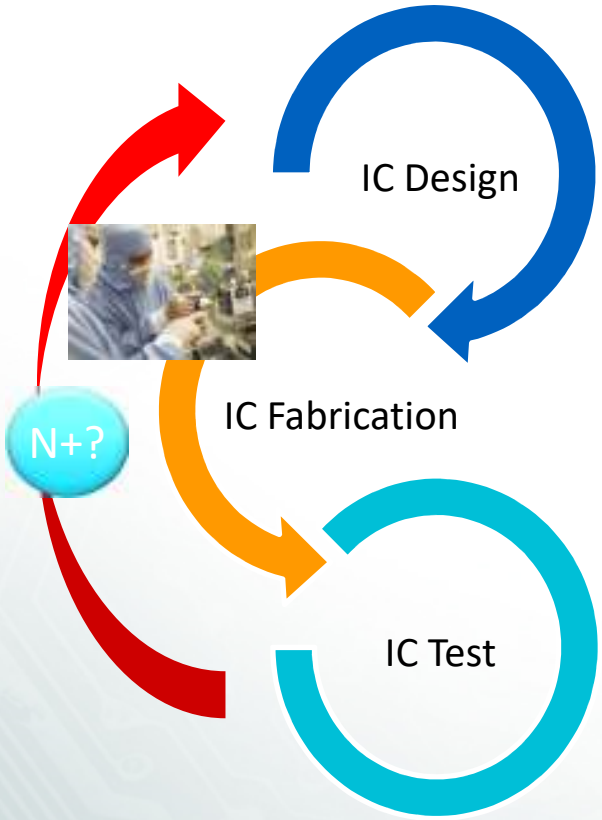
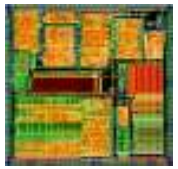
Autonomous RF Measurement assistant

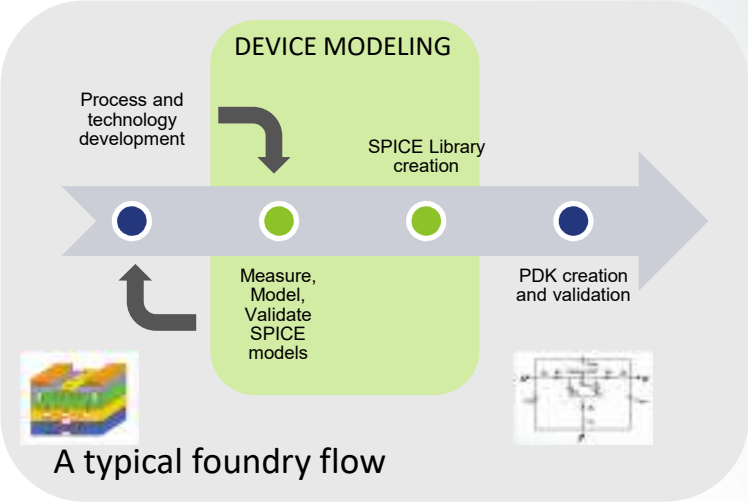
Gavin Fisher – Applications Specialist

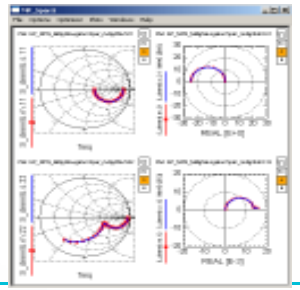
Why is Device Modeling Critical

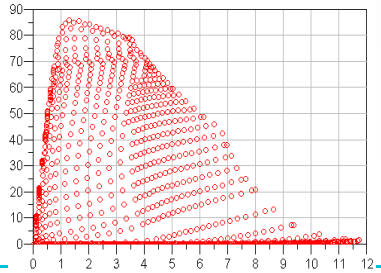




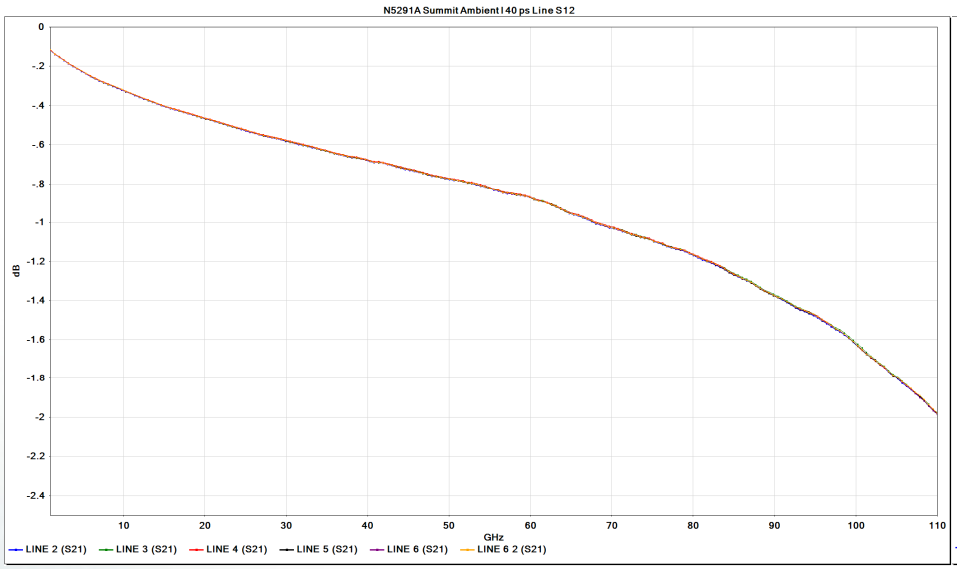
PDK

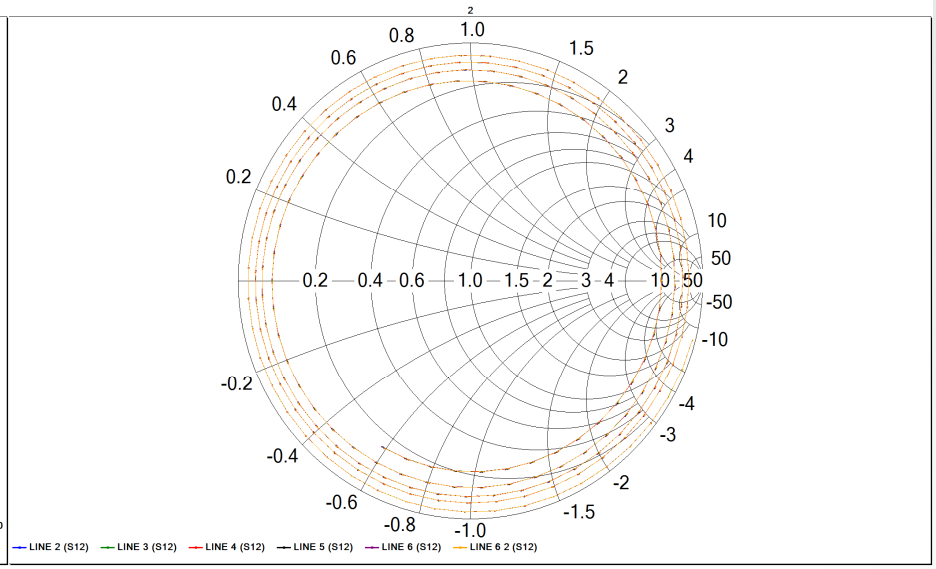






Goal – Accurate Data





More Accurate Data = Better PDK = Faster Time to Market = $$$

Pain Points – Testing over Temperature

Measurements at ambient can be challenging, but measuring over temperature is much harder

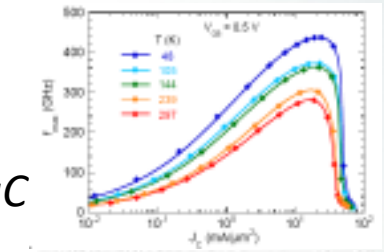
Device modelling for Process Design Kits requires testing from -40degC to +125degC

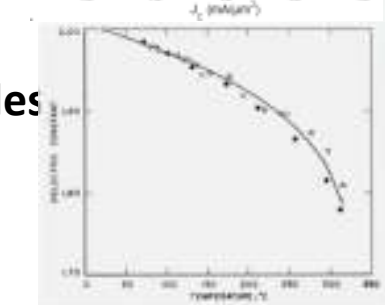
Calibration more prone to drift due to expansion of probes and cables

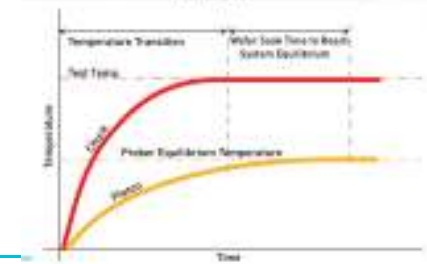
Probe to pad alignment errors due to expansion of chuck, wafer, platen, positioners, probes and more

Problems have become more significant with shrinking pad dimensions

RF Pads typically as small at 50x50um







Mechanical effects of growth

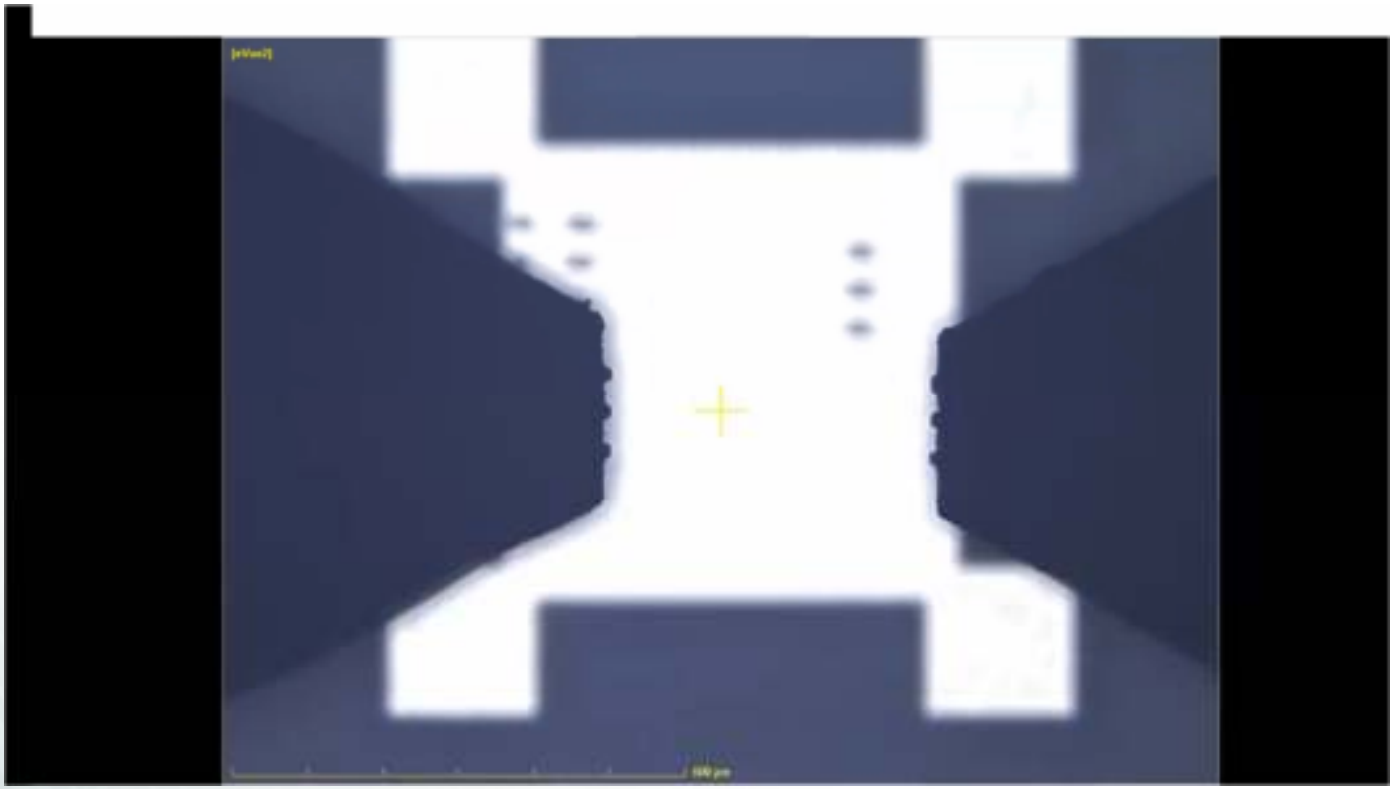
Probes grow / retract with temperature in XZ

Some movement in Y but comparatively minimal

For significant thermal changes evaluate theta also

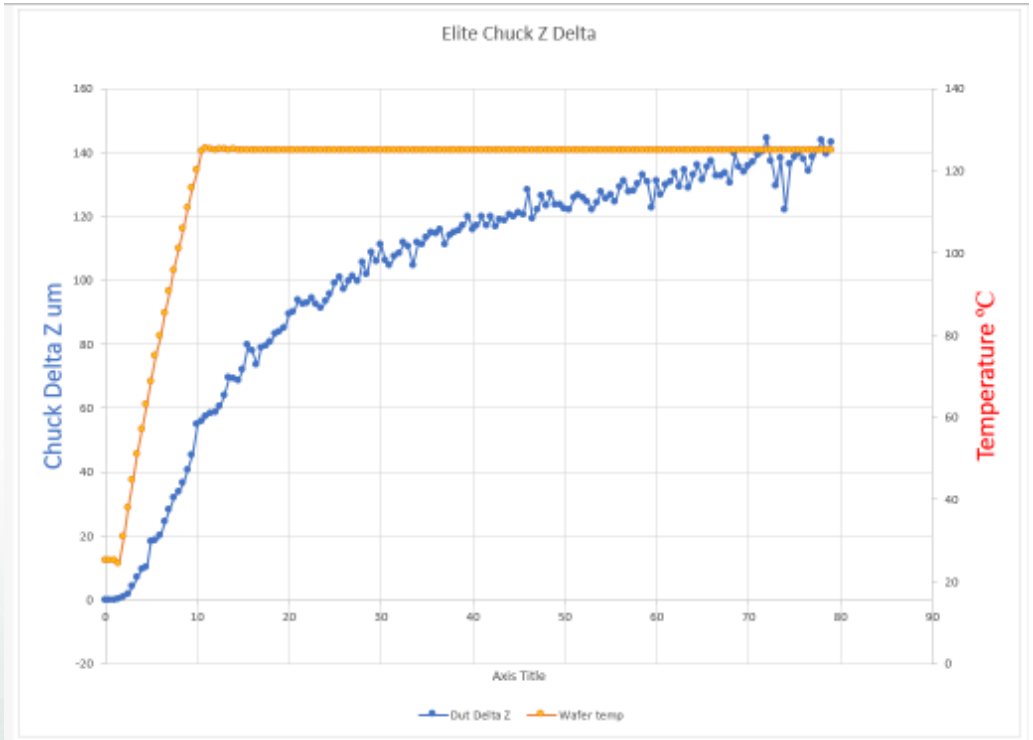
Chuck grows in XYZ

Probe expansion 25ºC>>125ºC>>25ºC



Video

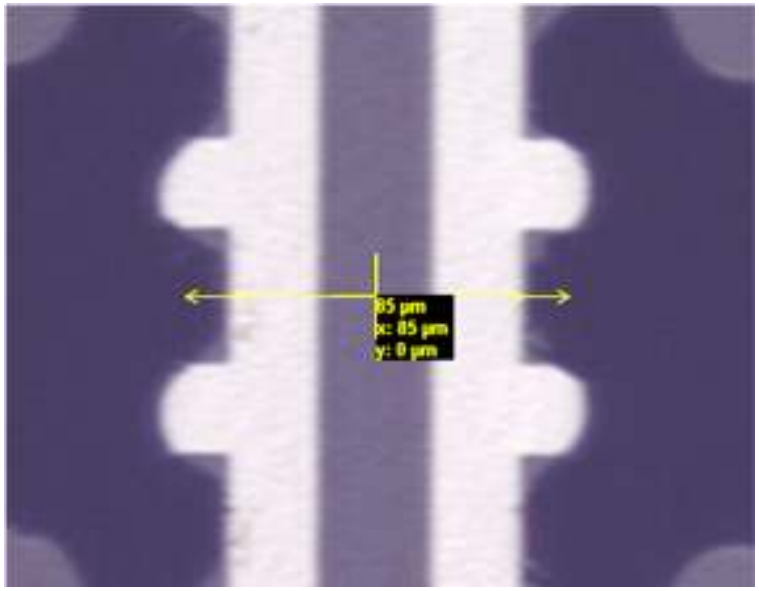
Chuck Z expansion

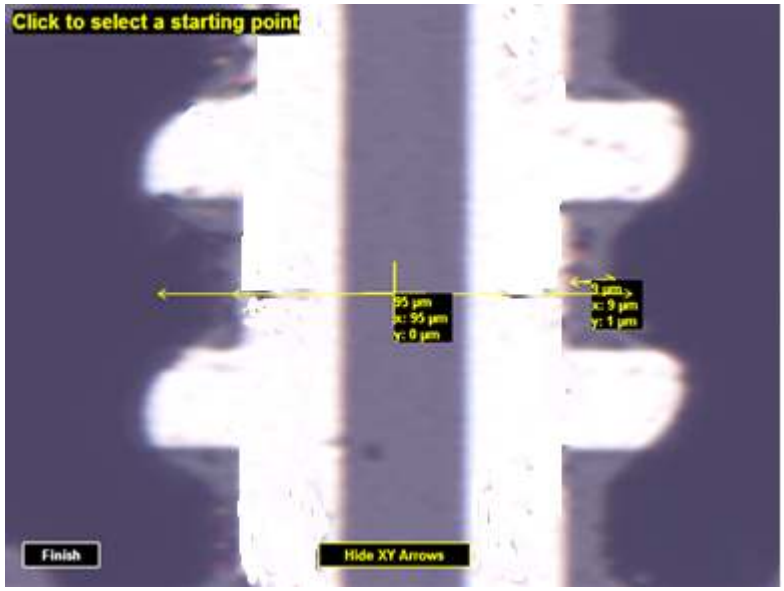


Chuck to probe geometry change during soak

Ideally we would like to probe during growth to save time

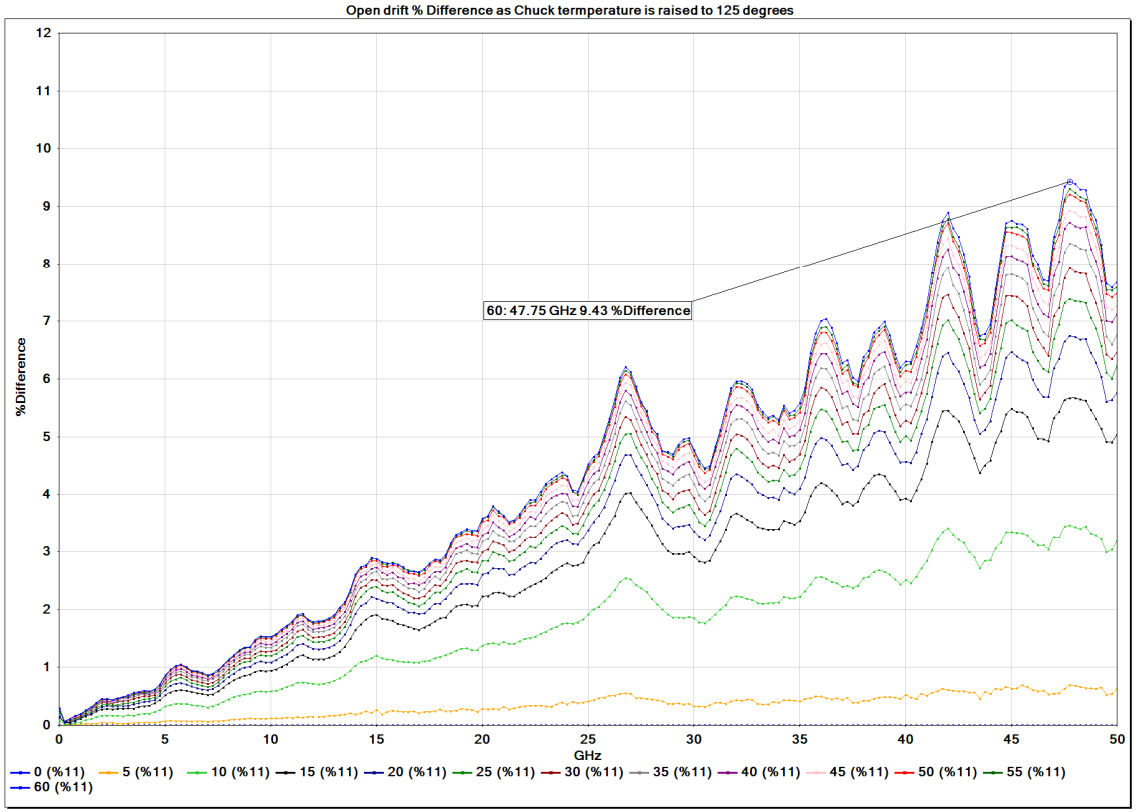
Mechanical effects during calibration itself





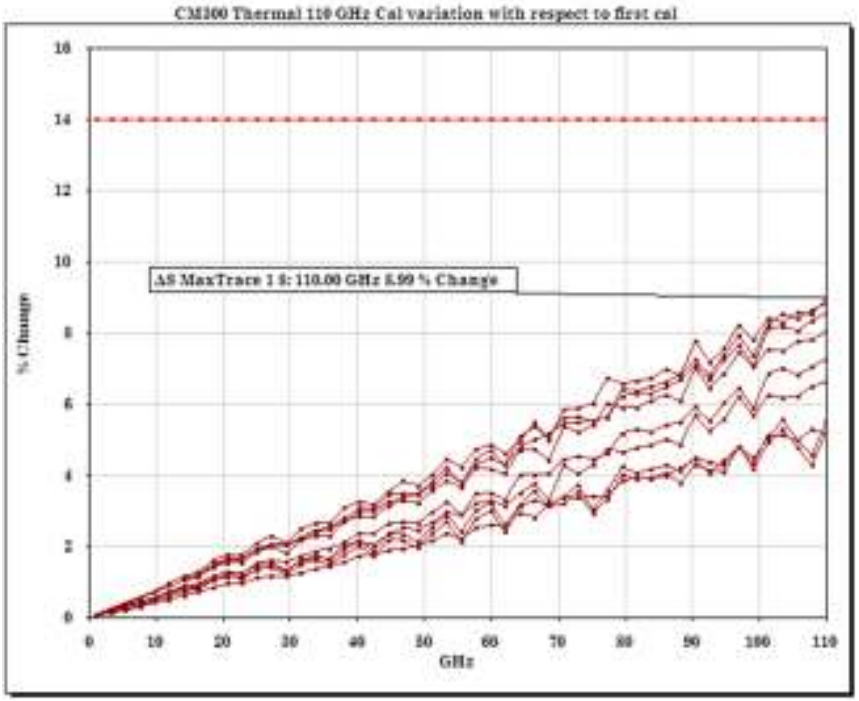
- **Probe shrinkage during 1 minute LRRM calibration**
- **East probe further from hot chuck has 9 um delta in contact position**
- **Critical line measurement is measured first in calibration**

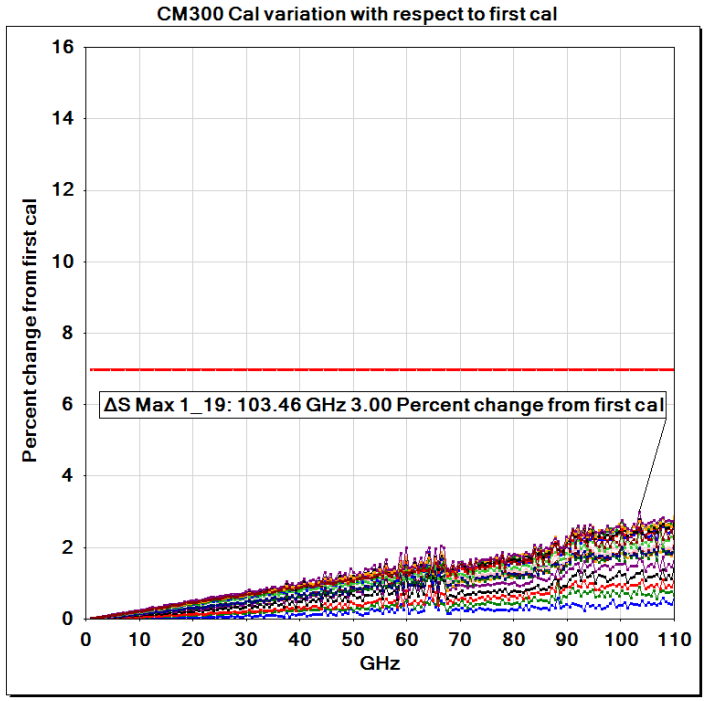
S parameter change during probe warm up



- This was a 50 GHz example
- Reference set at ambient
- System was calibrated and probes left above chuck
- Chuck temperature raised to 125 degrees
- This is the Vector delta * 100 change during warm up without contact to the chuck
- Because of these changes we need to calibrate at operating temperature

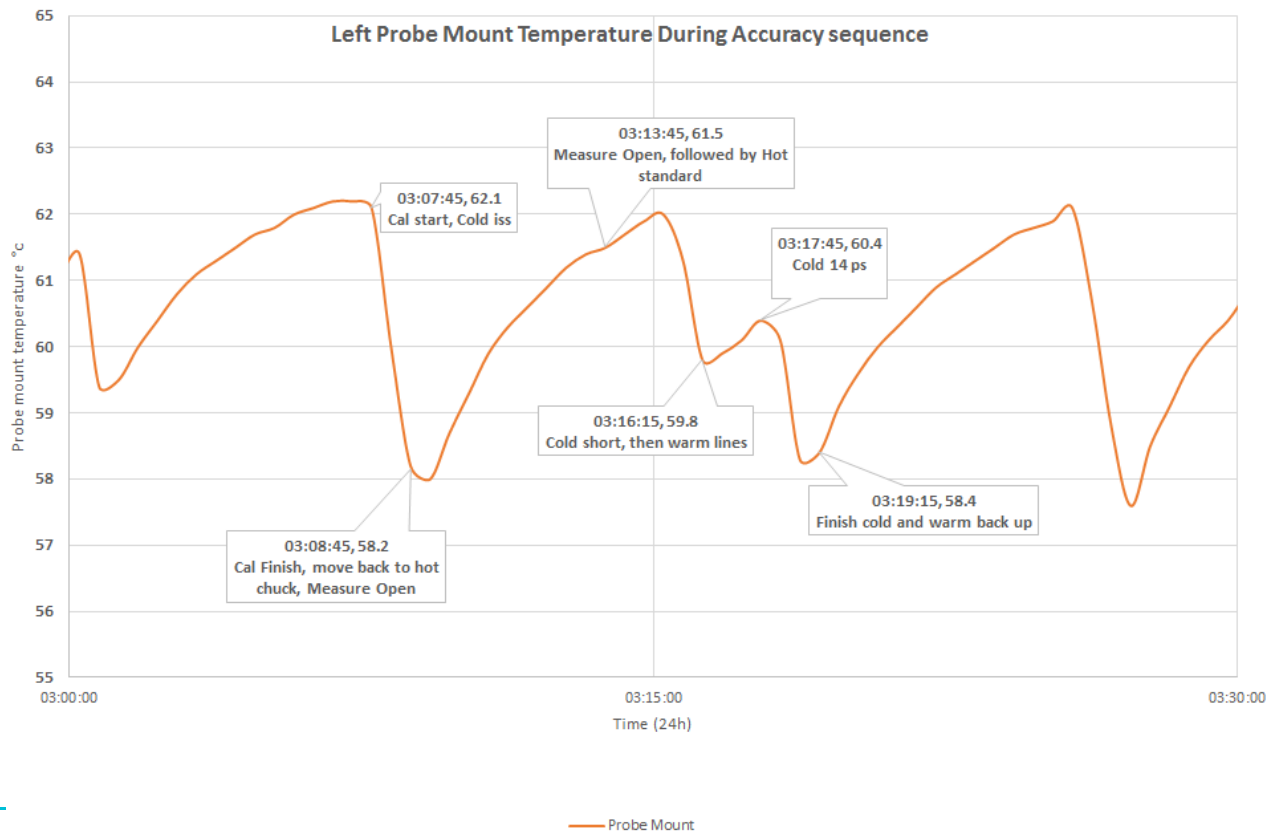
Thermal v Ambient error set stability (N5251A)





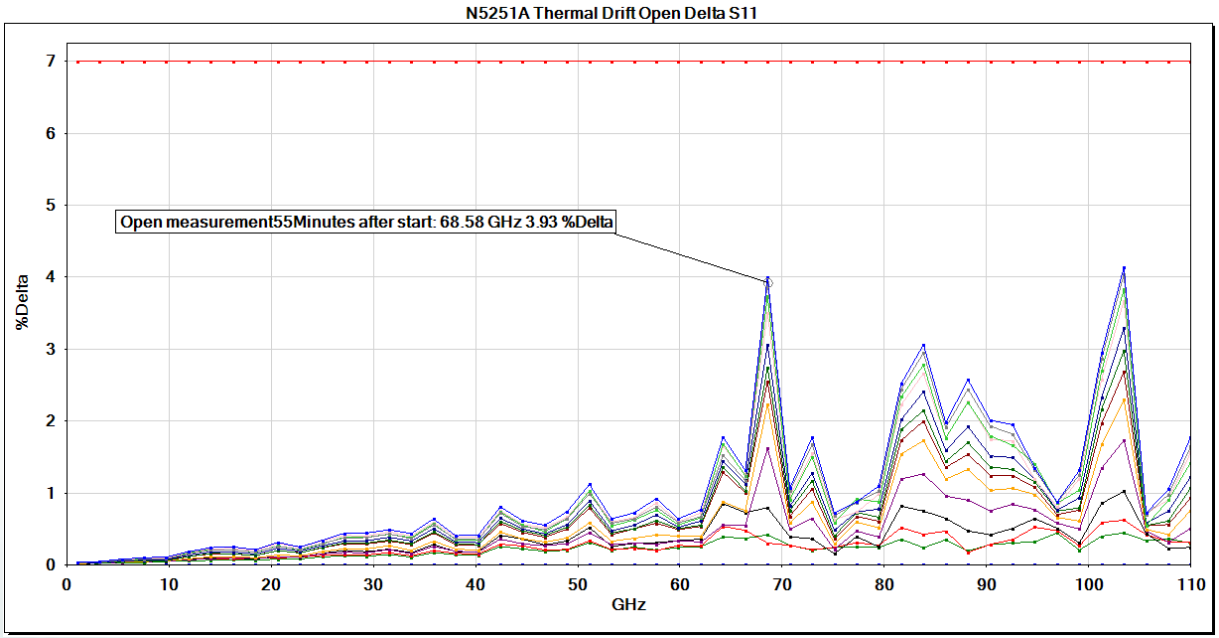
Some of the deterioration may be due to room temperature variation

Temperature variation during calibration



- **Graph shows the change in temperature of probe base during 1.5 minute calibration cycle**
- **Manually positioning probes on ambient iss can be inaccurate and time consuming**

Problem – Calibration Drift



- Calibration drifts with time and temperature changes
- Magnitude increases with frequency
- Transitioning chuck temperature invalidates calibration
- Drift has been greatly improved using N5291A system but still a consideration

Pain Points – Calibration Drift

Even a good calibration will drift with time, temperature changes and movement of cables

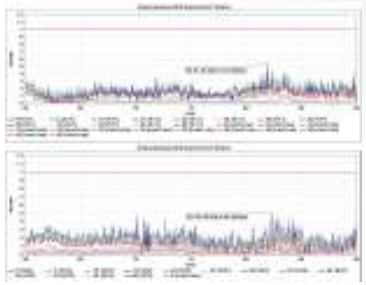
Even small temperature changes in the room, can cause higher frequency calibrations to drift

There is no automation of monitoring the magnitude of drift error

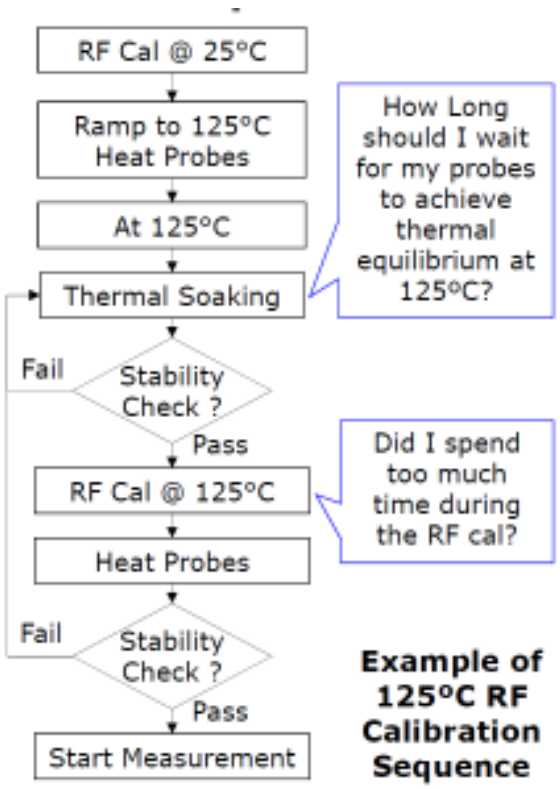
Manual checks can me made of the open standard at any time, but automating this requires programming in the test executive

And no autonomous way to re-calibrate once the drift has exceeded a limit

If the calibration is found to be no longer valid, then the user needs to stop the testing and perform the whole calibration again



Over temperature calibration general approach



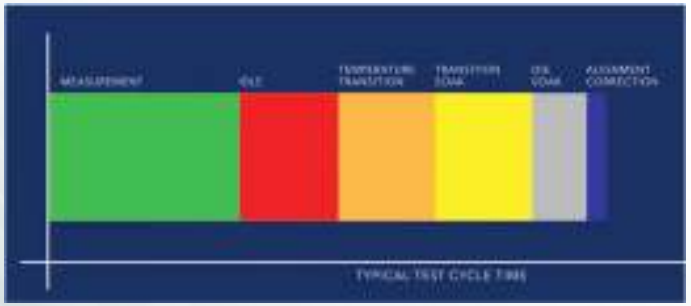
- **Doing all of this takes skill patience and experience**
- **Doing things without the checks can result in erroneous data**
- **Getting calibration fast enough is very tricky even for experienced users and compromises are often made**
- **Machine must be "nursed"**

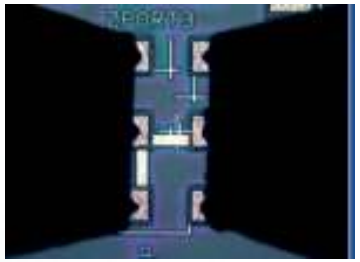
Problem – Device Soak Times over Temperature

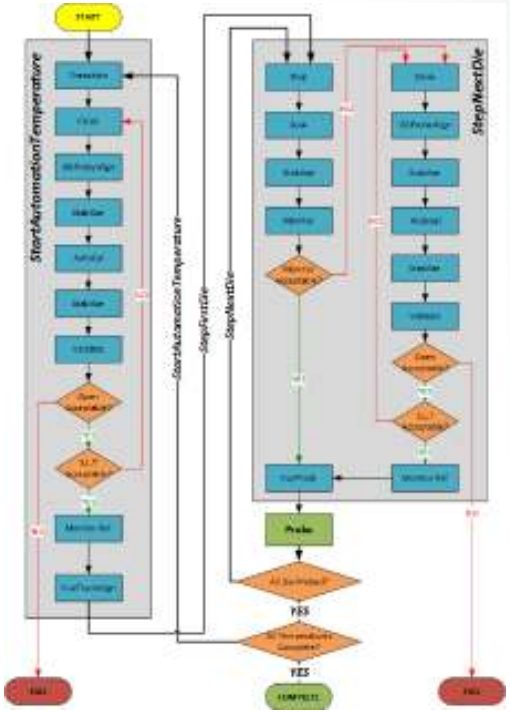
System and DUT continue to soak after temperature transition

Requires re-alignment after transition and for long duration tests a soak needed for die and frequent probe re-alignment on pads

Reaching thermal equilibrium can take hours







Introducing – Autonomous RF Measurement Assistant

Contact Intelligence™

"Only the Autonomous RF Measurement Assistant, a combination of programmable positioners, a precise digital microscopy system and advanced pattern recognition algorithms, enables fully autonomous, hands-free calibrations and measurements of RF devices over multiple temperatures."

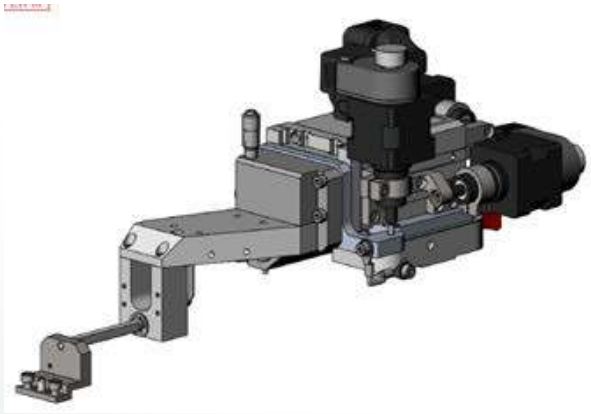
Autonomous RF

- **True Automatic, hands free calibration**
- **Setup of Calibration requires no expert placement, all automatic**
- **Monitors calibration drift, re-calibrates automatically**
- **Full management of system expansion and RF stability**
- **Full thermal automatic calibration**
- **Save time & increase data accuracy**
- **Corrects “thermally induced” probe electrical errors**

Compact High resolution Programmable Positioner

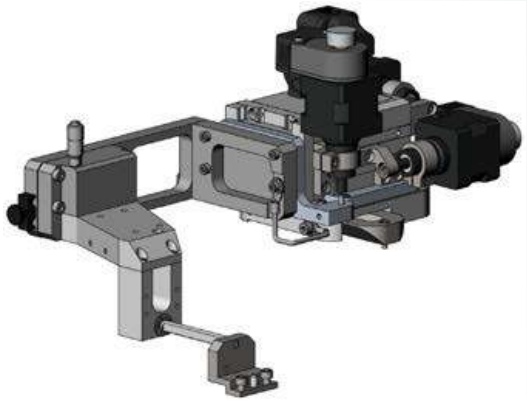
- **Compact positioner allows for multiple motorised positioners on the same prober**
- **Designed from the ground up for best accuracy, repeatability and service life**

New RPP504 Programmable Positioners



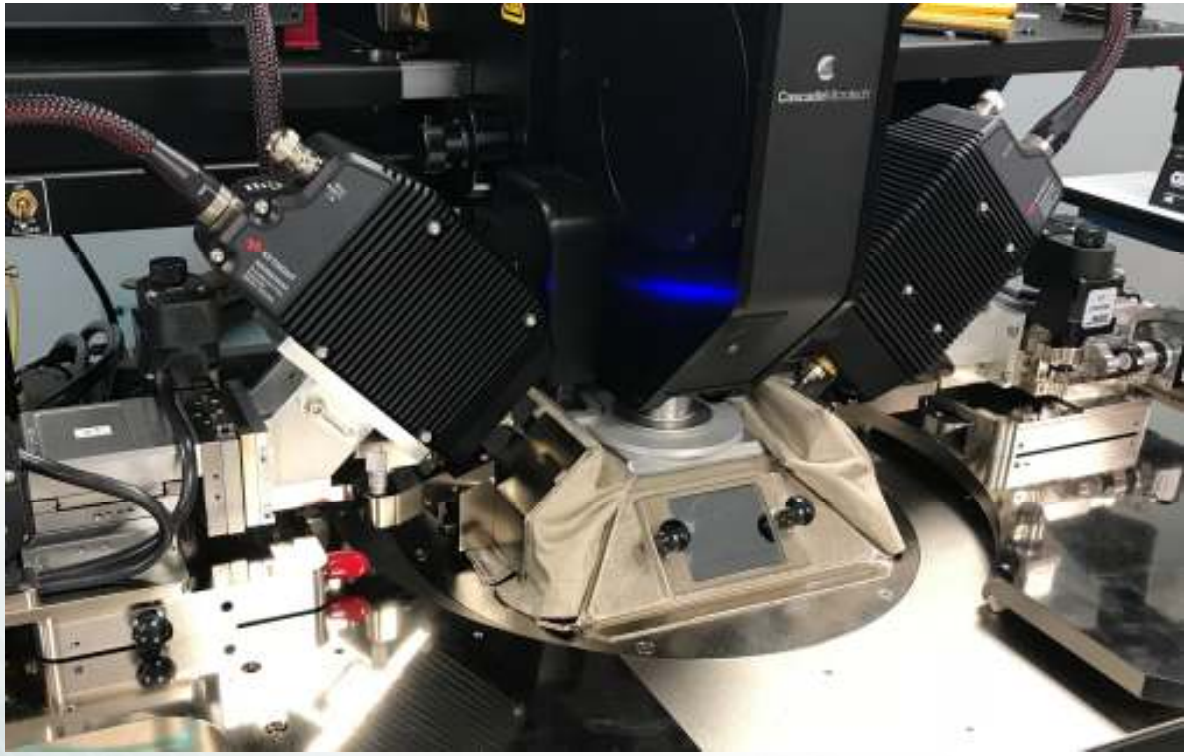
RPP504-EW-67

RPP504-EW-120



RPP504-NS-67

RF TopHat reduces path length and improved accuracy



Tophat designed to minimise cable lengths and prevent stiction which impacts motorised positioner accuracy

Reducing cable length helps to improve system drift and dynamic range

Autonomous RF currently limited to max 130 GHz and Infinity probes

Can be used with conventional sub 67 GHz coaxial probes

System Photos – Probe Window

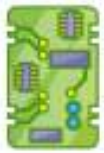
Clear window designed to ease setup when south positioner is not in use

Quickly sealable using metal cover

Shielded to prevent charge build up

Positioner Configurations

Summit 12000/E lite300 → RPP504 + 174-544 Electronics adapter Kit (inc ECA-53) + ECX-56-D + 174-889 Pla ten adapter for S ummit

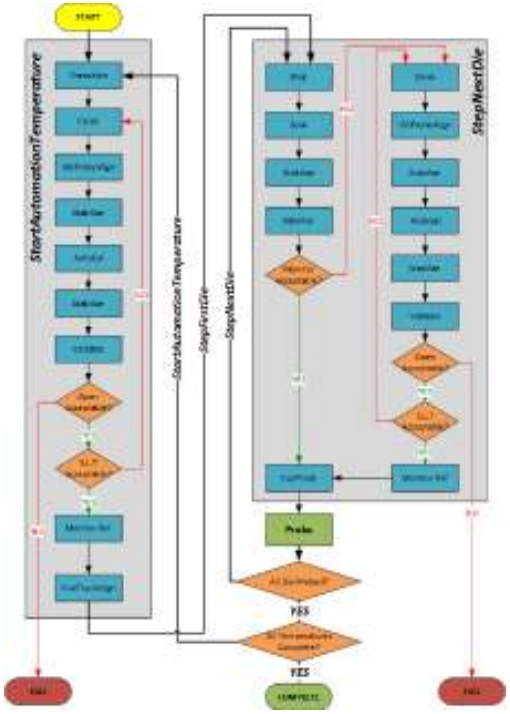


Summit 200/ CM300 → RPP504 + MPX Box + 178-518/ 178-924 Mounting kits

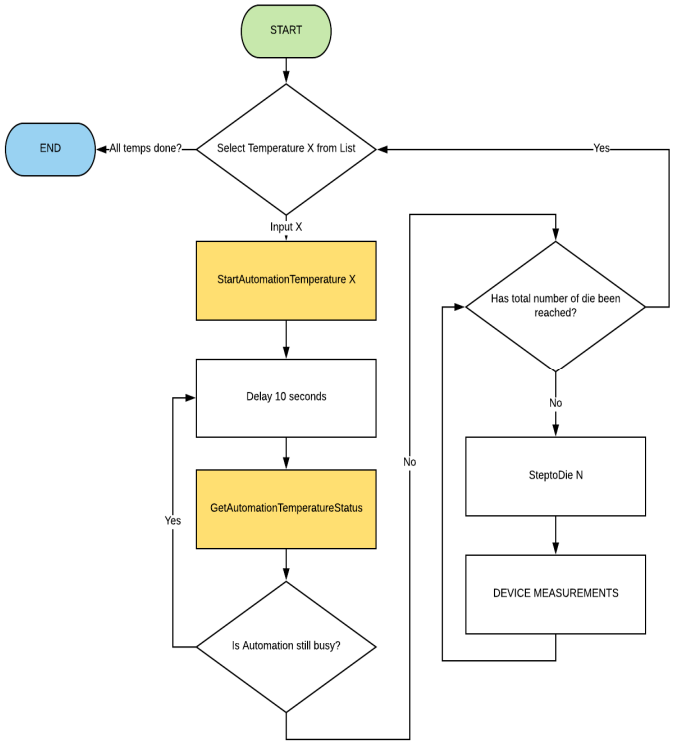
Integrating Automation assistant into test executive

StartAutomationTemperature X does all this…

- *Changes temperature and maintains probe to probe, and probe to wafer geometry at Separate*
- *Die soak at end of transition at align height always maintaining geometry*
- *Checks using VNA to test for electrical stability*
- *Moves bias probes out of field of view*
- *Aligns probes at ISS using defined spacings*
- *Re-checks stability to ensure probes didn't cool down*
- *Calibrates system*
- *Verifies*
- *Takes monitoring data to check system is stable later on*
- *Returns probes to wafer Geometry ready for test*
- *Addition options of this command peforms Theta align and sizing*

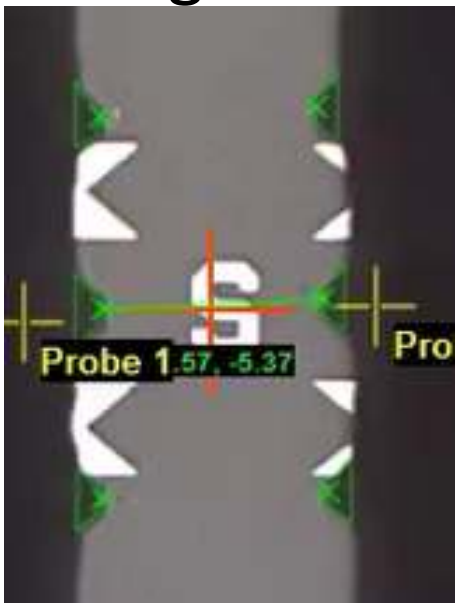


Using StartAutomationTemperature



- *Coloured processes are the two new commands StartAutomationTemperature GetAutomationTemperature Status*
- *Test exec never needs to ask system to calibrate, monitor or soak. Its all automatic*
- *Only needs to send temperature automation, wait till complete and then step to numbered die as normal*
- *Next die commands will check for drift, recalibrate if needed and automate probe on die placement*

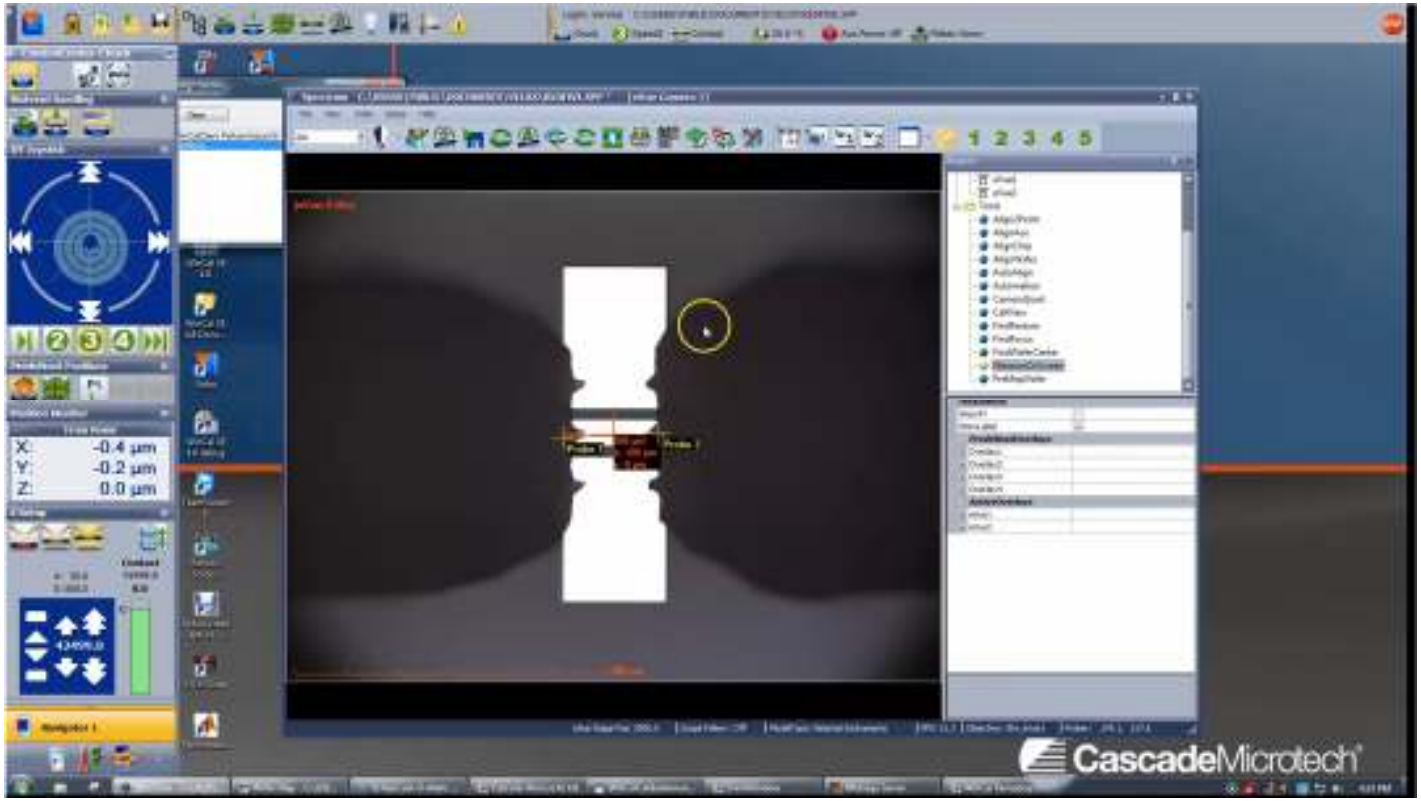
Training Autonomous RF – Tip finding



Auto RF tip location and iteration is at the heart of the process

Required for Autonomous calibration

Autonomous Rf Measurement Setup video

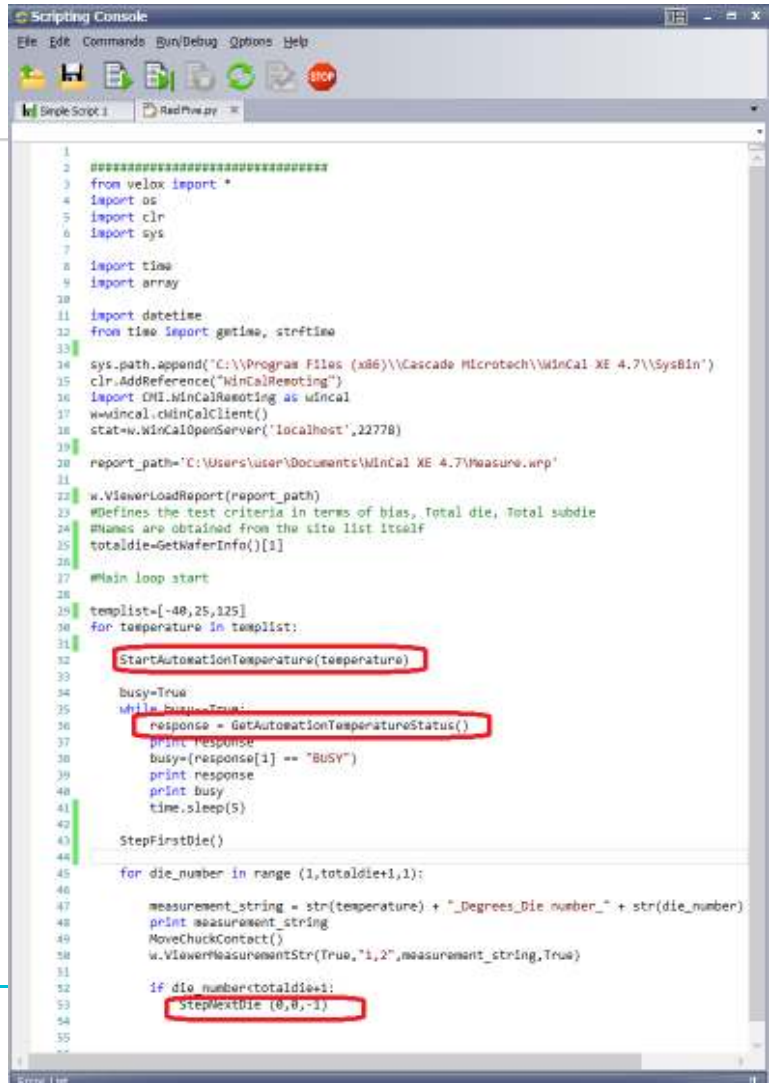


Video

Scripting in Python

This code is enough to measure all die on a wafer at 3 different temperatures using Wincal

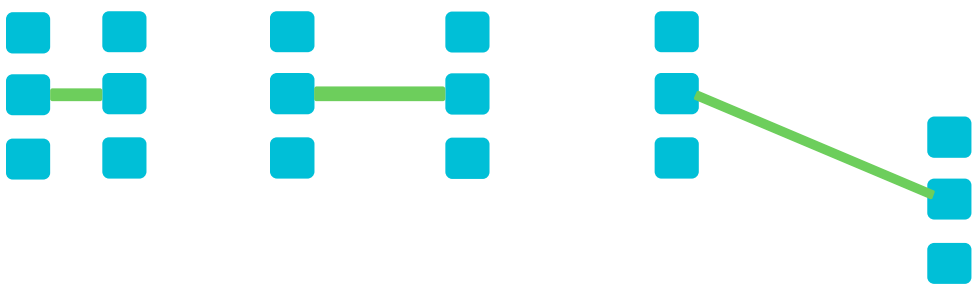
Red Ringed are automation activities




```
#################################
from velox import *
import os
import clr
import sys

import time
import array

import datetime
from time import gmtime, strftime

sys.path.append("C:\\Program Files (x86)\\Cascade Microtech\\WinCal XE 4.7\\SysBin")
clr.AddReference("WinCalRemoting")
import CMI.WinCalRemoting as wincal
w=wincal.cWinCalClient()
stat=w.WinCalOpenServer('localhost',22778)

report_path='C:\Users\user\Documents\WinCal XE 4.7\Measure.wrp'

w.ViewerLoadReport(report_path)
#Defines the test criteria in terms of bias, Total die, Total subdie
#Names are obtained from the site list itself
totaldie=GetWaferInfo()[1]

#Main loop start

templist=[-40,25,125]
for temperature in templist:

    StartAutomationTemperature(temperature)

    busy=True
    while busy==True:
        response = GetAutomationTemperatureStatus()
        print response
        busy=(response[1] == "BUSY")
        print response
        print busy
        time.sleep(5)

    StepFirstDie()

    for die_number in range (1,totaldie+1,1):

        measurement_string = str(temperature) + "_Degrees_Die number_" + str(die_number)
        print measurement_string
        MoveChuckContact()
        w.ViewerMeasurementStr(True,"1,2",measurement_string,True)

        if die_number<totaldie+1:
            StepNextDie (0,0,-1)
```

Multiple device layouts

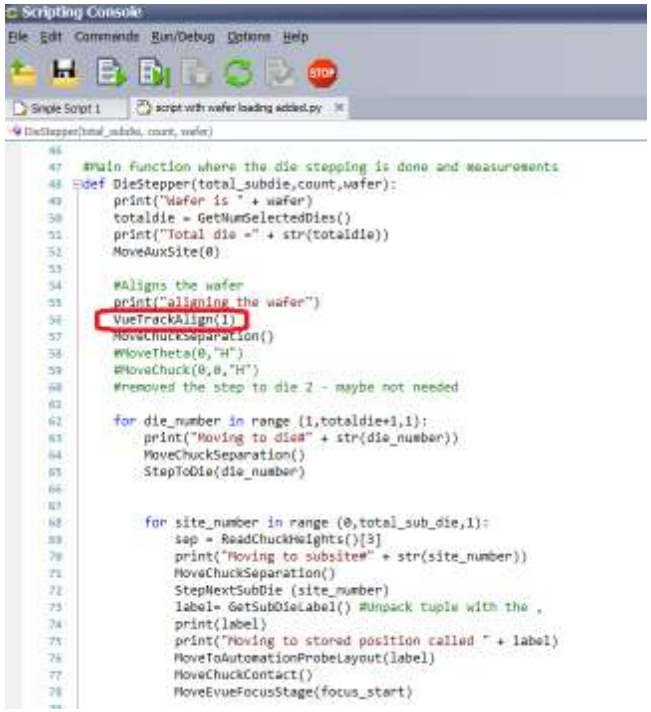
- **Autonomous Rf supports different probe spacings for automatic movement to different device topologies**
- **Setup using script commands**
- **Scripting examples supplied to use the wafermap label to dynamically set a probe spacing for a given Subdie**



Label
site1_0_0ps
site2_248_3ps
site3_697_6.3ps

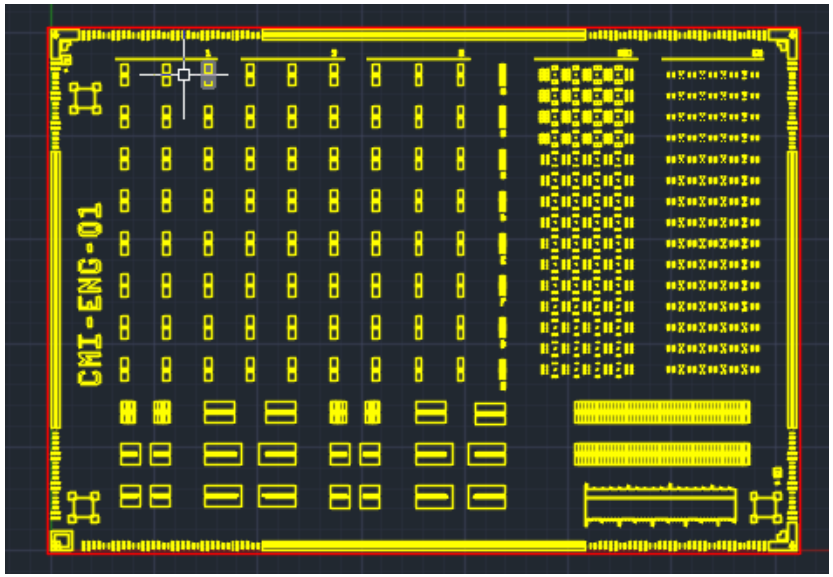
UseScrubMarkAlign	☐
⊞ FocusParameters	
⊞ VueTrackFeatures	
⊟ ProbeLayouts	
LayoutCount	2
⊞ layout1	
⊟ layout2	
LayoutName	GoodLayout
ProbeCount	3
⊟ probe1	
ProbeID	3
⊞ XYOffset	1.00, 2.00
⊟ probe2	
ProbeID	4
⊞ XYOffset	2.00, 3.00
⊟ probe3	

Using with Robotic loader on Summit 200 or CM300



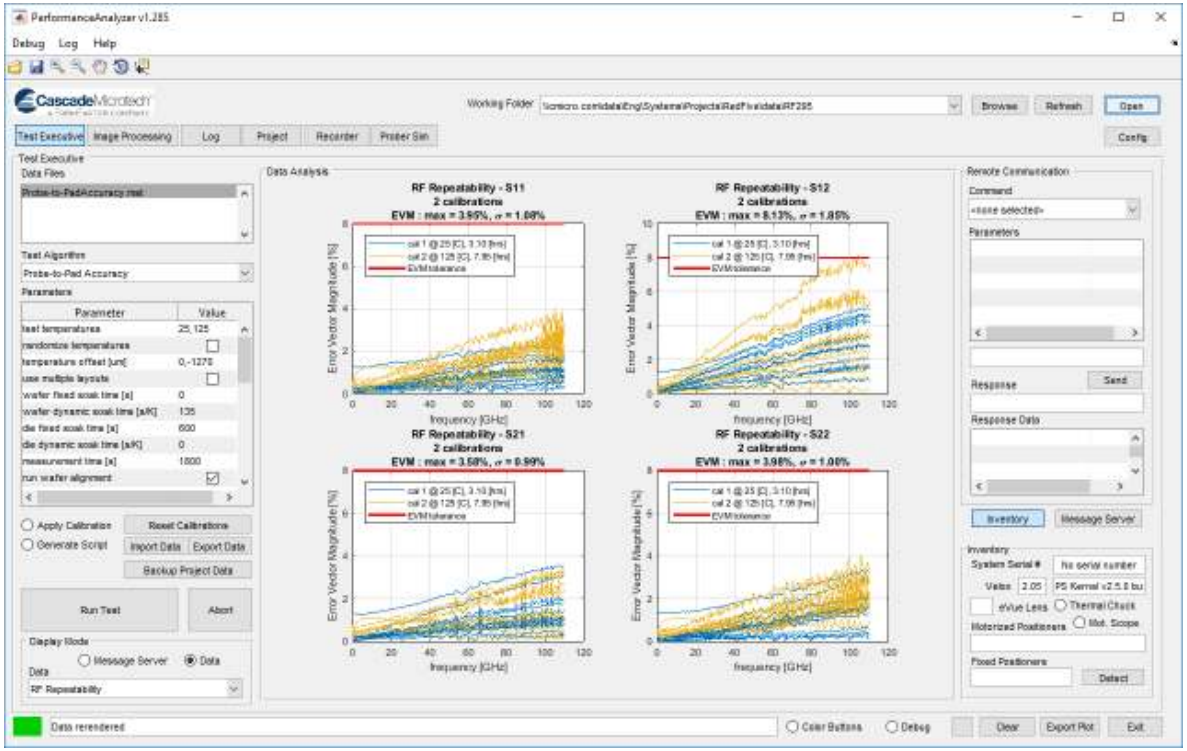
- **Sample scripts available to show multi wafer, multi die, multi site automatic over temperature automation**

Custom validation wafer for performance evaluation



- **Aluminium on glass Wafer contains array of validation lines and offset shorts and other open structures**
- **200 and 300 mm versions**
- **Used for factory and field performance evaluation**

Performance analyser

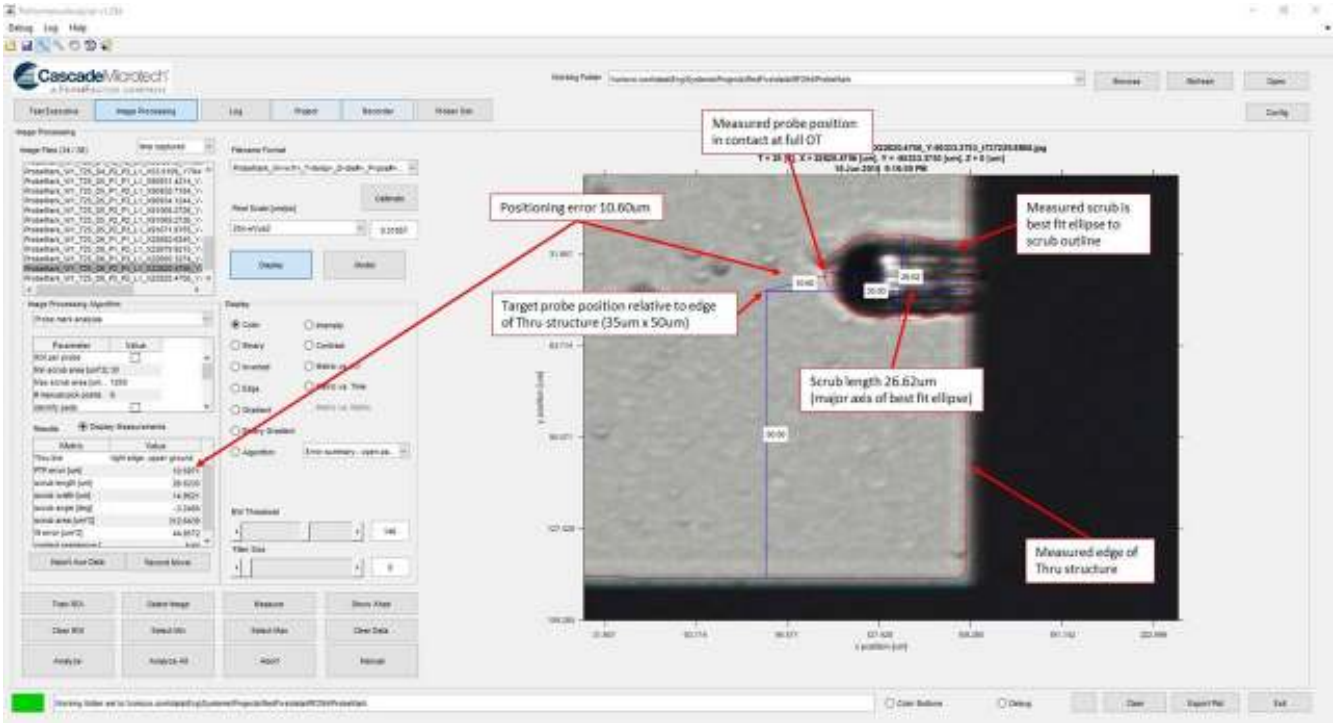


Formfactor internal reference tool used to benchmark automation performance automatically

Gives measurement deltas of standard across the wafer

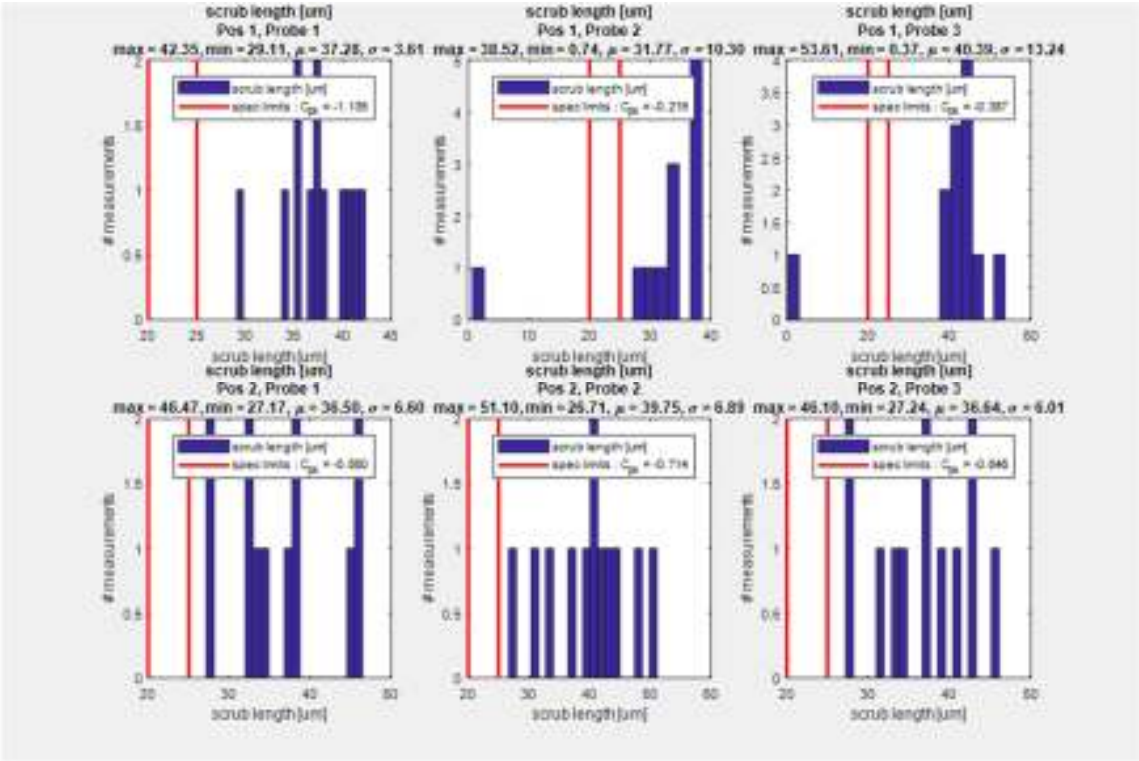
Comparison is made of Thru structures across wafer at different temperatures

Performance analyser



- **Performance analyser will be used to evaluate probe placement mechanically as well as electrically during installation**

Performance analyser



Statistical measurements are given from optical mark inspection to evaluate positioning error

We also evaluate time between human interaction (we have tested to 3 days un-interruped during trials)

Usually issues relate to probe contamination

Autonomous RF Key Value Propositions

Ease of use – An inexperienced operator can perform an RF calibration up to 130 GHz by simply pushing a button. This reduces the need of the experienced users full time on each system

Reduced Soak Time – System will re-align the probes to the pads if they drift away from alignment. This reduces the time of test and increases throughput

Unattended Use – Measurements can be left running over night, testing all devices on the wafer, and at different temperatures without the need of the operator.

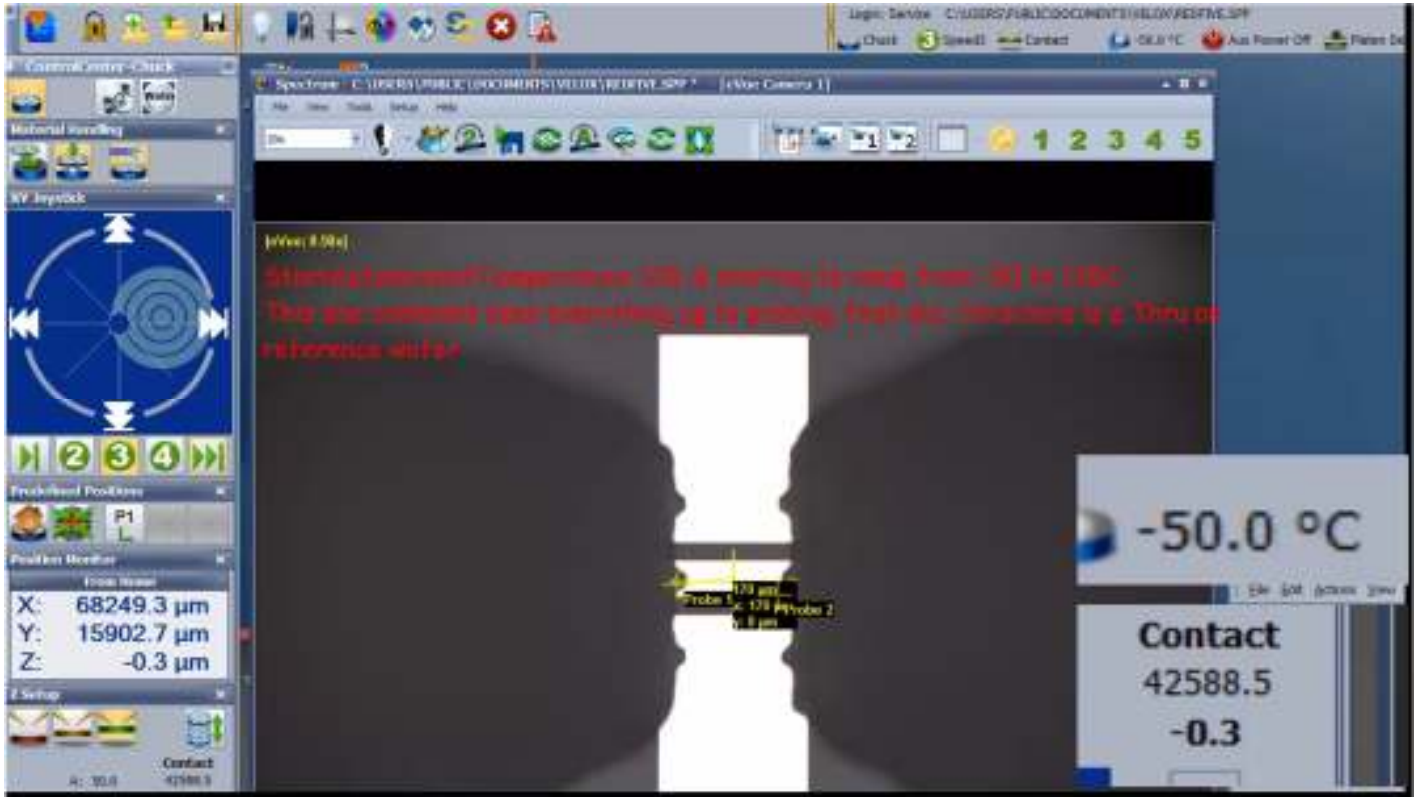
Calibration Monitor and Re-calibration – System will continuously monitor calibration drift, and automatically re-calibrate the system should the drift exceed a pre-defined limit

Data volume – unattended test allows more tool utilisation without additional time and money

Faster Time to Data

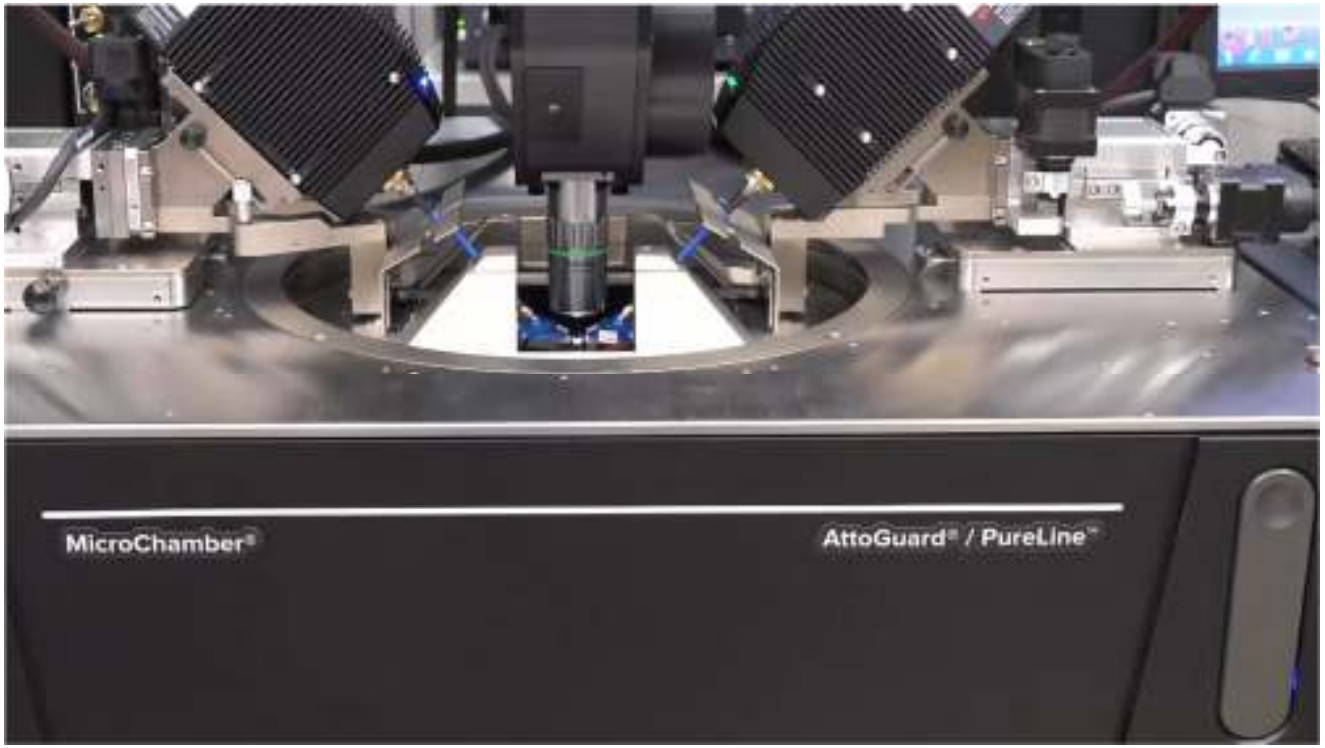
Lower Costs of Testing

Video –Temperature transition Run -50C to 125C



Video

Video –Summit 200



Video