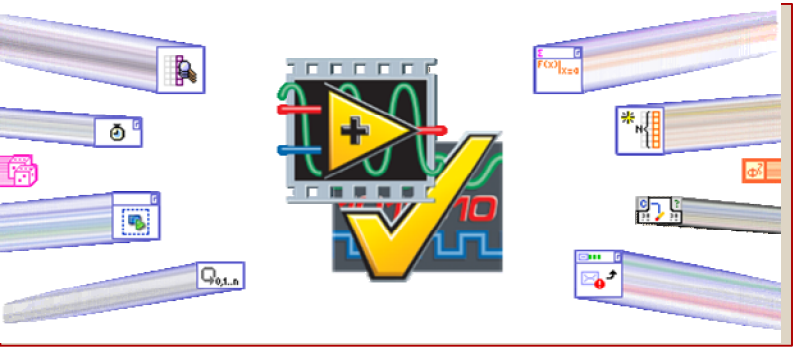
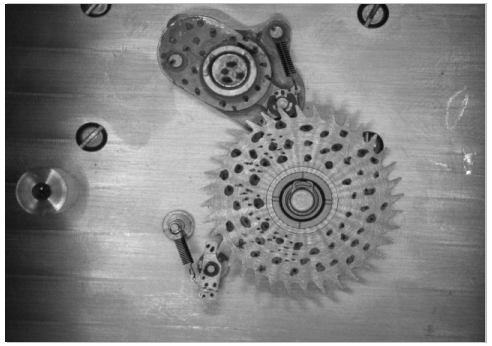
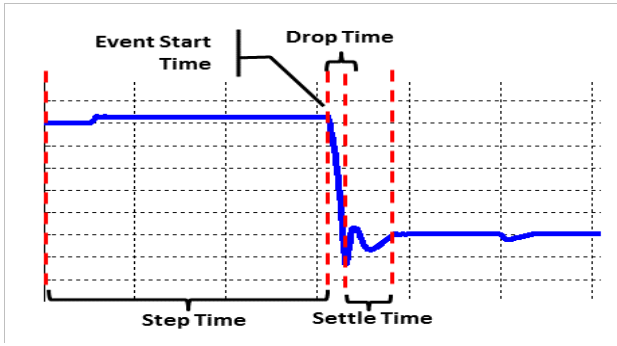
SAND2017-5336C







Using NI Tools and Hardware to Collaborate Between National Security Campus (NSC) and Sandia National Laboratories (SNL)

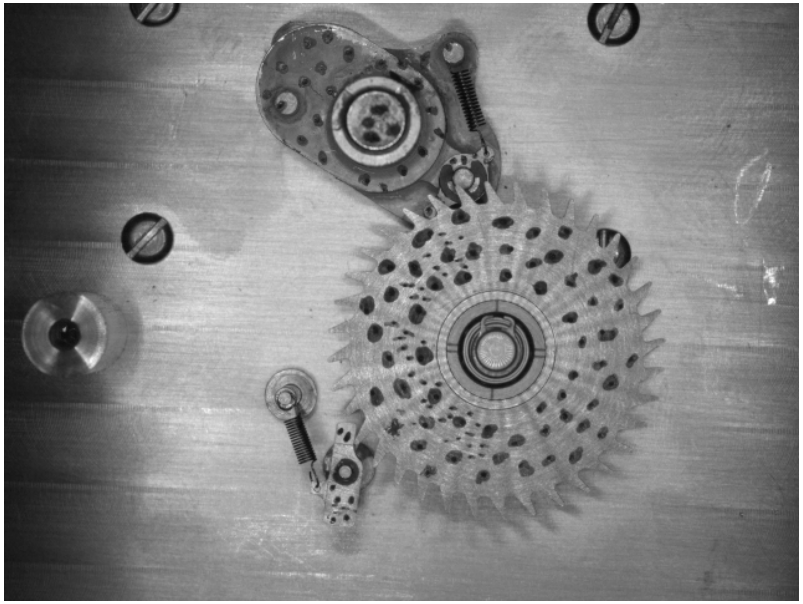
By Scott Walkington

U.S. DEPARTMENT OF ENERGY
NNSA National Nuclear Security Administration

Sandia National Laboratories is a multimission laboratory managed and operated by National Technology and Engineering Solutions of Sandia, LLC., a wholly owned subsidiary of Honeywell International, Inc., for the U.S. Department of Energy's National Nuclear Security Administration under contract DE-NA0003525.

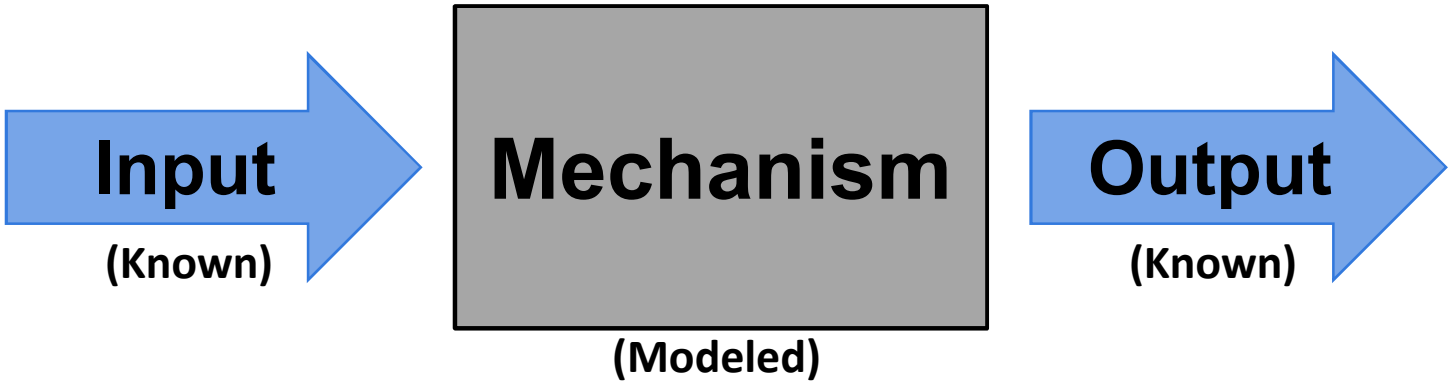
Outline

- Introduction
- Overview
  - Production Environment
  - Setup/Hardware for High-Speed Video System
  - Digital Image Correlation (DIC)
  - Problems with Commercial-off-the-Shelve(COTS) Software- PCC and VIC 2D
- Initial LabVIEW software
  - Creating DLL from C code (.h Files)
  - Speckle Track Software
  - Independent SDK's (Vision Research)
  - Camera Control Software
- Finalized TestStand Solution
  - Source Control
  - Sequencing of all the LabVIEW and Matlab Code
  - TDMS files
- Results
- Conclusion



Introduction and Motivation

We want a profound understanding of our mechanisms



What can we use to assess the performance, design, and state of health of the devices?

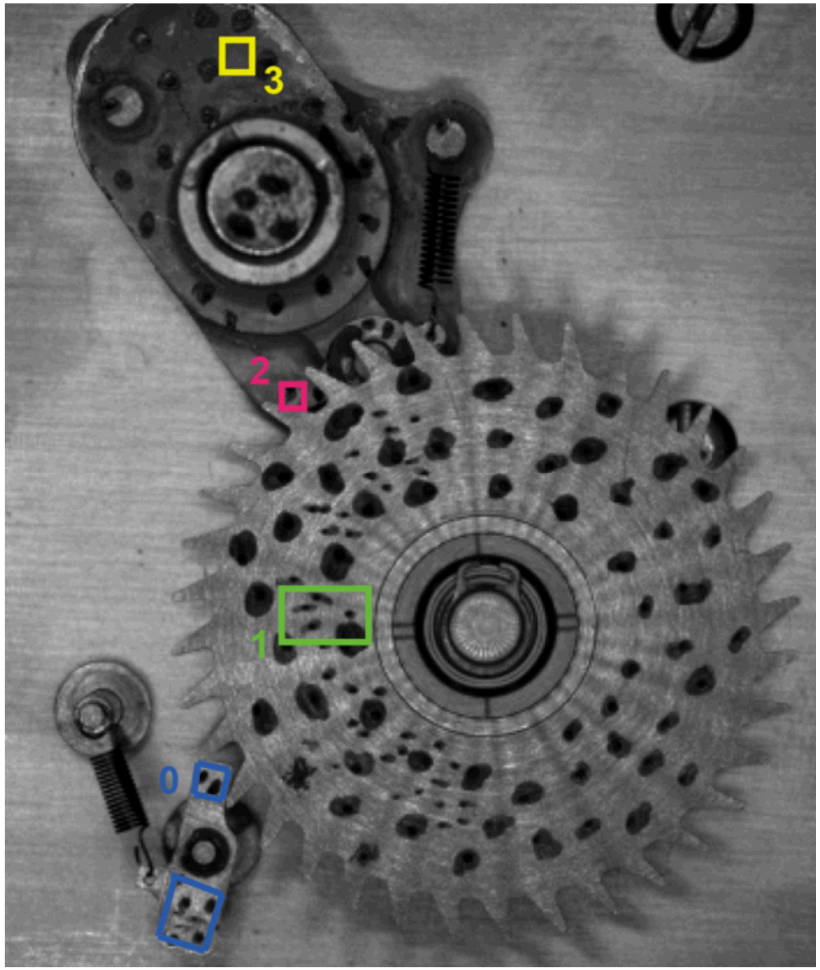
- High-Speed Video (HSV) and Accelerometer Sensing Characterization (ASC)

What if we need to asses large numbers of devices?

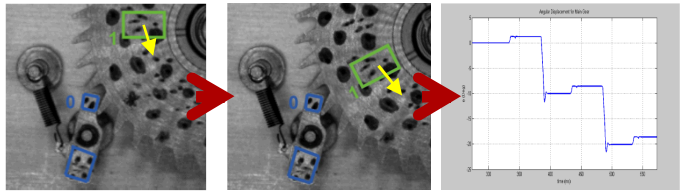
- Mechanism Production Tester

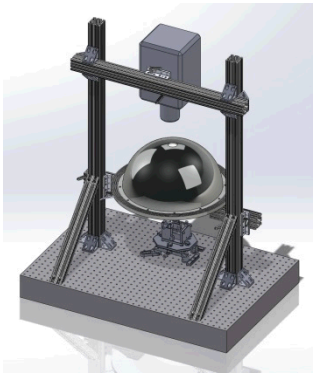
Overview - HSV and ASC testing

- Higher Fidelity Data
  - Yields critical metrics which tie directly back to the mechanism design, specific components or subsystems
  - Sensitive enough to detect performance changes before failure (State of Health)
- Benefits:
  - Non-contact and non-destructive
  - Can be automated
  - Performance metrics can be fed back into modeling

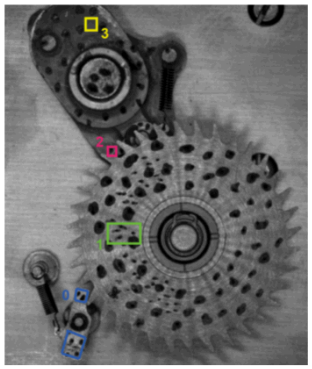


Overview - Data Analysis Process

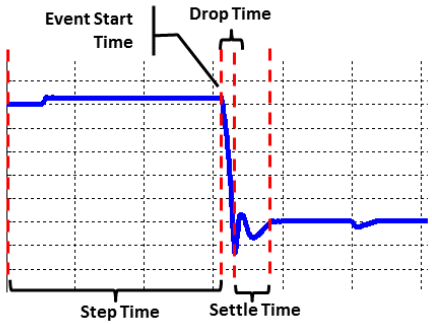




- Capture video of mechanism operation
- Parts to track are marked with speckle markings



- Specify Region of Interest (ROI) to track
- DIC tracks ROI from frame to frame
- Subpixel precision obtained with interpolant
- Result is x-y position and angle curves of each ROI



HSV and ASC Data Acquired and Saved

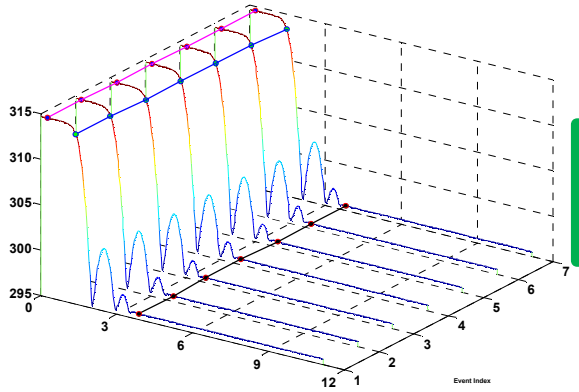
Raw Image Data

DIC Analysis via Labview

Pixel Displacement Data

Post Processing via Matlab

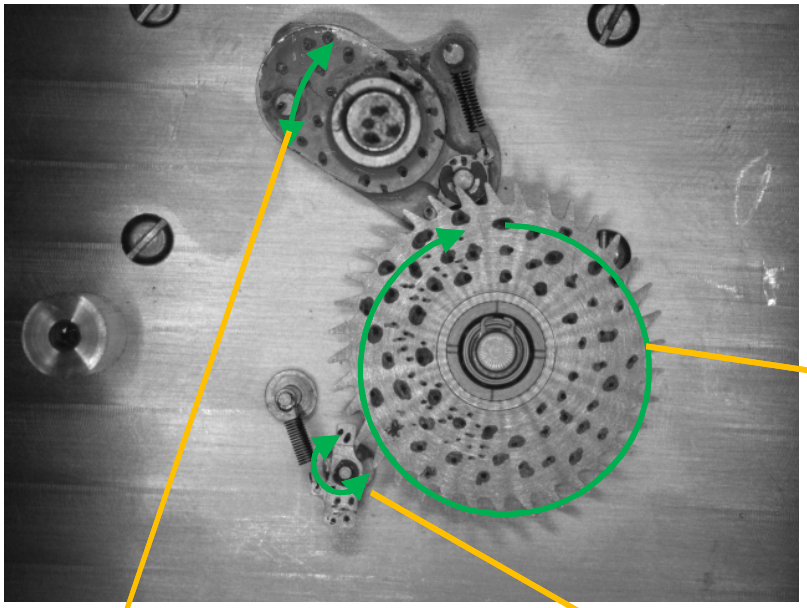
Mechanism Dynamics Data

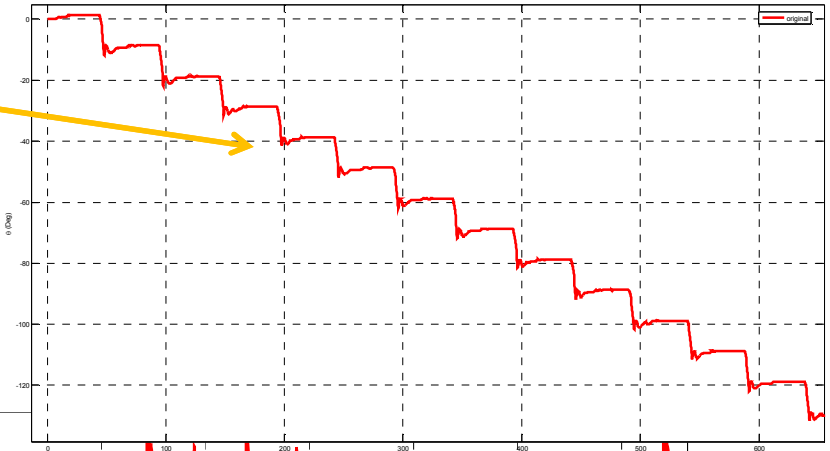


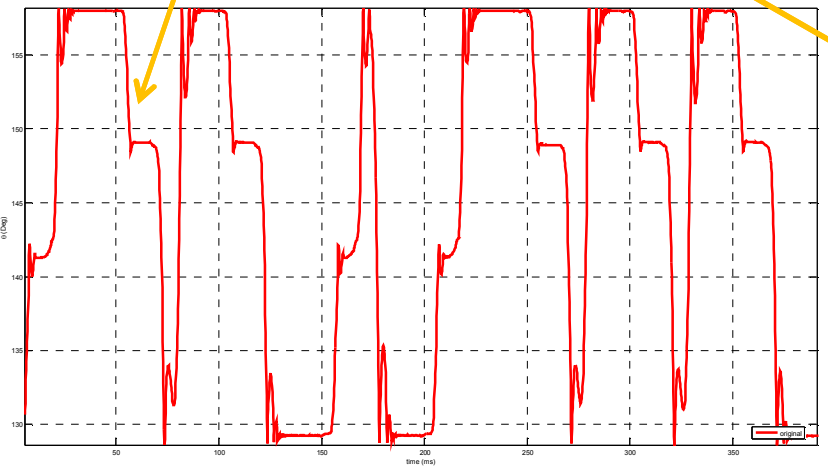
Performance metric extraction

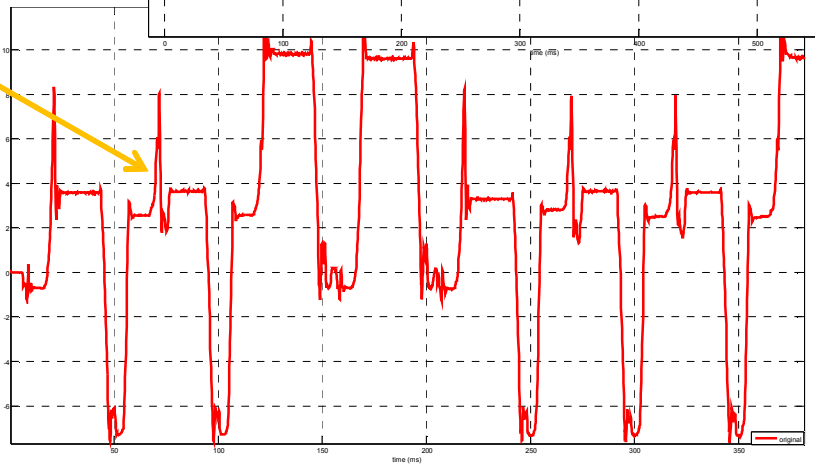
- Result is coupled to input and critical metrics are extracted
- Critical metrics are compared against physics model, unit population, and historical performance

Overview – Mechanism: Motion Curves





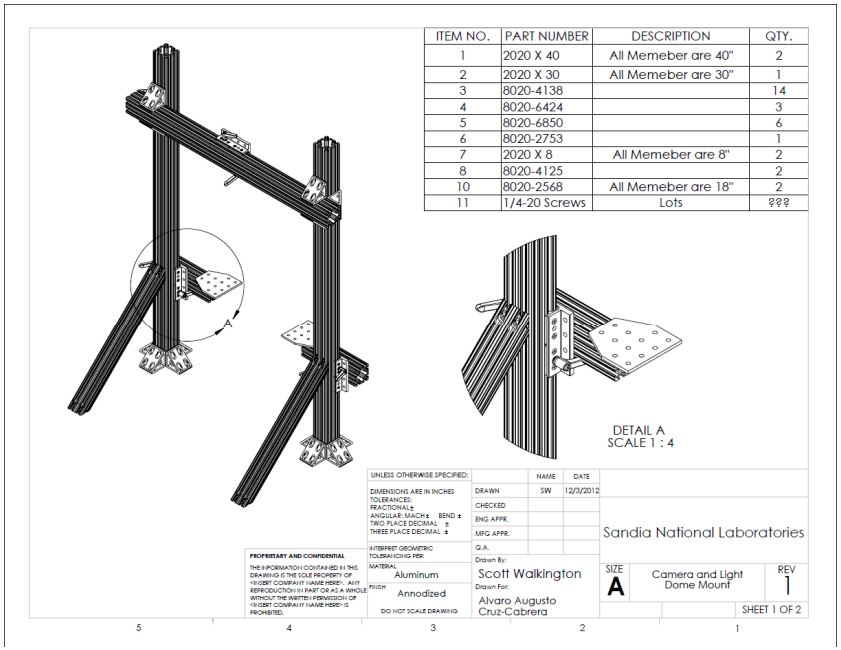




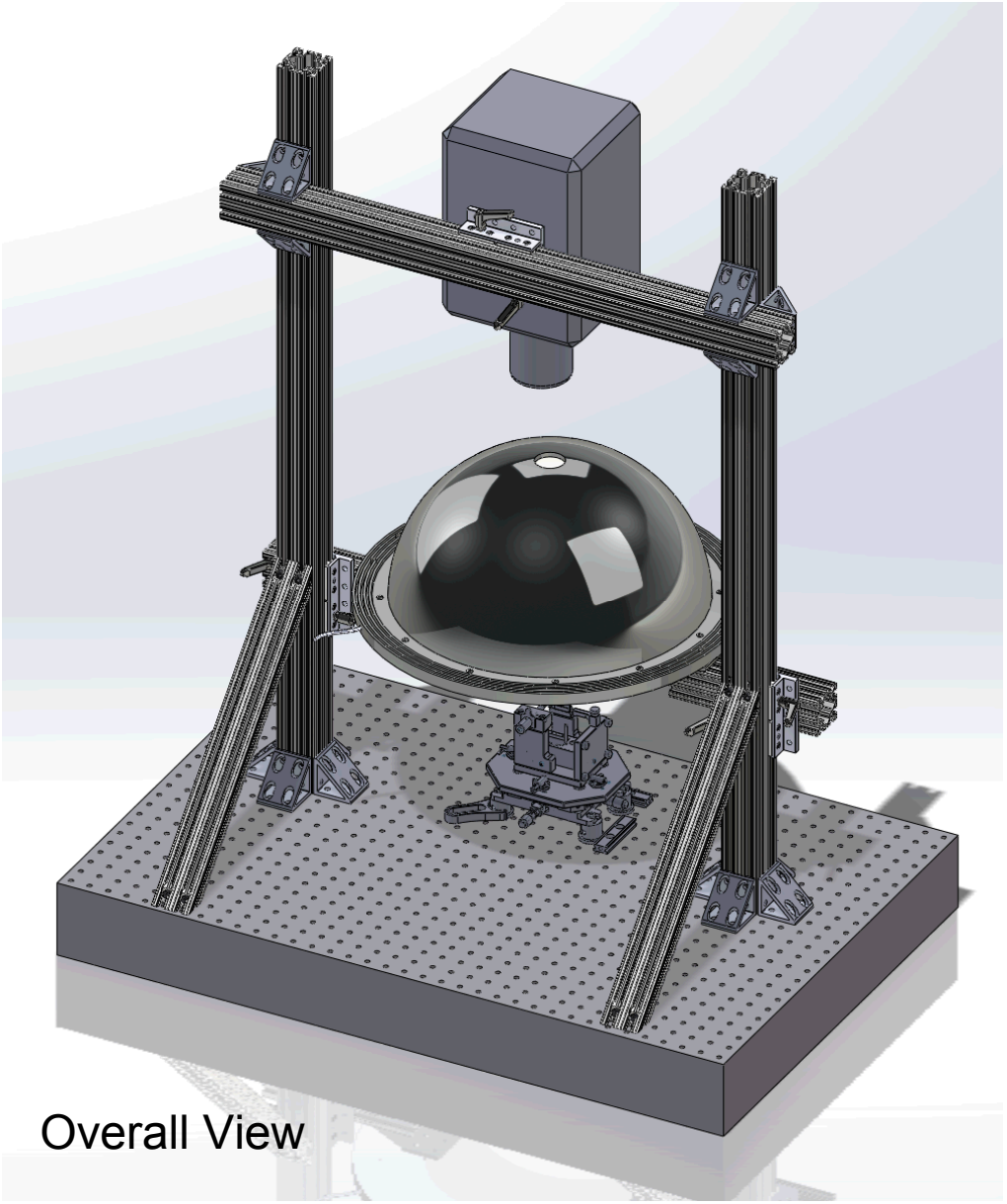
Overview - Different Environment: Production

- Sandia National Laboratories - R&D Laboratory
  - Research and Development environment
  - Software Developers are the users of the software
  - Multi-COTS systems acceptable
  - Provide Mechanism designs
    - Rarely Provides testers
- National Security Campus(NSC) - Production Facility
  - Reliability, Maintainability, and Supportability of the Systems
  - Initially limited support at NSC
  - Speed
  - Repeatability
  - Automated
  - Production line- Deadlines
  - Simplicity to use
  - Low technical maturity level
  - Data storage
  - Integration with existing tester
  - Complexity of data analysis
  - Data transfer
  - Added time
  - Cost

Setup - Camera and Light Dome Mount + Fixture.

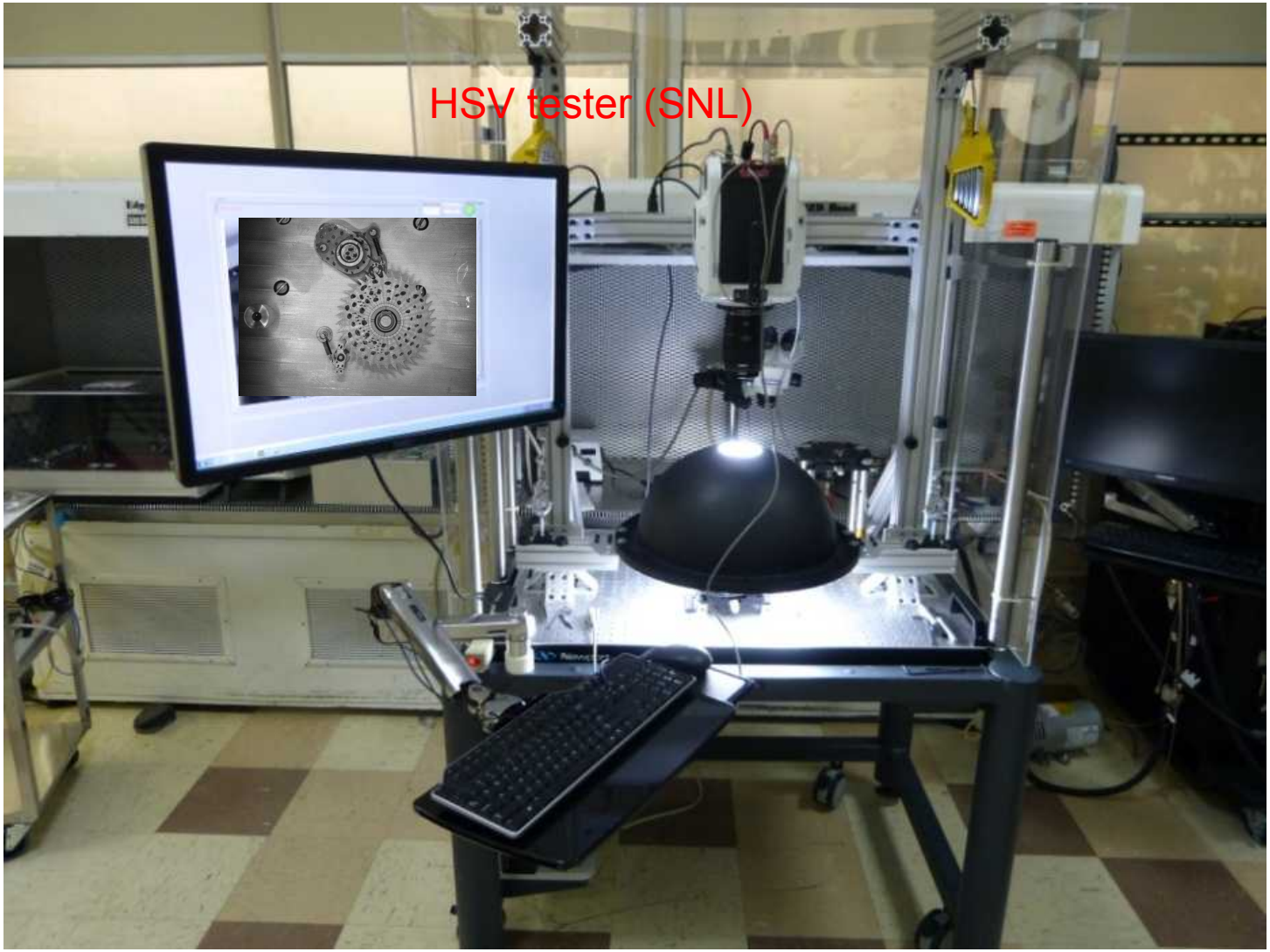


ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	2020 X 40	All Memeber are 40"	2
2	2020 X 30	All Memeber are 30"	1
3	8020-4138		14
4	8020-6424		3
5	8020-6850		6
6	8020-2753		1
7	2020 X 8	All Memeber are 8"	2
8	8020-4125		2
10	8020-2568	All Memeber are 18"	2
11	1/4-20 Screws	Lots	???



Overall View

Setup - Two Different Testers



Main tester (NSC)

- Sequence Events/Signals sent to Mechanism
- Using PXI/NI Hardware to Acquire Accelerometer signal
- Use Prompts/text boxes to control flow
- Two different Main Testers:
  - Simpler Tester at SNL
  - Production Tester at NSC

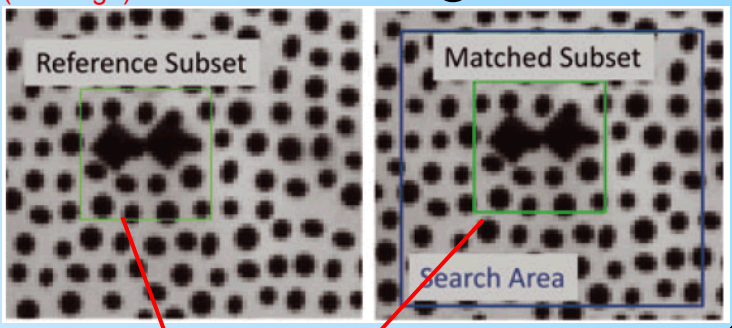
The three important components of 2D-DIC:

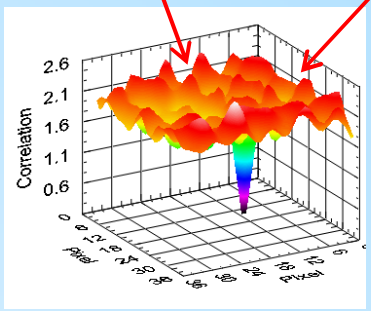
Sandia National Laboratories

Matching

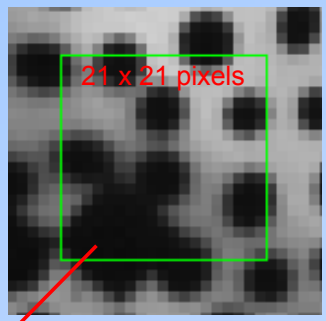
(1st Image)

(2nd Image)





Interpolation



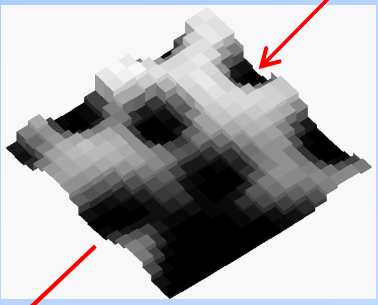
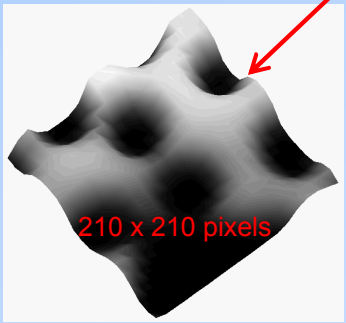
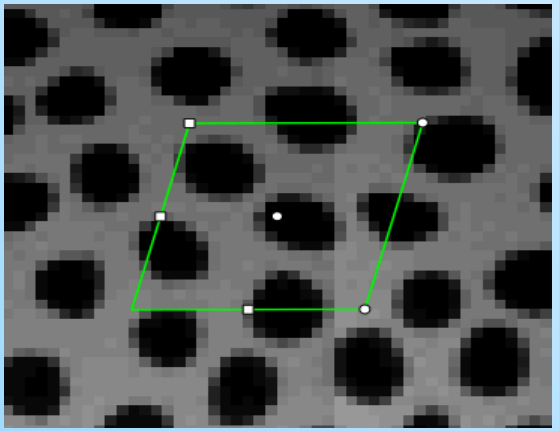


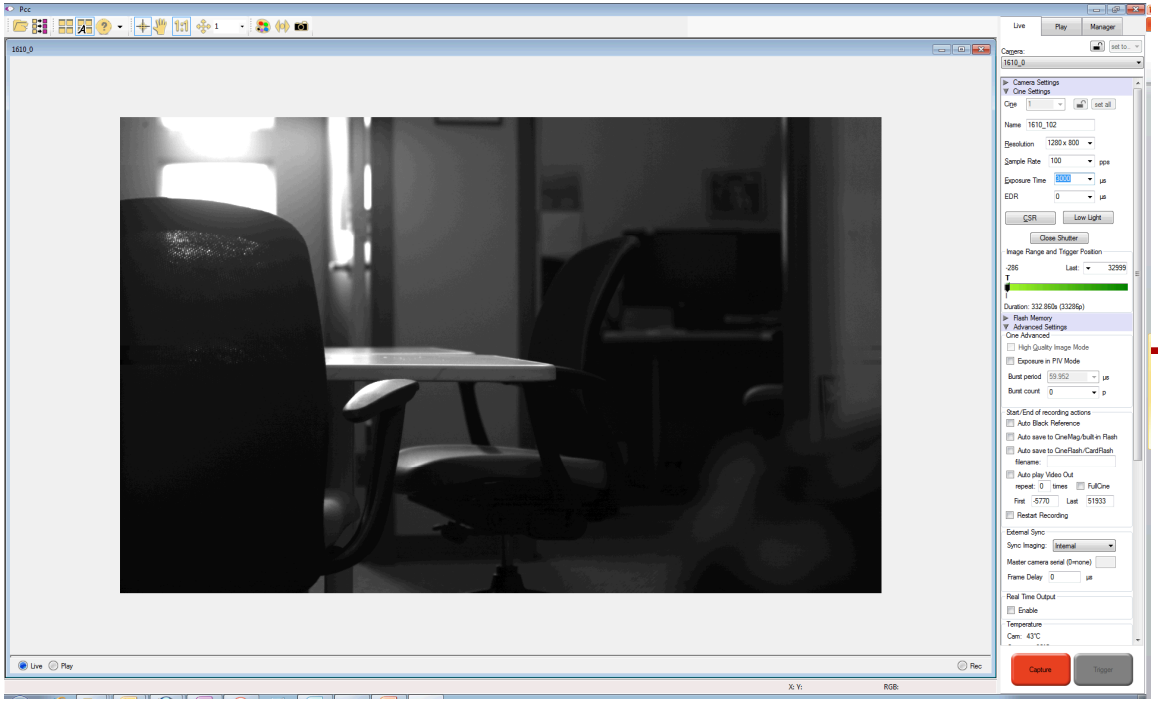
Image interpolated by a factor of 10x

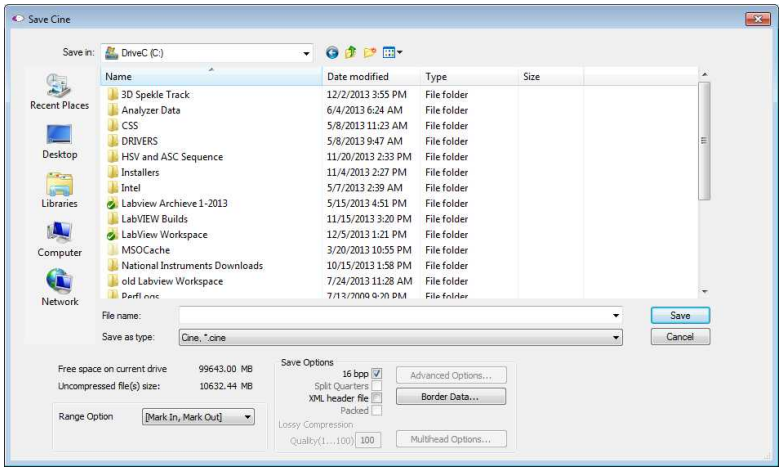




Shape Function

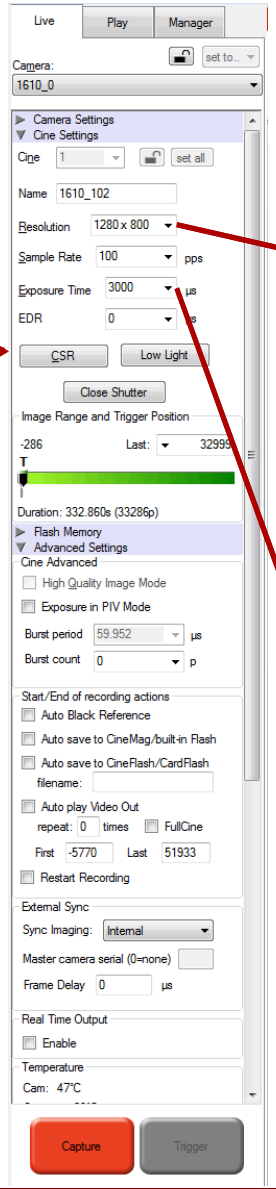
Initially COTS Were Used to Perform All Analysis

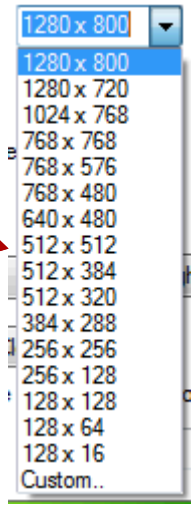


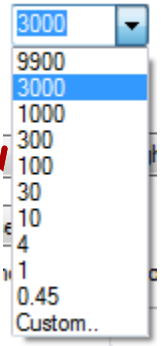


Disadvantages

- Long time to track a full run of a unit(about 8 hours)
- No easy way to save ROI
- Must convert .cine to .tiff
- Manually Save Tracked data to file
- No Batch Mode!







To much control/ complexity for a standard user! Easy to make a mistake!

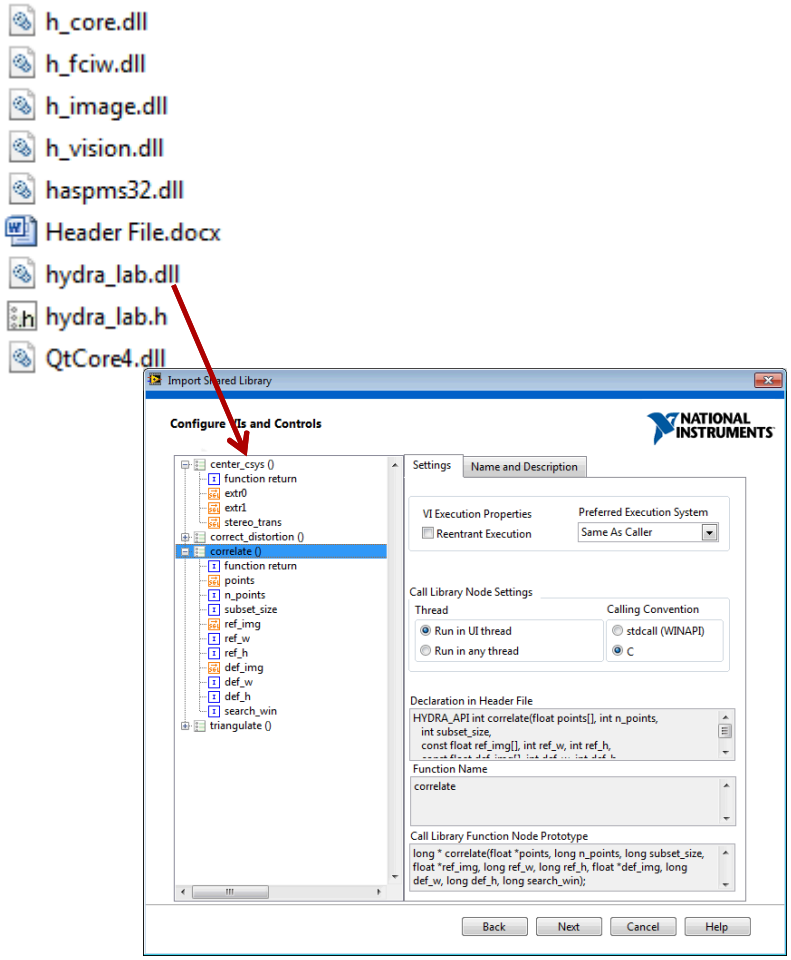
Start of the Solution: LabVIEW!!

Sandia National Laboratories

1. Eliminated VIC – 2D software (COTS) which performed the DIC tracking and Replaced with LabVIEW software (Speckle Track)
    1. Made possible the entire .cine to be tracked
    2. Save and open ROI's
    3. Save data directly to .csv/.tdms
    4. Most Importantly added a Batch Mode.
    5. Many more additions
2. Eliminated Vision Research Phantom Camera Control software (COTS) with LabVIEW software (Camera Control)
    1. More details in future slide
3. Error Handling and Error Recovery
4. Calling of MatLab code

Creating Call Function Library Nodes from C code DLL's and .h Files

- Correlated Solutions (VIC – 2D) provided the .h files



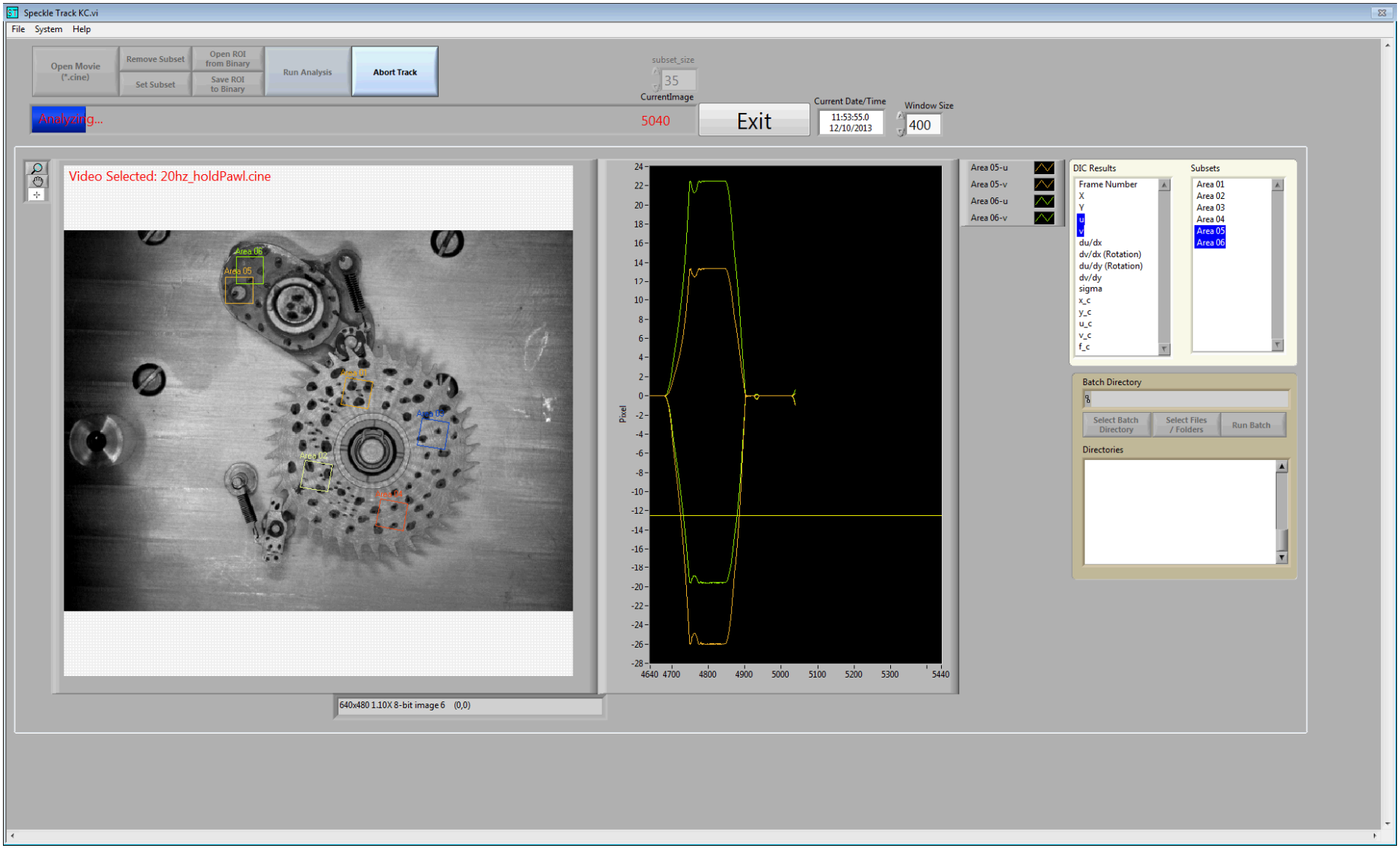
Pro's:

- Enable developer to control all aspects of hardware
- Streamline processes
- Develop custom software
- Eliminate user mistakes when using hardware
- Allows consistent results by limiting what the user can see and do

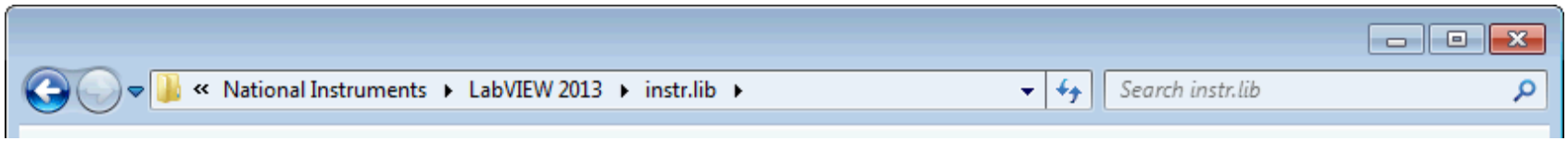
Con's:

- Can cause LabVIEW to crash spectacularly!
- Poor documentation
- Odd behavior between runs of the program- Need to completely exit LabVIEW to correct issue
- Lots of guess work to figure out what the dll is doing
- No support in many cases

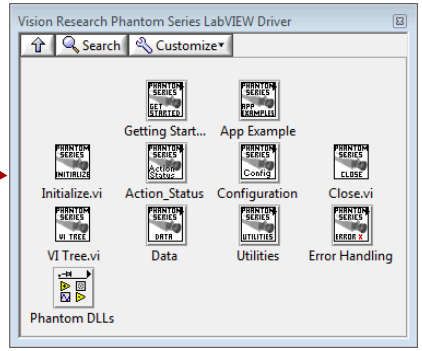
Speckle Track Software

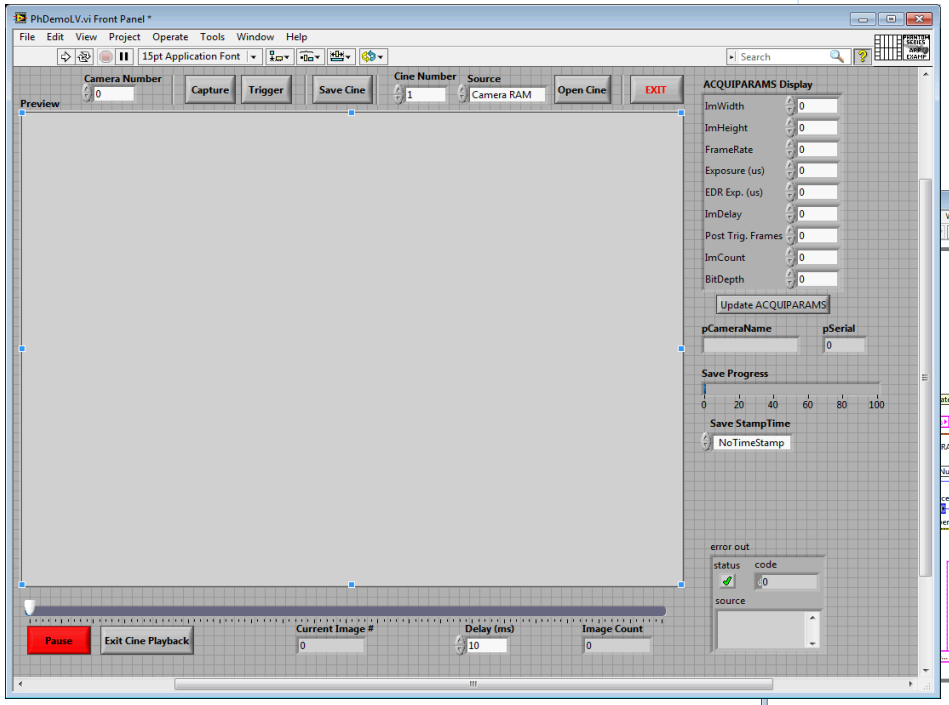


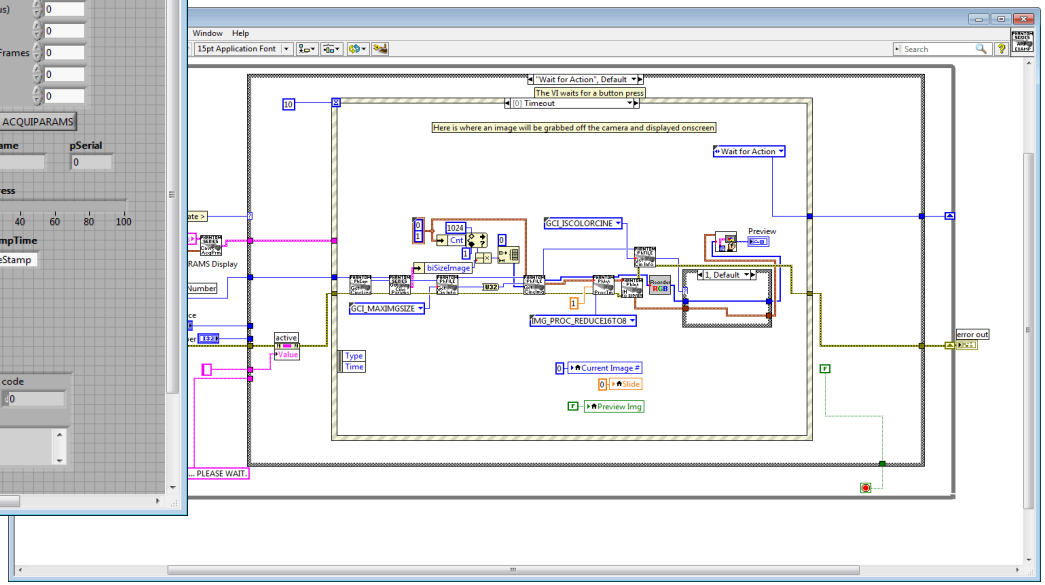
Example Program From Vision Research



niScope	12/2/2013 6:25 PM
niSwitch	12/2/2013 6:09 PM
niTClk	12/2/2013 6:25 PM
niVST	12/2/2013 6:16 PM
Vision Research Phantom Series Labview Driver	10/24/2013 4:06 PM
dir.mnu	7/1/2013 8:02 PM







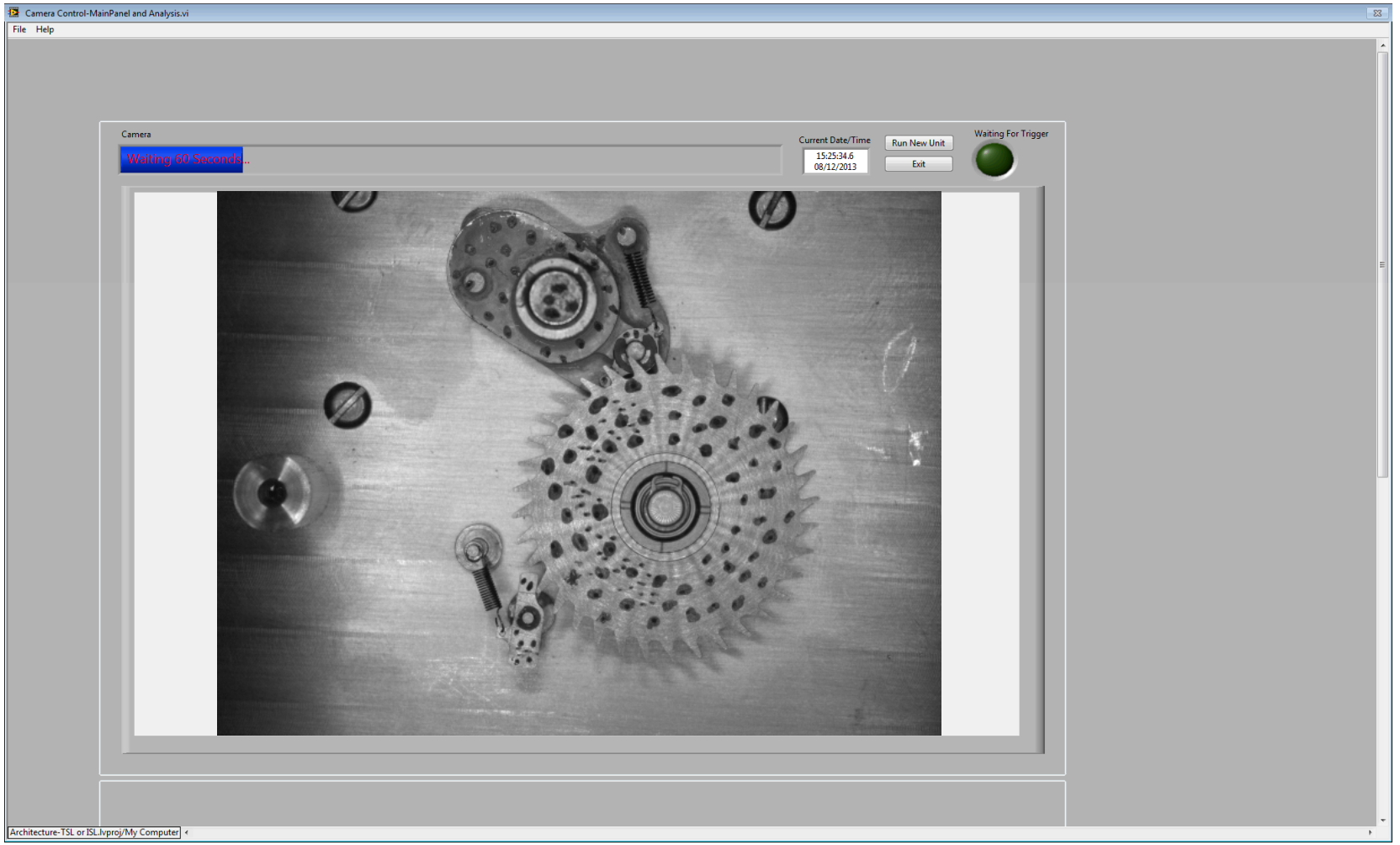
Camera Control Software:

- Knowing how tricky it was to train individuals and get quality videos here at Sandia I set out to create a program that was easy to use for anyone.
- Steps:

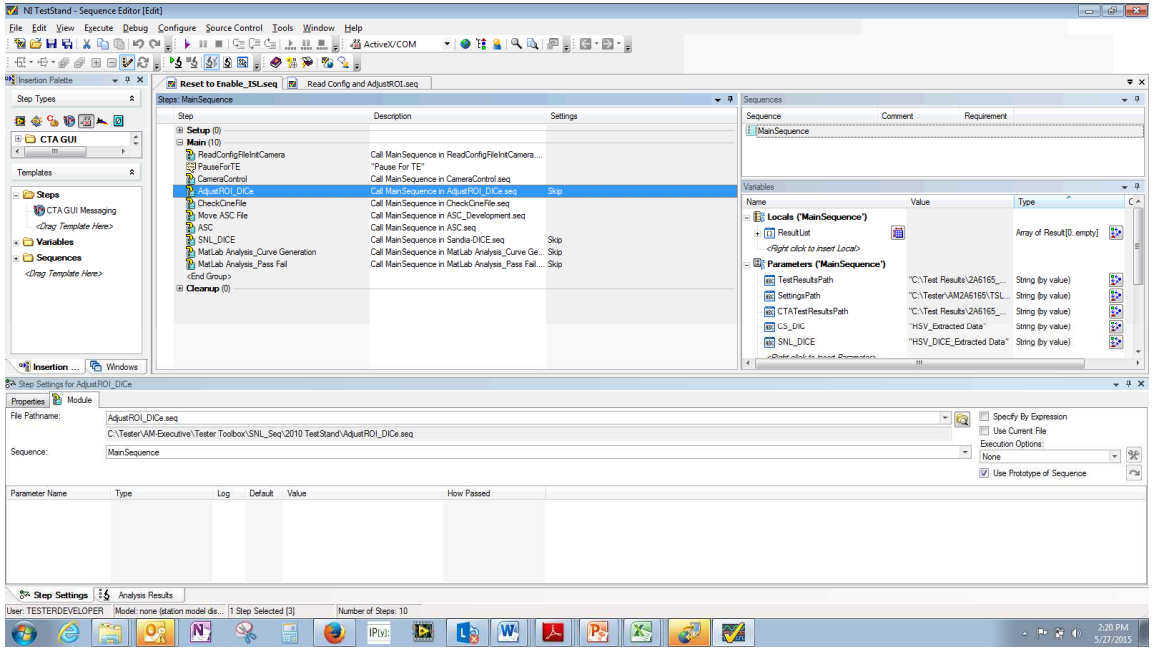
1. Checklist to remind operator to perform certain tasks- No longer needed
2. Operator Selects the type of unit they are running
3. Operator enters serial number of unit- Only time operator needs to type anything into the program
4. Operator Selects the test to be run

- Based on the prompts the correct settings are sent to the Camera
  - Frames Per Second
  - Resolution
  - Range to Save
  - Performs a Current Session Reference
  - Adjusts the lens to the correct focus position
  - Intelligent enough to know what test should be run next.
  - Creates a file path to save the .cine

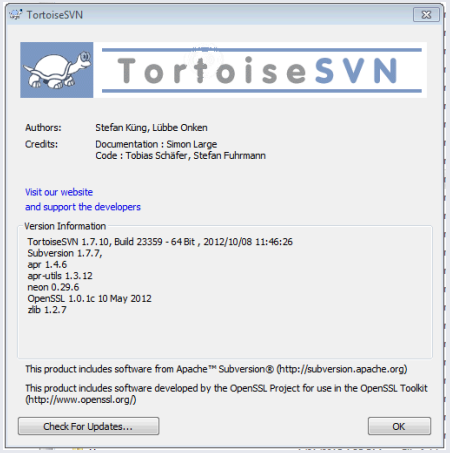
Camera Control Software



First LabVIEW then integrate in TestStand



- **Tortoise SVN, (Subversion) with LabVIEW for Diff and Merge Operations**
- **https://decibel.ni.com/content/docs/DOC-2936**
- **Many other options: GIT, PerForce, Mercurial**

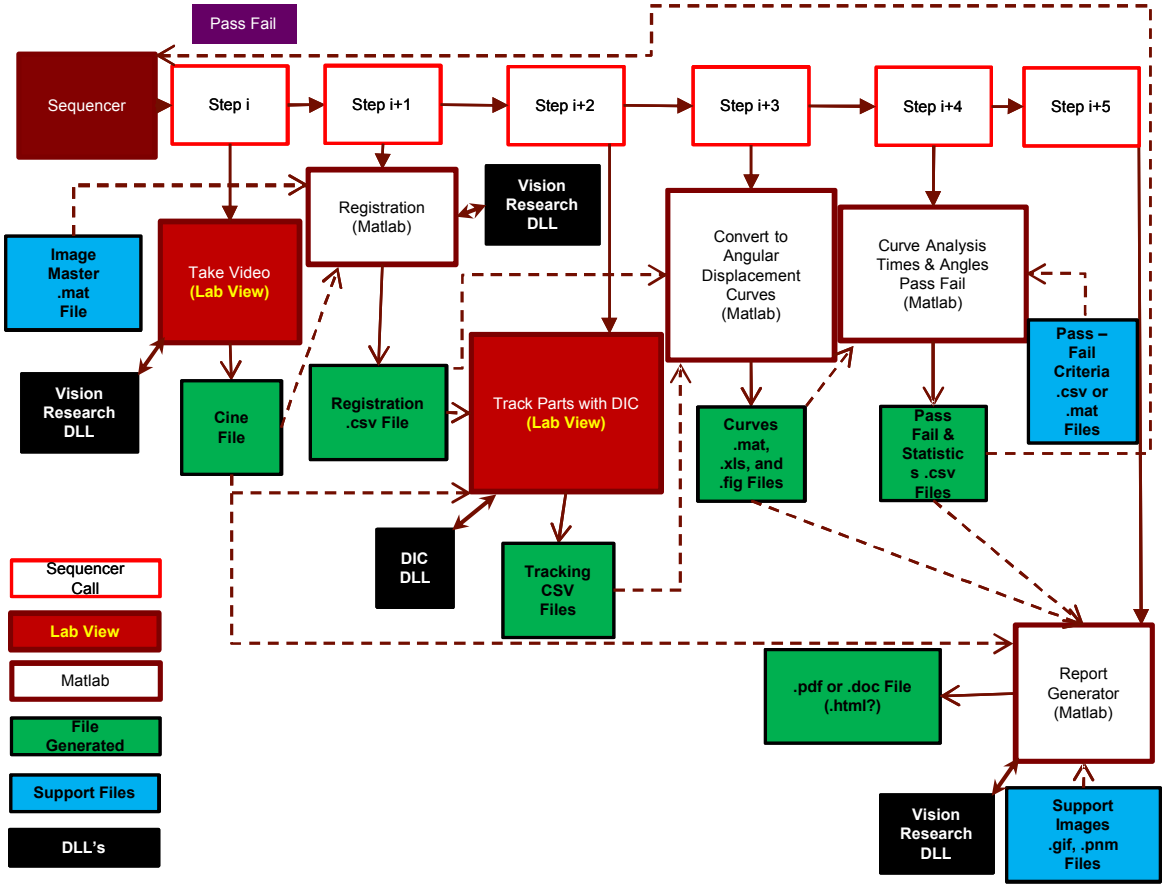


Diverse Team:

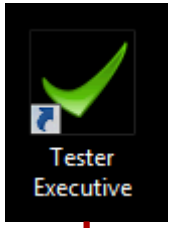
- TDMS Usage
- At Sandia:
  - 1 LabVIEW/ TestStand Developer/Integrator/Sequencer (ME)
  - 3 Matlab Developers
    - ASC Analysis and Parameter Extraction
    - Registration and Curve Generation
    - Parameter Extraction
  - 1 C developer
    - DICe
- At NSC:
  - Tester Development Team
    - 4 Visual Basic/ Developers
    - NI Hardware and LabVIEW expertise

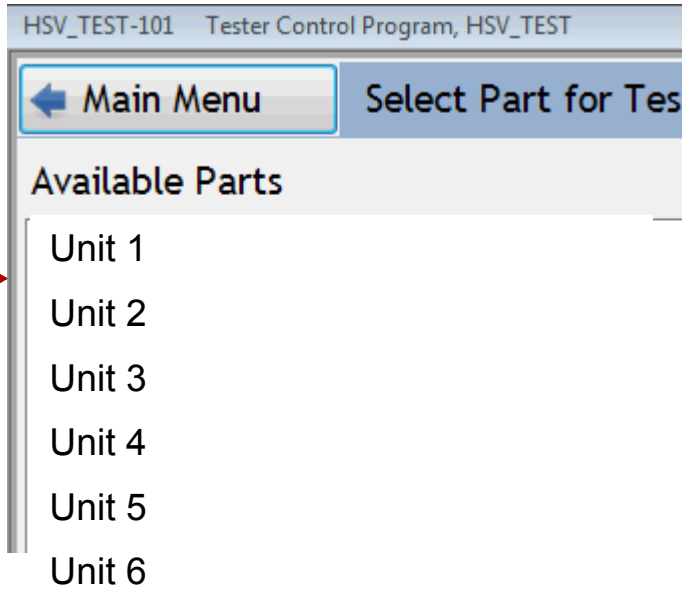
Rough Flow in TestStand

- Walk through Test Sequence
  - Initialize
  - Capture Video
  - Registration
  - ASC Transfer and Analysis
  - DIC Analysis
  - Curve Generation
  - Parameter Extraction
  - Limits Checking

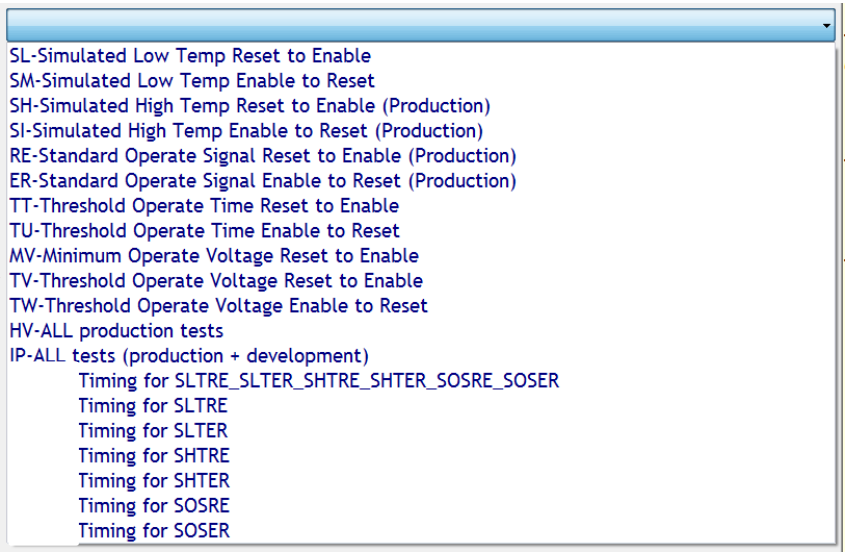


NSC- Certified Tester Architecture(CTA)





- API for TestStand
- File structure for code and data
- Improvements on limits checking
  - Stores limits in Microsoft Access database

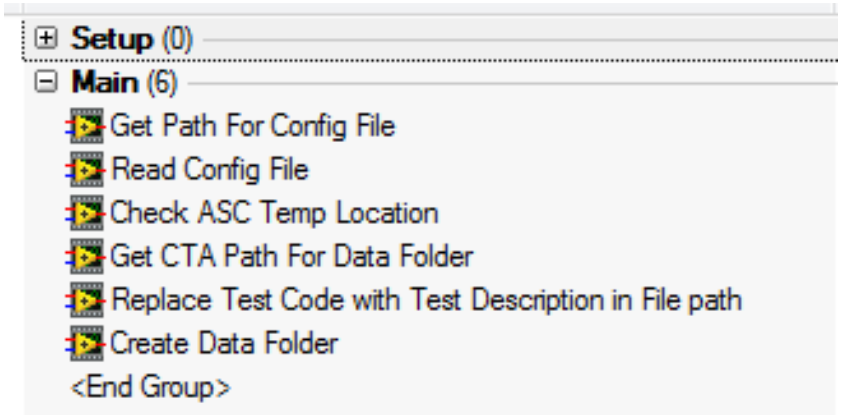


Initializing/Setup

SOSRE.ini - Notepad

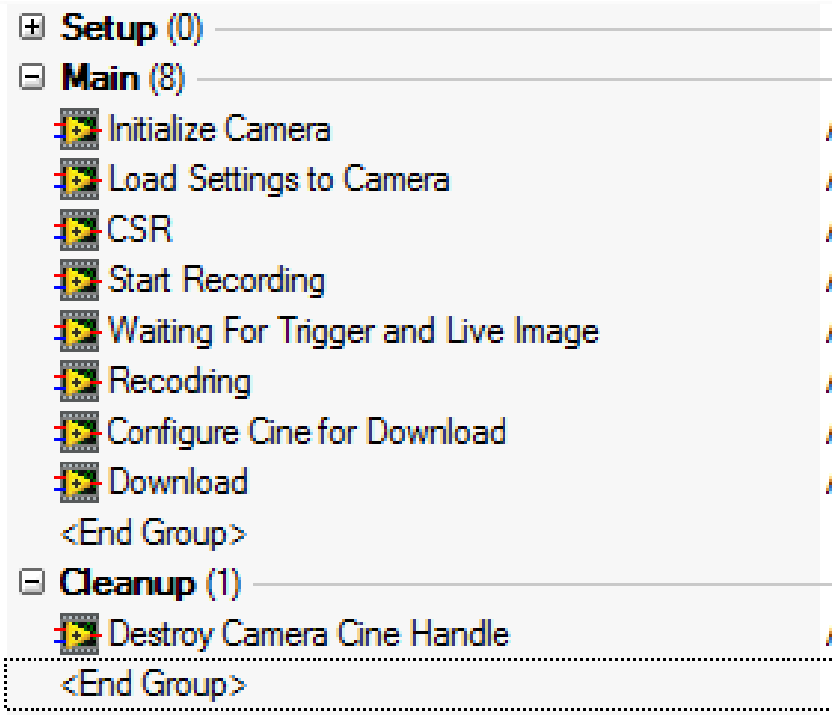
File Edit Format View Help

```
[Test Description]
Test Description = SOSRE

[Paths]
DataFolder = C:\Test Results
Cine =
DIC Results Folder =
CurveGenerationCode = C:\Tester\AM-Executive\Tester Toolbox\SNL_Se
CurveGenerationCode Settings =
ASC Code = C:\Tester\AM-Executive\Tester Toolbox\SNL_Seq\MatLab\AS
ASC Code Settings = C:\Tester\AM-Executive\Tester Toolbox\SNL_Seq\
Temp ASC Data Folder = \\LT6035496\ASCFileshare\For HSV
TDMS Data Path =
PassFail Code = C:\Tester\AM-Executive\Tester Toolbox\SNL_Seq\MatL
PassFail Code Settings =
Feature Recognition Code = C:\Tester\AM-Executive\Tester Toolbox\S
The Closer Code = C:\Tester\AM-Executive\Tester Toolbox\SNL_Seq\Ma
Phantom STG File = C:\ProgramData\Phantom\744\14020.stg
PhantomPConDll = C:\Tester\AM-Executive\Tester Toolbox\SNL_Seq\Pha
PhantomPFileDll = C:\Tester\AM-Executive\Tester Toolbox\SNL_Seq\Ph
CfgFile = C:\Tester\AM2A1503\ISL\Settings Files\SOSRE.ini
ROI Path = C:\Tester\AM2A1503\ISL\Settings Files\subset_defs_RE.tx
Master Cine Path = C:\Tester\AM2A1503\ISL\Settings Files\MasterISL

[Camera Number and Save Range]
Camera Number = "0"
MaxSaveValue = "18050"
MinSaveValue = "-100"

[Lens Settings]
HomeFocusPosition = -2600
FocalLength = 943
FStop = 4617991057905706598

[DIC Settings]
ROI size = 19
Sigma Threshold = .07
Sigma Jump Limit = .02
Correlation Criterion = ZNNSD
Search Window = 0

[Cine Parameters]
ImWidth = "896"
ImHeight = "400"
FrameRate = "10000"
Exposure = "50000"
EDRExposure = "0"
ImDelay = "0"
PTFrames = "19000"
ImCount = "65776"
SyncImaging = "SYNC_INTERNAL"
```

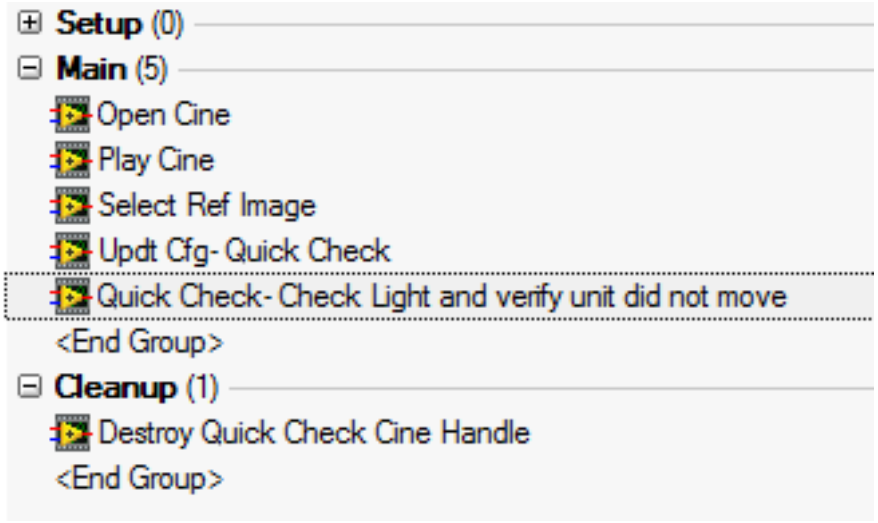


Camera Control + Movie Check

- Live Image and Test Description are provided
- In this state the Camera waits for a trigger supplied from the main tester
- Automatically names and downloads movie

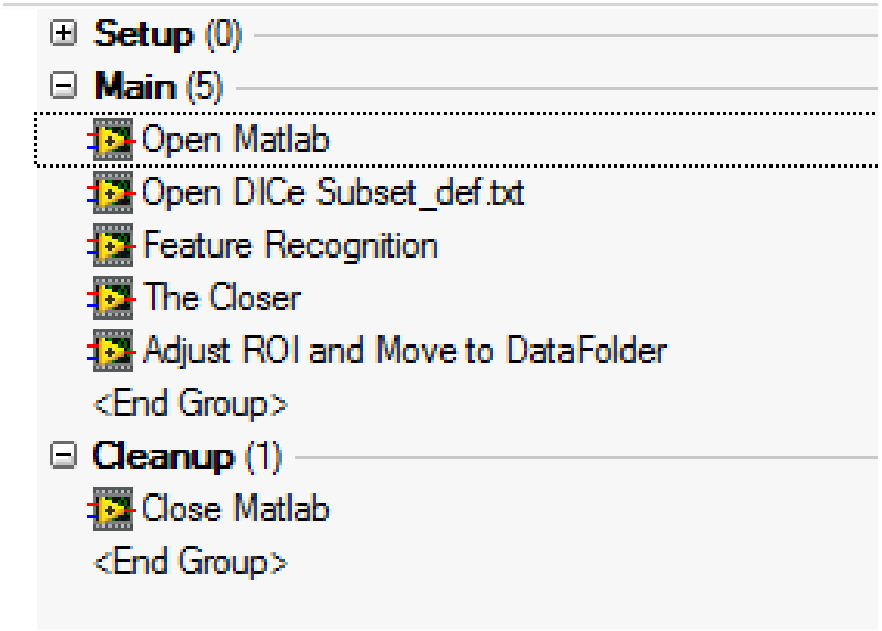


- Plays back the cine and checks for errors
  - Checks to see if unit has vibrated
  - Checked to make sure cine opens and plays



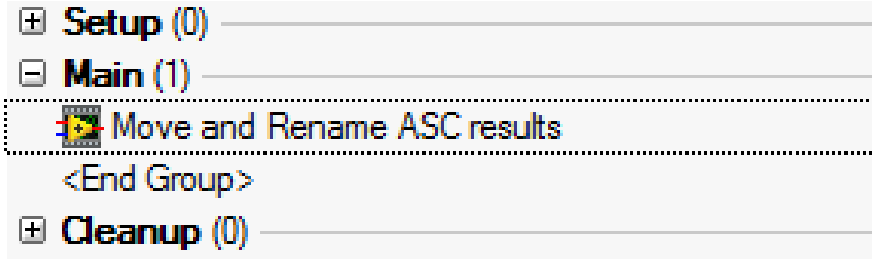
Registration to Adjust ROI's

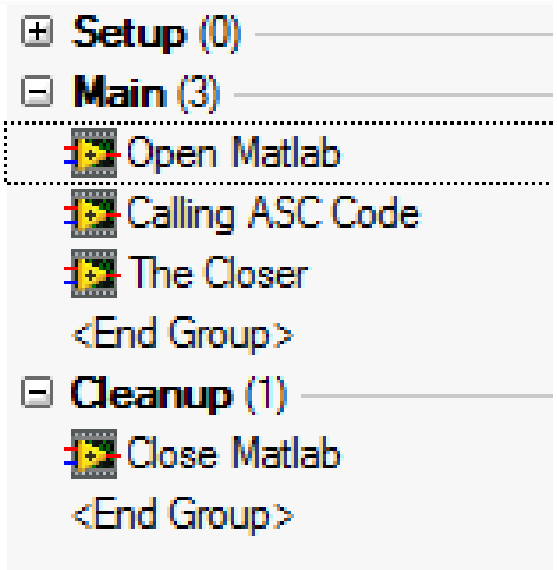
- Need to adjust ROI's due to variability in unit position
- Matlabs Registration out puts the change in: x, y, scale, and theta.
- This information is sufficient to get the ROI's to fall into the region of speckle



Move ASC File and ASC Analysis

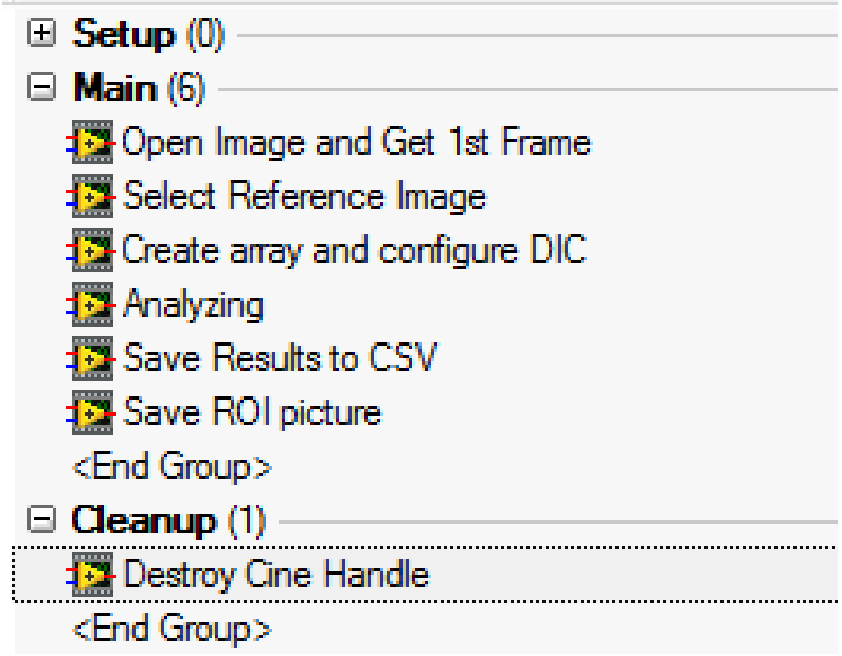
- Moves ASC data from acquisition PC to Data Analysis PC
- Extracts Parameters and writes them to a file to be later limit checked against.



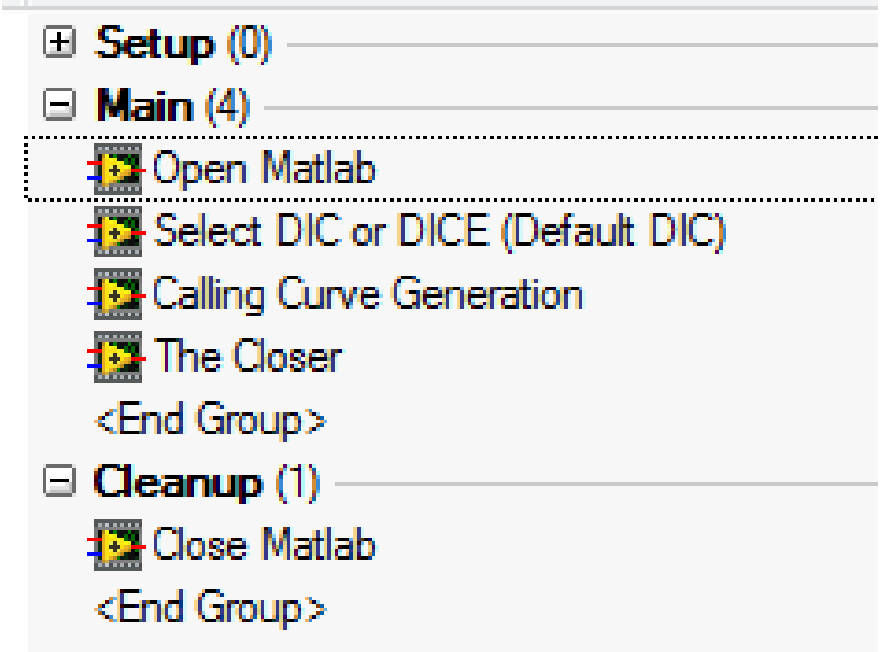


DIC + Curve Generation

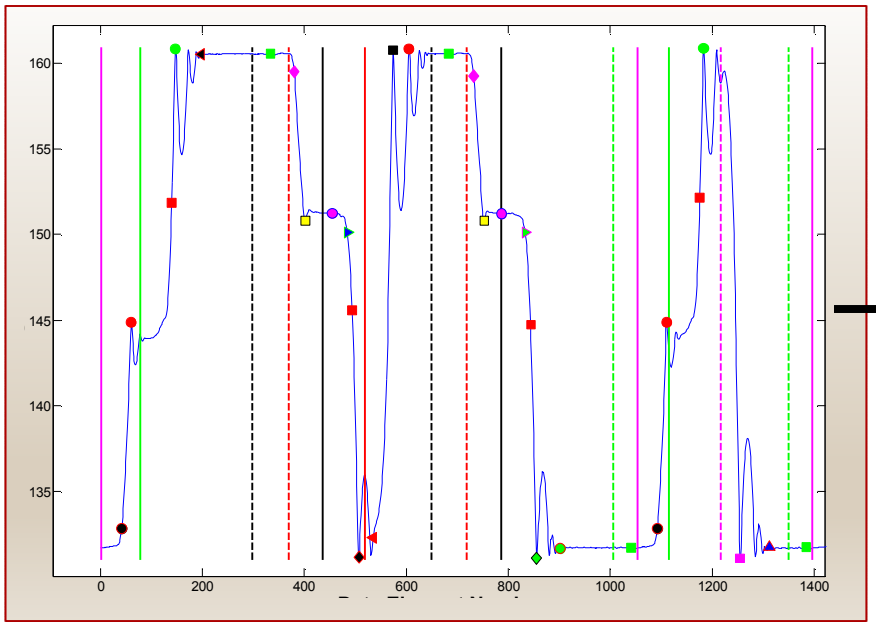
- Utilizing Both Correlated Solutions DIC code and Sandia's DICe code

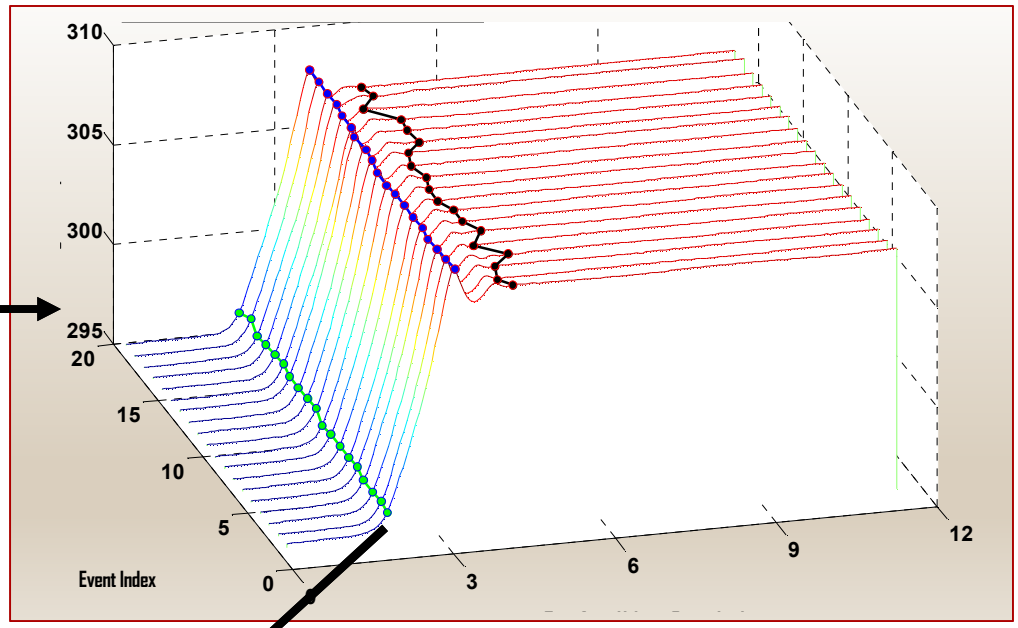


- Takes Data from Pixels vs frame rate into more usable engineering data
  - Converts to Angle vs Time, Velocity vs Time, and Acceleration vs Time

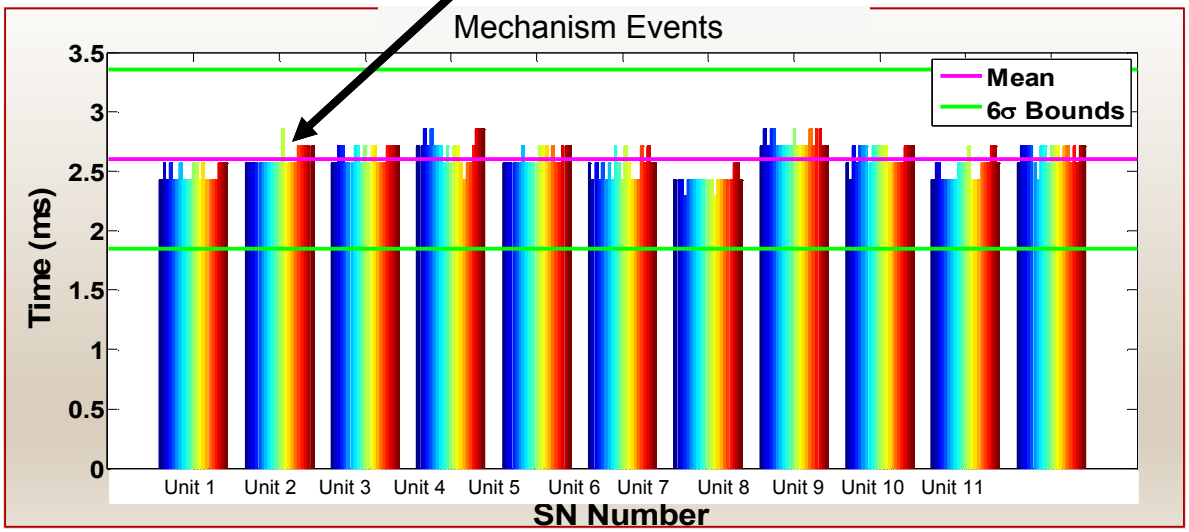


Performance Metrics





- Metrics of interest (e.g. event times) are identified and computed with a post-processing algorithm
  - Markers identify behaviors of interest



So we have a Tester, So What? Outcomes:

Sandia National Laboratories

- **NNSA 2014 Defense Programs Award of Excellence**
- **Sandia 2015 Employee Recognition Award**
- **To Date hundreds of development units have been analyzed using the development and production tester.**
- **Discovered several unknown failure modes in the units.**
- **Greatly improved the dynamic understanding of the units, which in turn has improved the models of units.**
- **Decision was made to implement a HSV and ASC tester at NSC for production.**

Conclusion

- Custom software is the only way this technology can be incorporated into a production environment.
- NI Products were easy to use to integrate many different platforms.
- Using 3rd party DLL comes with certain challenges but benefits out-weigh cons.
- DIC is automatable for complex mechanisms and tests
- Vision and motion toolkits have become incredible powerful tools.
- Under optimized setup DIC can provide robust and repeatable tacking
- LabVIEW/TestStand works with a large diverse development team.
- TDMS file formats easy to utilize.

- Big Thanks to:
  - Michael Herzberg
  - Miguel Palaviccini
  - Dan Turner
  - Alvaro Cruz-Cabrera
  - John Griffin
  - Bob Dearth
  - Brandon Leslie
  - Phil Reu
  - John Wagner