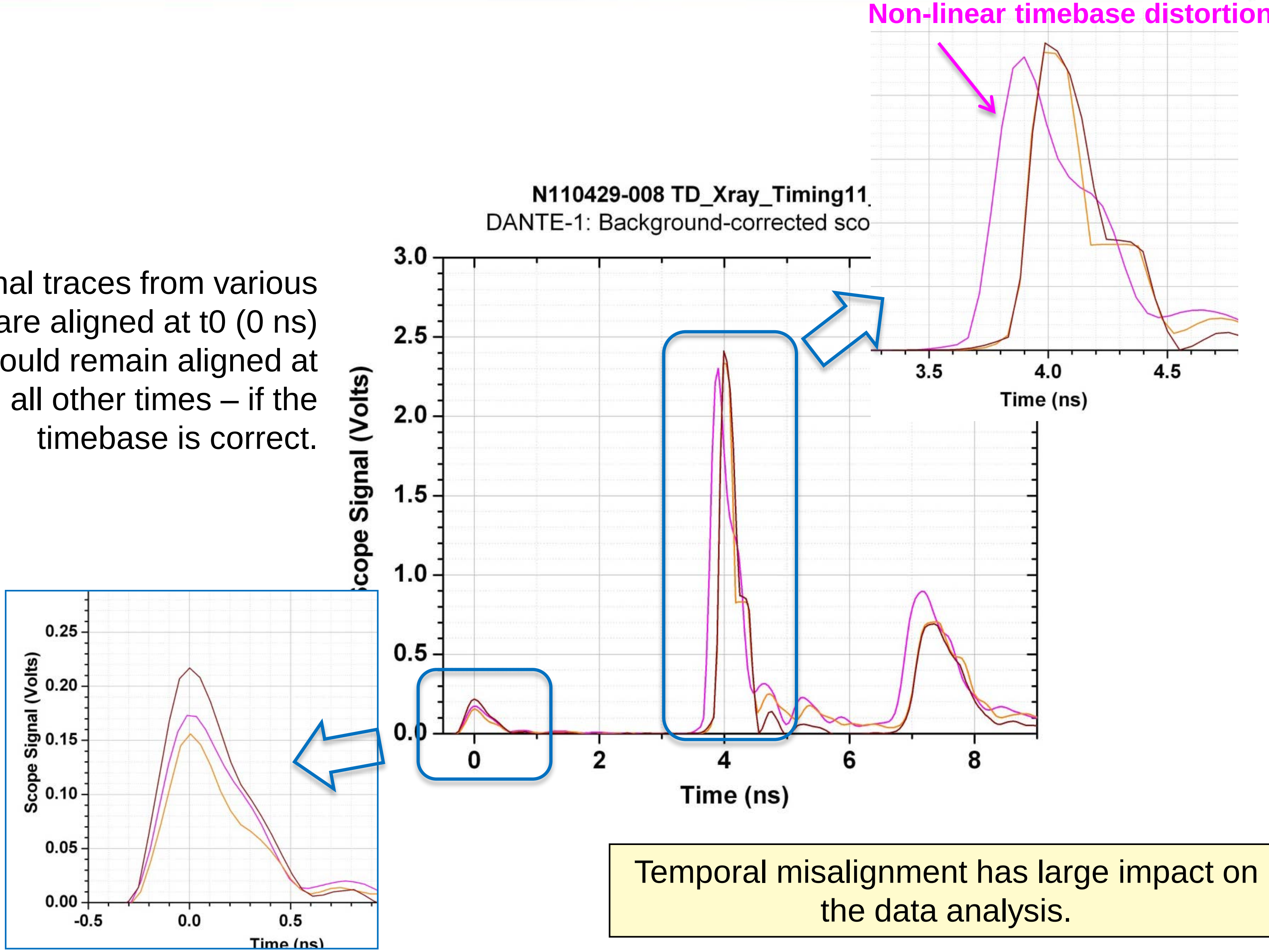


Quality Assurance Testing:
1. Developer Unit Tests
2. Independent Unit Tests
3. End to End Tests
4. Full Suite Regression Tests
5. Independent System Tests

Calibration data omissions, formatting problems, and stale data are the leading cause of target diagnostic analysis failures during operations. With between 500 and 5000 calibration parameters per diagnostic, there are usually several calibration issues to follow up on every week.

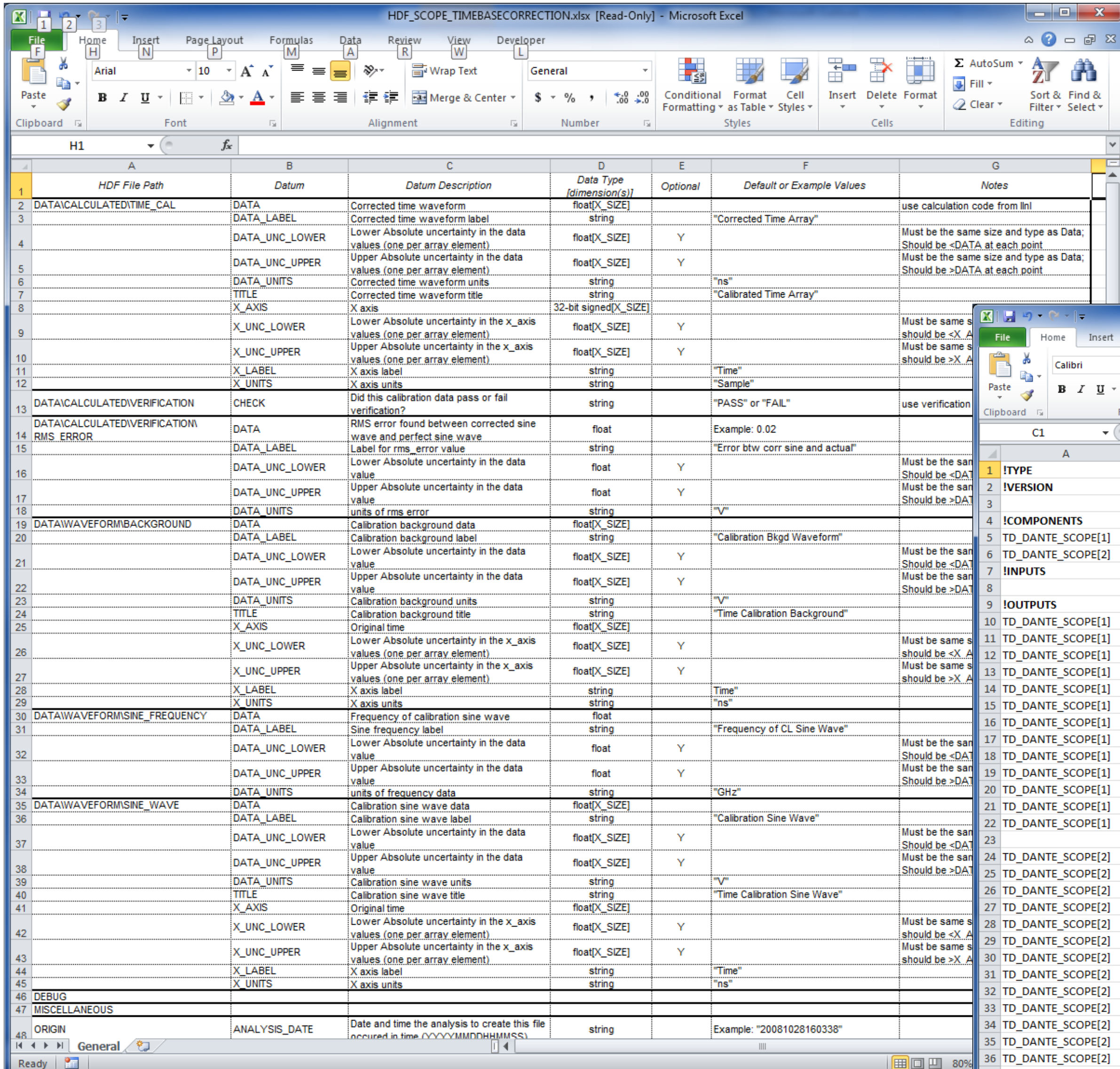
Calibration data example: Dante data is recorded on oscilloscopes that exhibit significant time-base distortion

Signal traces from various scopes are aligned at t0 (0 ns) and should remain aligned at all other times – if the timebase is correct.



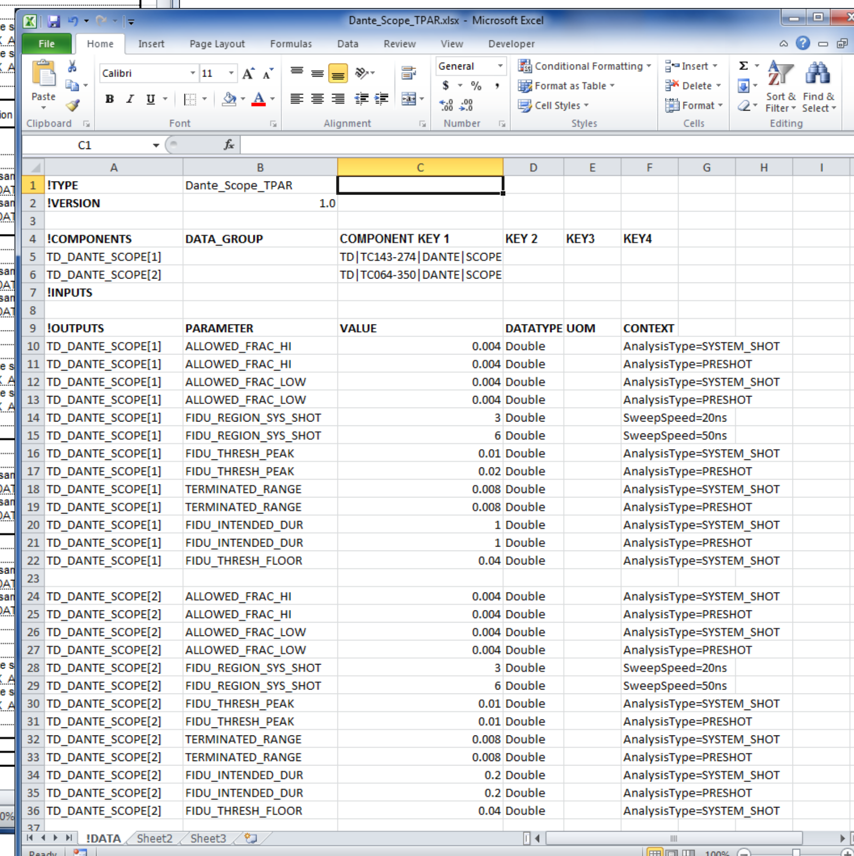
Temporal misalignment has large impact on the data analysis.

Formatting and naming interface documents define how analysis software reads in the calibration data



	HDF File Path	Datum	Datum Description	Data Type [dimension(s)]	Optional	Default or Example Values	Notes
2	DATA\CALCULATED\TIME_CAL	DATA	Corrected time waveform	float[X_SIZE]			use calculation code from lnl
3		DATA_LABEL	Corrected time waveform label	string		"Corrected Time Array"	
4		DATA_UNC_LOWER	Lower Absolute uncertainty in the data values (one per array element)	float[X_SIZE]	Y		Must be the same size and type as Data; Should be <DATA at each point
5		DATA_UNC_UPPER	Upper Absolute uncertainty in the data values (one per array element)	float[X_SIZE]	Y		Must be the same size and type as Data; Should be >DATA at each point
6		DATA_UNITS	Corrected time waveform units	string		"ns"	
7		TITLE	Corrected time waveform title	string		"Calibrated Time Array"	
8		X_AXIS	X axis	32-bit signed[X_SIZE]			
9		X_UNC_LOWER	Lower Absolute uncertainty in the x_axis values (one per array element)	float[X_SIZE]	Y		Must be same s should be <X_A
10		X_UNC_UPPER	Upper Absolute uncertainty in the x_axis values (one per array element)	float[X_SIZE]	Y		Must be same s should be >X_A
11		X_LABEL	X axis label	string		"Time"	
12		X_UNITS	X axis units	string		"Sample"	
13	DATA\CALCULATED\VERIFICATION	CHECK	Did this calibration data pass or fail verification?	string		"PASS" or "FAIL"	use verification
14	DATA\CALCULATED\VERIFICATION\ RMS_ERROR	DATA	RMS error found between corrected sine wave and perfect sine wave	float		Example: 0.02	
15		DATA_LABEL	Label for rms_error value	string		"Error btw corr sine and actual"	
16		DATA_UNC_LOWER	Lower Absolute uncertainty in the data value	float	Y		Must be the san Should be <DAT
17		DATA_UNC_UPPER	Upper Absolute uncertainty in the data value	float	Y		Must be the san Should be >DAT
18		DATA_UNITS	units of rms error	string		"V"	
19	DATA\WAVEFORM\BACKGROUND	DATA	Calibration background data	float[X_SIZE]			
20		DATA_LABEL	Calibration background label	string		"Calibration Bkgd Waveform"	
21		DATA_UNC_LOWER	Lower Absolute uncertainty in the data value	float[X_SIZE]	Y		Must be the san Should be <DAT
22		DATA_UNC_UPPER	Upper Absolute uncertainty in the data value	float[X_SIZE]	Y		Must be the san Should be >DAT
23		DATA_UNITS	Calibration background units	string		"V"	
24		TITLE	Calibration background title	string		"Time Calibration Background"	
25		X_AXIS	Original time	float[X_SIZE]			
26		X_UNC_LOWER	Lower Absolute uncertainty in the x_axis values (one per array element)	float[X_SIZE]	Y		Must be same s should be <X_A
27		X_UNC_UPPER	Upper Absolute uncertainty in the x_axis values (one per array element)	float[X_SIZE]	Y		Must be same s should be >X_A
28		X_LABEL	X axis label	string		Time"	
29		X_UNITS	X axis units	string		"ns"	
30	DATA\WAVEFORM\SINE_FREQUENCY	DATA	Frequency of calibration sine wave	float			
31		DATA_LABEL	Sine frequency label	string		"Frequency of CL Sine Wave"	
32		DATA_UNC_LOWER	Lower Absolute uncertainty in the data value	float	Y		Must be the san Should be <DAT
33		DATA_UNC_UPPER	Upper Absolute uncertainty in the data value	float	Y		Must be the san Should be >DAT
34		DATA_UNITS	units of frequency data	string		"GHz"	
35	DATA\WAVEFORM\SINE_WAVE	DATA	Calibration sine wave data	float[X_SIZE]			
36		DATA_LABEL	Calibration sine wave label	string		"Calibration Sine Wave"	
37		DATA_UNC_LOWER	Lower Absolute uncertainty in the data value	float[X_SIZE]	Y		Must be the san Should be <DAT
38		DATA_UNC_UPPER	Upper Absolute uncertainty in the data value	float[X_SIZE]	Y		Must be the san Should be >DAT
39		DATA_UNITS	Calibration sine wave units	string		"V"	
40		TITLE	Calibration sine wave title	string		"Time Calibration Sine Wave"	
41		X_AXIS	Original time	float[X_SIZE]			
42		X_UNC_LOWER	Lower Absolute uncertainty in the x_axis values (one per array element)	float[X_SIZE]	Y		Must be same s should be <X_A
43		X_UNC_UPPER	Upper Absolute uncertainty in the x_axis values (one per array element)	float[X_SIZE]	Y		Must be same s should be >X_A
44		X_LABEL	X axis label	string		"Time"	
45		X_UNITS	X axis units	string		"ns"	
46	DEBUG						
47	MISCELLANEOUS						
48	ORIGIN	ANALYSIS_DATE	Date and time the analysis to create this file occured in time (YYYYMMDDHHMMSS)	string		Example: "20081028160338"	

- Array and image data is stored in an H5 format – this is stored without opening in the database and parsed when analysis is run.
- Scalar data is stored in a Locos standard spreadsheet format



	A	B	C	D	E	F
1	!TYPE	Dante_Scope_TPAR				
2	!VERSION	1.0				
3						
4	!COMPONENTS	DATA_GROUP	COMPONENT KEY 1	KEY 2	KEY3	KEY4
5	TD_DANTE_SCOPE[1]		TD|TC143-274|DANTE|SCOPE			
6	TD_DANTE_SCOPE[2]		TD|TC064-350|DANTE|SCOPE			
7	!INPUTS					
8						
9	!OUTPUTS	PARAMETER	VALUE	DATATYPE	UOM	CONTEXT
10	TD_DANTE_SCOPE[1]	ALLOWED_FRAC_HI	0.004	Double		AnalysisType=SYSTEM_SHOT
11	TD_DANTE_SCOPE[1]	ALLOWED_FRAC_HI	0.004	Double		AnalysisType=PRESHOT
12	TD_DANTE_SCOPE[1]	ALLOWED_FRAC_LOW	0.004	Double		AnalysisType=SYSTEM_SHOT
13	TD_DANTE_SCOPE[1]	ALLOWED_FRAC_LOW	0.004	Double		AnalysisType=PRESHOT
14	TD_DANTE_SCOPE[1]	FIDU_REGION_SYS_SHOT	3	Double		SweepSpeed=20ns
15	TD_DANTE_SCOPE[1]	FIDU_REGION_SYS_SHOT	6	Double		SweepSpeed=50ns
16	TD_DANTE_SCOPE[1]	FIDU_THRESH_PEAK	0.01	Double		AnalysisType=SYSTEM_SHOT
17	TD_DANTE_SCOPE[1]	FIDU_THRESH_PEAK	0.02	Double		AnalysisType=PRESHOT
18	TD_DANTE_SCOPE[1]	TERMINATED_RANGE	0.008	Double		AnalysisType=SYSTEM_SHOT
19	TD_DANTE_SCOPE[1]	TERMINATED_RANGE	0.008	Double		AnalysisType=PRESHOT
20	TD_DANTE_SCOPE[1]	FIDU_INTENDED_DUR	1	Double		AnalysisType=SYSTEM_SHOT
21	TD_DANTE_SCOPE[1]	FIDU_INTENDED_DUR	1	Double		AnalysisType=PRESHOT
22	TD_DANTE_SCOPE[1]	FIDU_THRESH_FLOOR	0.04	Double		AnalysisType=SYSTEM_SHOT
23						
24	TD_DANTE_SCOPE[2]	ALLOWED_FRAC_HI	0.004	Double		AnalysisType=SYSTEM_SHOT
25	TD_DANTE_SCOPE[2]	ALLOWED_FRAC_HI	0.004	Double		AnalysisType=PRESHOT
26	TD_DANTE_SCOPE[2]	ALLOWED_FRAC_LOW	0.004	Double		AnalysisType=SYSTEM_SHOT
27	TD_DANTE_SCOPE[2]	ALLOWED_FRAC_LOW	0.004	Double		AnalysisType=PRESHOT
28	TD_DANTE_SCOPE[2]	FIDU_REGION_SYS_SHOT	3	Double		SweepSpeed=20ns
29	TD_DANTE_SCOPE[2]	FIDU_REGION_SYS_SHOT	6	Double		SweepSpeed=50ns
30	TD_DANTE_SCOPE[2]	FIDU_THRESH_PEAK	0.01	Double		AnalysisType=SYSTEM_SHOT
31	TD_DANTE_SCOPE[2]	FIDU_THRESH_PEAK	0.01	Double		AnalysisType=PRESHOT
32	TD_DANTE_SCOPE[2]	TERMINATED_RANGE	0.008	Double		AnalysisType=SYSTEM_SHOT
33	TD_DANTE_SCOPE[2]	TERMINATED_RANGE	0.008	Double		AnalysisType=PRESHOT
34	TD_DANTE_SCOPE[2]	FIDU_INTENDED_DUR	0.2	Double		AnalysisType=SYSTEM_SHOT
35	TD_DANTE_SCOPE[2]	FIDU_INTENDED_DUR	0.2	Double		AnalysisType=PRESHOT
36	TD_DANTE_SCOPE[2]	FIDU_THRESH_FLOOR	0.04	Double		AnalysisType=SYSTEM_SHOT

Time-base calibration data is stored in Locos database associated with oscilloscope serial number and sweep speed

NIF Archive Viewer - Firefox by LLNL

https://nifitint.llnl.gov/viewer/viewInstalledCalibration.action

NIF Archive Viewer — User: Logoff — Monday - May 13, 2013

MAIN CALENDAR SEARCH SUITCASE TAGS REPORTS ADMIN HELP

Show calibration of serialized parts for diagnostic DANTE installed (current) Search

Export (Excel) Display (Expand | Collapse) Copy Group Field: (None)

Location	Internal Lo...	Serial Num	Context	Param Name	Value	UOM	Dataset ID	Dataset Type	Part Description	Effective Start	Effective End
								Scope			
TC143-274-DANTE1	RACK2S07	13010147	AnalysisType=time|SweepSpeed=5ns	DOCUMENT_ID	CL_SCD50...		53816001	Dante_Scope	SCOPE,DGTZR,WAVEFORM,4.5GHZ BW,11 BIT	2009-05-01 13:56:00	9999-01-01
TC143-274-DANTE1	RACK1S04	13010107	AnalysisType=time|SweepSpeed=5ns	DOCUMENT_ID	CL_SCD50...		52913058	Dante_Scope	SCOPE,DGTZR,WAVEFORM,4.5GHZ BW,11 BIT	2009-05-01 15:30:00	9999-01-01
TC143-274-DANTE1	RACK1S02	13010111	AnalysisType=time|SweepSpeed=5ns	DOCUMENT_ID	CL_SCD50...		53815346	Dante_Scope	SCOPE,DGTZR,WAVEFORM,4.5GHZ BW,11 BIT	2009-05-01 16:44:00	9999-01-01
TC143-274-DANTE1	RACK2S08	13010148	AnalysisType=time|SweepSpeed=5ns	DOCUMENT_ID	CL_SCD50...		53816024	Dante_Scope	SCOPE,DGTZR,WAVEFORM,4.5GHZ BW,11 BIT	2009-05-01 22:24:00	9999-01-01
TC064-350-DANTE2	RACK1S03	13011118	AnalysisType=time|SweepSpeed=5ns	DOCUMENT_ID	CL_SCD50...		52906419	Dante_Scope	SCOPE, DGTZR, WAVEFORM, 7GHZ BW,13 BIT	2009-06-01 14:22:00	9999-01-01
TC064-350-DANTE2	RACK4S17	13011125	AnalysisType=time|SweepSpeed=5ns	DOCUMENT_ID	CL_SCD50...		52906419	Dante_Scope	SCOPE, DGTZR, WAVEFORM, 7GHZ BW,13 BIT	2009-06-01 14:22:00	9999-01-01
TC064-350-DANTE2	RACK3S12	13011130	AnalysisType=time|SweepSpeed=5ns	DOCUMENT_ID	CL_SCD50...		52906419	Dante_Scope	SCOPE, DGTZR, WAVEFORM, 7GHZ BW,13 BIT	2009-06-01 14:22:00	9999-01-01
TC064-350-DANTE2	RACK1S02	13011129	AnalysisType=time|SweepSpeed=5ns	DOCUMENT_ID	CL_SCD50...		52906419	Dante_Scope	SCOPE, DGTZR, WAVEFORM, 7GHZ BW,13 BIT	2009-06-01 14:22:00	9999-01-01
TC064-350-DANTE2	RACK3S16	13011115	AnalysisType=time|SweepSpeed=5ns	DOCUMENT_ID	CL_SCD50...		52906419	Dante_Scope	SCOPE, DGTZR, WAVEFORM, 7GHZ BW,13 BIT	2009-06-01 14:22:00	9999-01-01
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TC064-350-DANTE2	RACK2S09	13011128	AnalysisType=time|SweepSpeed=5ns	DOCUMENT_ID	CL_SCD50...		52906419	Dante_Scope	SCOPE, DGTZR, WAVEFORM, 7GHZ BW,13 BIT	2009-06-01 14:22:00	9999-01-01
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TC064-350-DANTE2	RACK3S13	13011127	AnalysisType=time|SweepSpeed=5ns	DOCUMENT_ID	CL_SCD50...		52906419	Dante_Scope	SCOPE, DGTZR, WAVEFORM, 7GHZ BW,13 BIT	2009-06-01 14:22:00	9999-01-01
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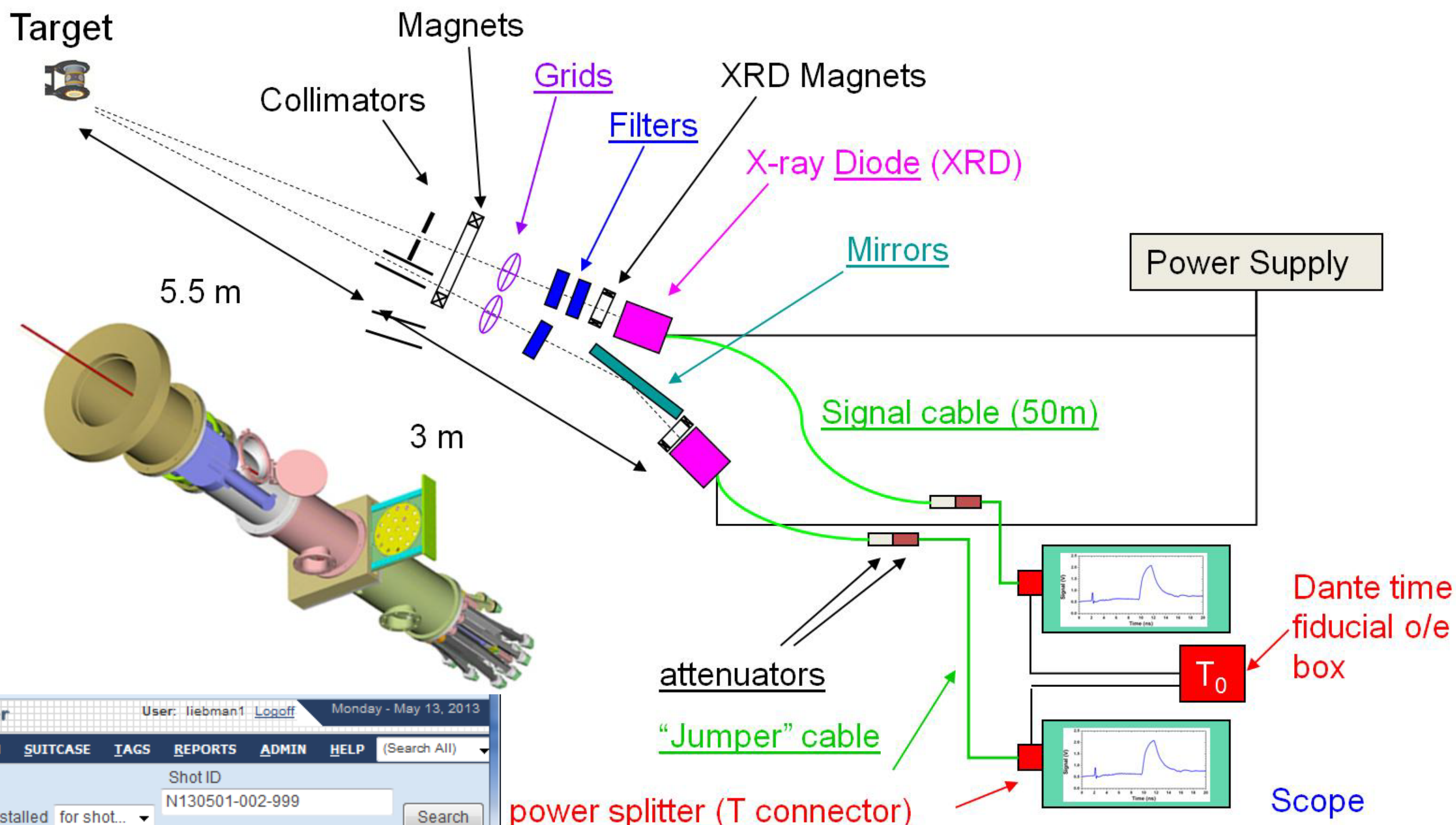
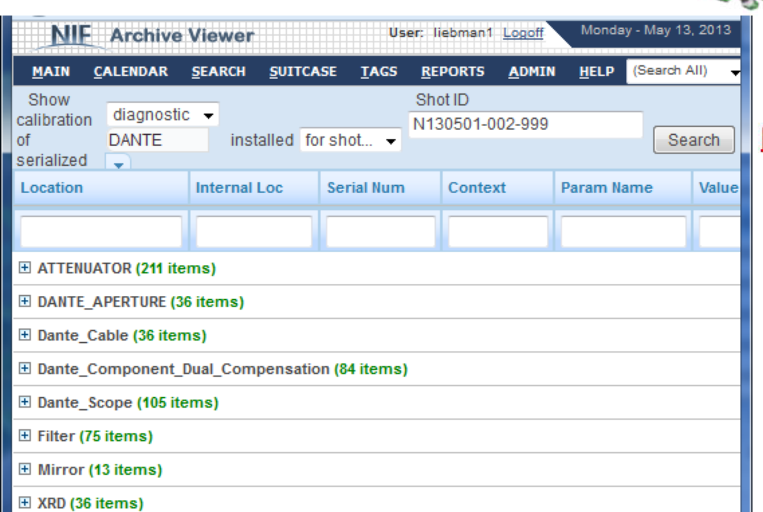
TC064-350-DANTE2	RACK2S07	13011122	AnalysisType=time|SweepSpeed=5ns	DOCUMENT_ID	CL_SCD50		52906419	Dante_Scope	SCOPE, DGTZR, WAVEFORM, 7GHZ BW,13 BIT	2009-06-01 14:22:00	9999-01-01
TC143-274-DANTE1	RACK1S01	13010140	AnalysisType=time|SweepSpeed=5ns	DOCUMENT_							
TC143-274-DANTE1	RACK3S16	13010142	AnalysisType=time|SweepSpeed=5ns	DOCUMENT_							
TC143-274-DANTE1	RACK3S17	13010132	AnalysisType=time|SweepSpeed=5ns	DOCUMENT_							
TC143-274-DANTE1	RACK2S09	13010121	AnalysisType=time|SweepSpeed=5ns	DOCUMENT_							
TC143-274-DANTE1	RACK2S12	13010112	AnalysisType=time|SweepSpeed=5ns	DOCUMENT_							
TC143-274-DANTE1	RACK3S15	13010117	AnalysisType=time|SweepSpeed=5ns	DOCUMENT_							

Find: substance Next Previous Highlight all Match case

- 105 time-base correction calibration files have been uploaded to Locos
- The automated analysis engine queries Locos, in this example by serial number and sweep speed, and passes relevant calibration data file to analysis routines.

Scale of Dante calibration: two instruments with 18 detectors each adds up to > 500 calibrated elements





- The majority of the diagnostics with automated analysis require a similar or greater number of calibrated parts.
- Many of these calibrated items need to be recalibrated on a regular basis.
- Maintenance of recalibration is a pressing issue.

Partnering with scientific diagnostic teams to define calibration maintenance flow and design tools

Responsible Scientist (RS) *Initiates Updates*
- ***New Locos prompt & report*** will help ensure that RS or RI initiates maintenance calibration updates

→

RS Oversees *Re-formatting*, with Support from SAVI
- Use manual copy/paste for Scalars or individual H5s
- ***SAVI can creates and use efficient tool(s)*** to create bulk H5 waveform data

→

RS Oversees *Uploads* with Support from SAVI
- Find datasets using new ***self-documenting calibration report tool***
- Submit Locos Web forms
- ***New SAVI resource*** to help

↓

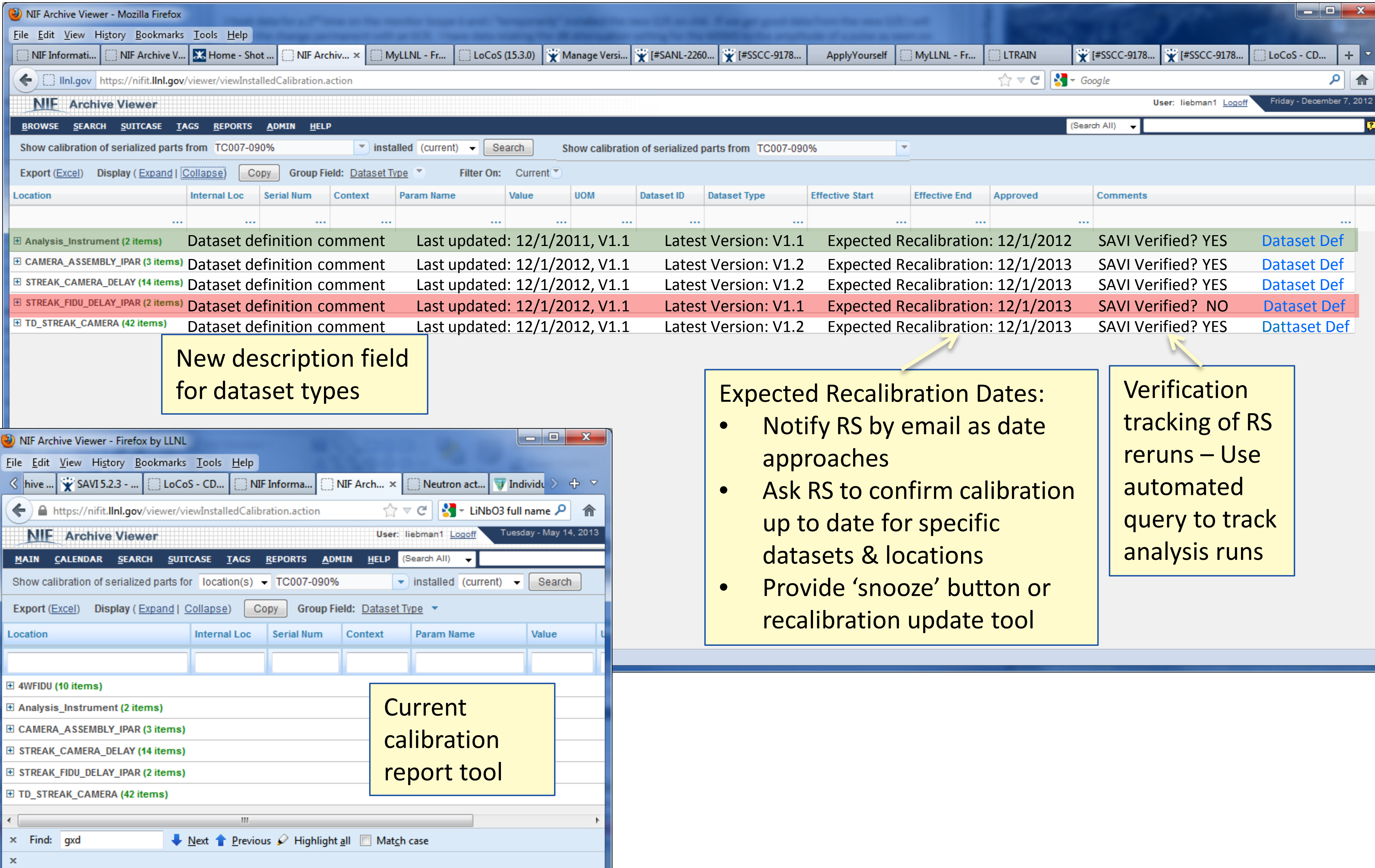
RS *Approves*
- Determines effective dates
- Submit Locos Web form
- Send notification

→

RS *Verifies*
- ***Rerun analysis***
- Use Archive Viewer to view results & version history
- ***SAVI assistance needed when installing new parts***

Analysis (SAVI) team is instrumental in the process of maintaining calibration data and thereby ensuring the success of target diagnostic algorithm automation and robust accurate results.

Design of calibration report tool with recalibration notifications, high level views, and verification tracking



New description field for dataset types

Expected Recalibration Dates:

- Notify RS by email as date approaches
- Ask RS to confirm calibration up to date for specific datasets & locations
- Provide 'snooze' button or recalibration update tool

Verification tracking of RS reruns – Use automated query to track analysis runs

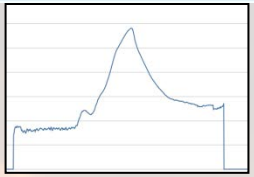
Current calibration report tool

Supporting operations, calibration, quality assurance and new analysis automation are the foundation for successful automated target diagnostic analysis

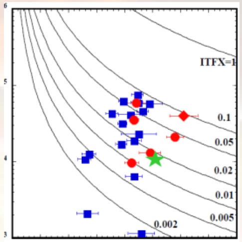
Key performance metrics

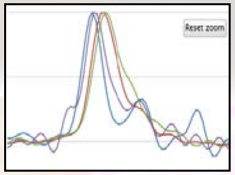
- **Temperature**:
  - Hot spot temperature
  - Hohlraum radiation temperature
- **Density** – areal density of hot spot
- **Yield** of fusion reaction– total production of neutrons or gammas
- **Velocity** – measure of capsule radius over time
- **Shape** – symmetry of the implosion
- **Timing**
  - Shock timing
  - Bang time – time of peak fusion reaction
- **Preheat** of the ablator

Dante analysis estimates radiation temperature

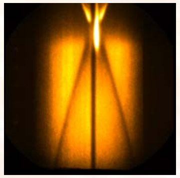


nTOF analysis reports hot spot temp, neutron yield and density metrics



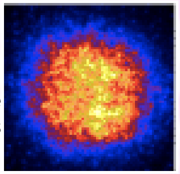


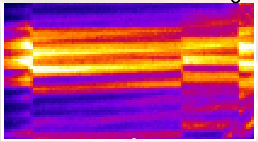
Gamma yield depends on **GRH** analysis



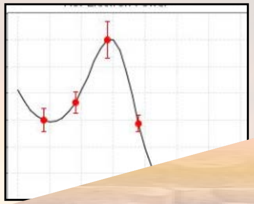
DISC uses camera corrected images

Shape metrics rely on **GXD, Ariane, NIS** timing and image analyses

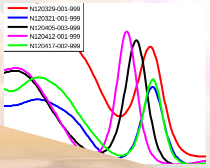




VISAR interferometry analysis enables shock timing



FFLEX analysis reports hot electrons & preheat



SPBT & GRH analyses report bang time

Operations Support
for changes & off-normal shot data

Calibrations Support
Creation design & maintenance tools

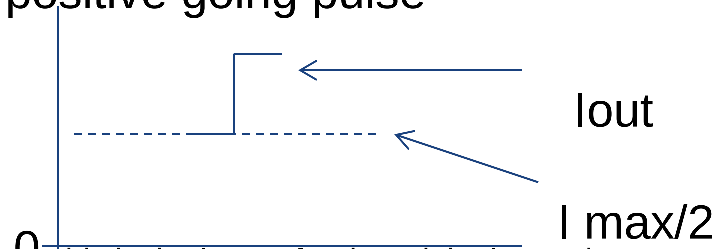
Quality Assurance
Unit and integrated testing

New Analysis & Automation
Automating new diagnostics and furthering existing


NIF

NIF GRH has a negative V0 with a positive going pulse, so we need to change signs from the positive baseline with positive going pulse

$$I_{out}(t) = \frac{I_{MaxIn}}{2}\left[1+\sin\left(\frac{\pi V_{pmt}(t)}{V^{\pi}_{pmt}} + \frac{\pi\Delta V_{bias}}{V^{\pi}_{bias}}\right)\right]$$



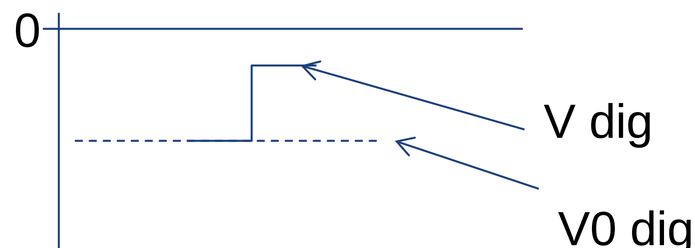
This is the layout for the original equation. Note than when Iout > Imax/2 then the asin argument is positive.

$$V_{dig} = I_{out} - I_{MaxIn}$$

$$V^{0shot}_{dig} = \frac{-I_{MaxIn}}{2} \longrightarrow I_{MaxIn} = -2V^{0shot}_{dig}$$

$$V_{pmt}(t) = \frac{V^{\pi}_{pmt}}{\pi}\left[\sin^{-1}\left(\frac{I_{out}(t)}{I_{MaxIn}/2}-1\right) - \frac{\pi\Delta V_{bias}}{V^{\pi}_{bias}}\right]$$

$$V_{pmt}(t) = \frac{V^{\pi}_{pmt}}{\pi}\left[\sin^{-1}\left(\frac{V_{dig}-2V^{0shot}_{dig}}{-V^{0shot}_{dig}}-1\right) - \frac{\pi\Delta V_{bias}}{V^{\pi}_{bias}}\right]$$



Here is our signal example layout. Note than when Vdig above V0dig the asin argument should be positive.

$$V_{pmt}(t) = \frac{V^{\pi}_{pmt}}{\pi}\left[\sin^{-1}\left(\frac{V_{dig}}{-V^{0shot}_{dig}}+1\right) - \sin^{-1}\left(\frac{V^{0shot}_{Dig}}{-V^{0@Q_-}_{Dig}}+1\right)\right]$$

$$V_{pmt}(t) = \frac{V^{\pi}_{pmt}}{\pi}\left[\sin^{-1}\left(\frac{V_{dig}}{abs(V^{0@Q_-}_{Dig})}+1\right) - \sin^{-1}\left(\frac{V^{0shot}_{Dig}}{abs(V^{0@Q_-}_{Dig})}+1\right)\right]$$

Where Vdig and V0shotDig are negative

The same logic results in this Phase Err eq

$$\Delta V_{bias} = \frac{V^{\pi}_{bias}}{\pi}\sin^{-1}\left(\frac{V^{0shot}_{Dig_{dc}}}{-V^{0@Q_-}_{Dig_{dc}}}+1\right)$$

NIF GRH AC coupled MZ equations:

$$V_{Dig\,ac}(t)=V_{Dig_{dc}}^{0@Q_-}c_{ac/dc}\left[\sin\left(\frac{\pi V_{pmt}(t)}{V_{pmt}^{\pi}}+\frac{\pi\Delta V_{bias}}{V_{bias}^{\pi}}\right)-\sin\left(\frac{\pi\Delta V_{bias}}{V_{bias}^{\pi}}\right)\right]$$

where $c_{ac/dc}$ ≅ splitter ratio (~1) * transmission thru bias tee (~.97)

Use this from DC channel:

$$\Delta V_{bias}=\frac{V_{bias}^{\pi}}{\pi}\sin^{-1}\left(\frac{V_{Dig_{dc}}^{0shot}}{-V_{Dig_{dc}}^{0@Q_-}}+1\right)$$

NIF GRH AC channel Inverted equations:

$$V_{pmt}(t)=\frac{V_{pmt}^{\pi}}{\pi}\left[\sin^{-1}\left[\frac{V_{Dig\,ac}(t)}{c_{ac/dc}V_{Dig_{dc}}^{0@Q_-}}+\sin\left(\frac{\pi\Delta V_{bias}}{V_{bias}^{\pi}}\right)\right]-\frac{\pi\Delta V_{bias}}{V_{bias}^{\pi}}\right]$$

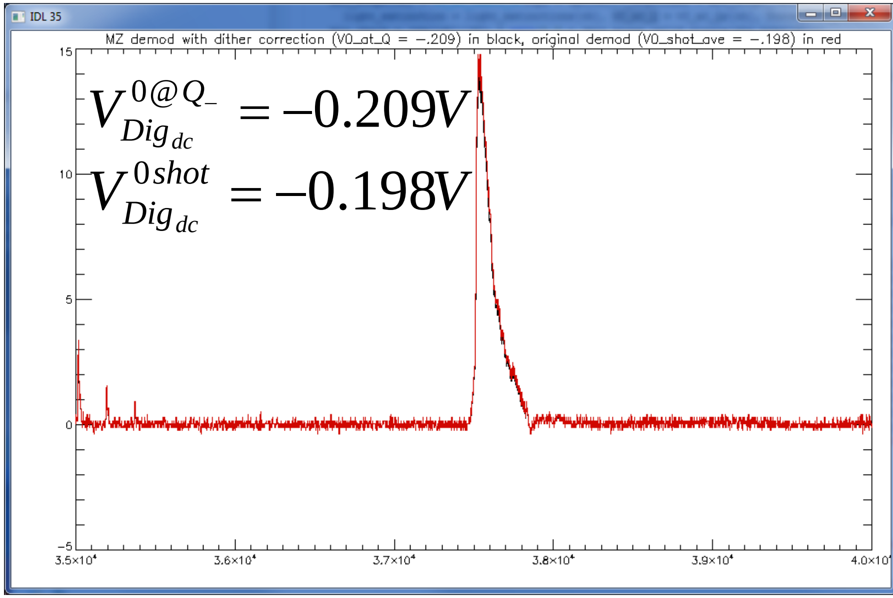
$$V_{pmt}(t)=\frac{V_{pmt}^{\pi}}{\pi}\left[\sin^{-1}\left[\frac{V_{Dig\,ac}(t)-baseline}{c_{ac/dc}abs(V_{Dig_{dc}}^{0@Q_-})}+\left(\frac{V_{Dig_{DC}}^{0shot}}{abs(V_{Dig_{DC}}^{0@Q_-})}+1\right)\right]-\sin^{-1}\left[\frac{V_{Dig_{DC}}^{0shot}}{abs(V_{Dig_{DC}}^{0@Q_-})}+1\right]\right]$$

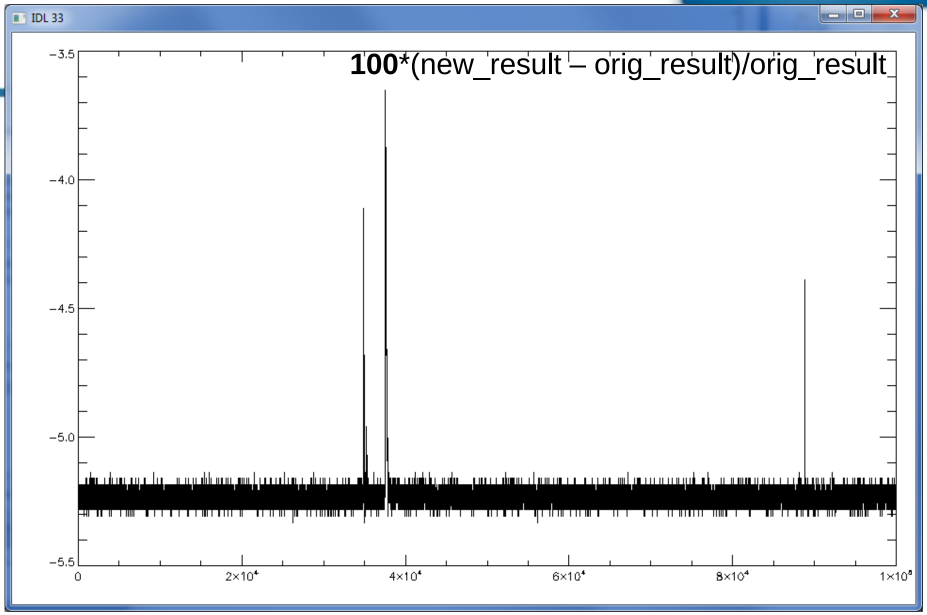
With a little algebra this does simplify to the eq Kirk suggested:

$$V_{pmt}(t)=\frac{V_{pmt}^{\pi}}{\pi}\left[\sin^{-1}\left[\frac{V_{Dig\,ac}(t)-baseline+c_{ac/dc}(V_{Dig_{dc}}^{0shot}+abs(V_{Dig_{dc}}^{0@Q_-}))}{c_{ac/dc}abs(V_{Dig_{dc}}^{0@Q_-})}\right]-\sin^{-1}\left[\frac{V_{Dig_{DC}}^{0shot}}{abs(V_{Dig_{DC}}^{0@Q_-})}+1\right]\right]$$

Where V0shotDigDC is negative

Example (J. Liebman):



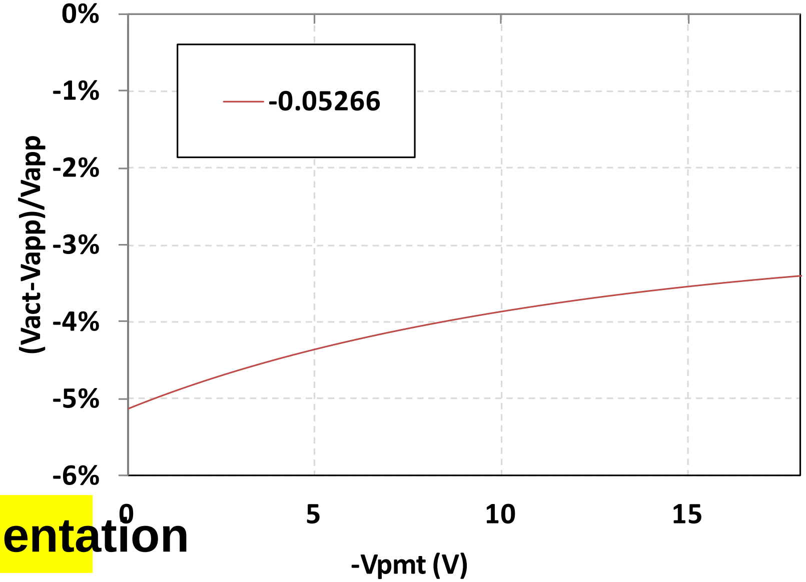


$$\phi = \frac{\pi \Delta V_{bias}}{V_{bias}^{\pi}} = \sin^{-1}\left(\frac{V_{Dig_{dc}}^{0shot}}{V_{Dig_{dc}}^{0@Q_-}} - 1\right) = -52.66 mrad$$

$$V_{pmt}^{actual}(t) = \frac{V_{pmt}^{\pi}}{\pi}\left[\sin^{-1}\left(\frac{V_{Dig}(t)}{V_{Dig_n}^{0@Q_-}} - 1\right) - \phi\right]$$

$$V_{pmt}^{apparent}(t) = \frac{V_{pmt}^{\pi}}{\pi}\left[\sin^{-1}\left(\frac{V_{Dig}(t)}{V_{Dig_n}^{0shot}} - 1\right)\right]$$

Expected error:



Good agreement! → Proceed with implementation