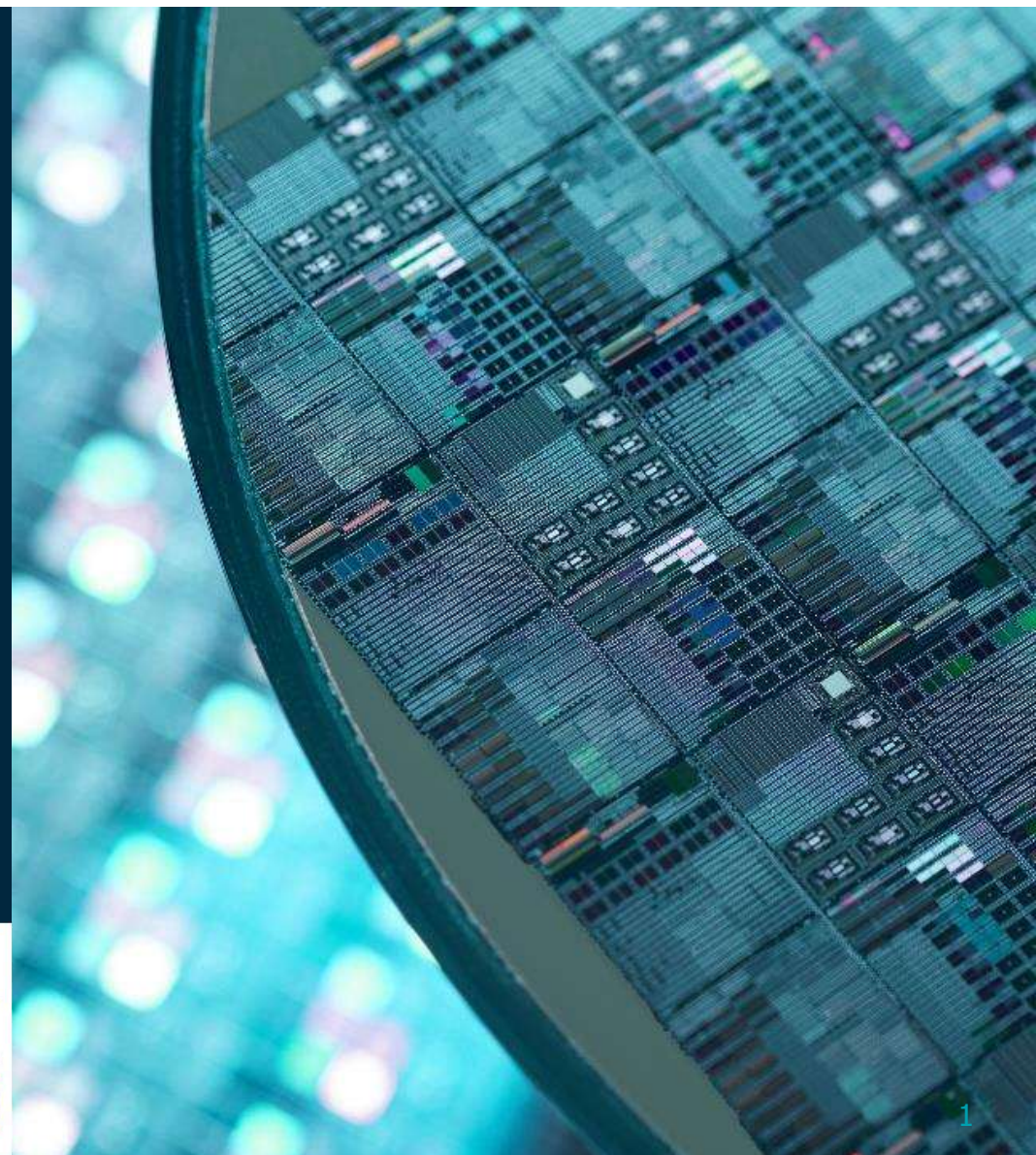




# Dynamic height adjustment using Vector Network Analyzer based contact sensing using FormFactor WinCal XE 4.9™ and Velox 3.4 - THMA6

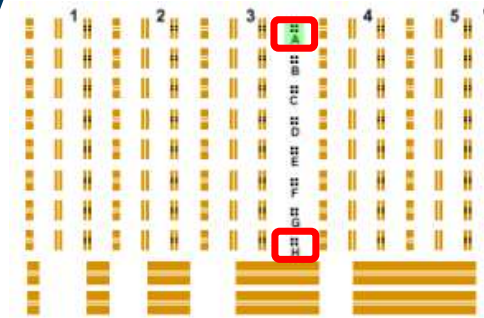
Gavin Fisher  
James Hibbert  
Thanks also to Pranav Shrivastava



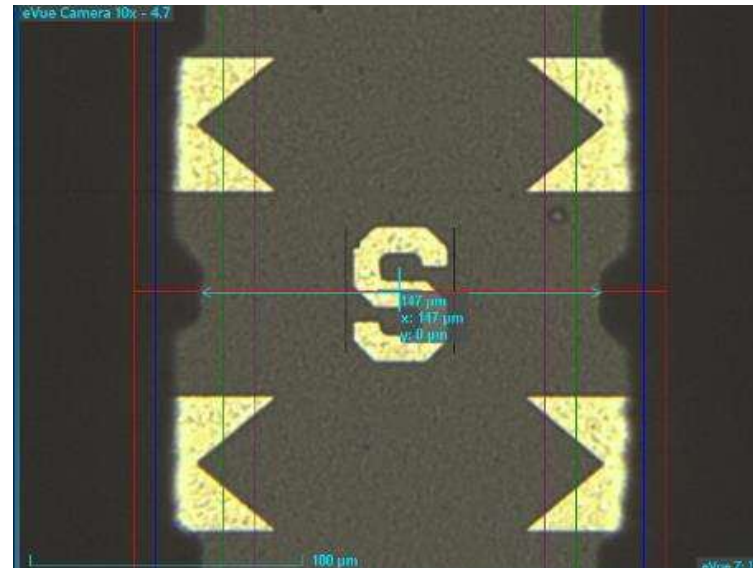
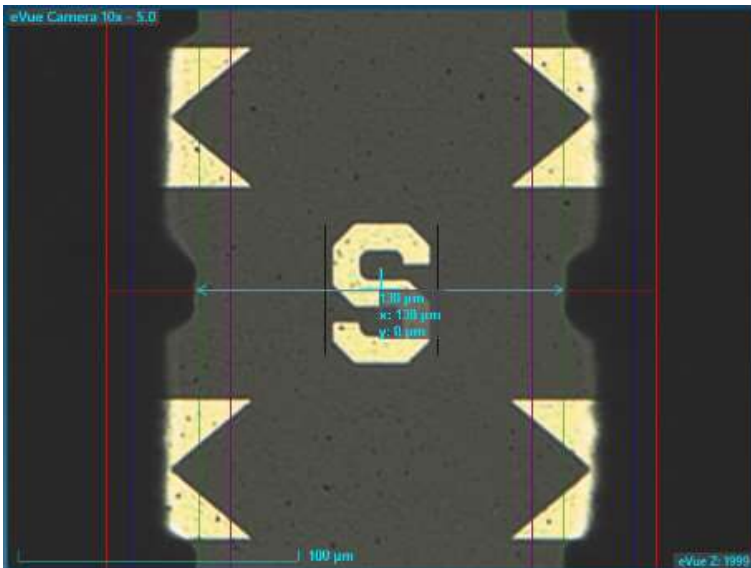
The IMS logo, featuring a stylized 'I' and 'M' inside a circle, with the letters 'IMS' below it.	<p>2023 IEEE MTT-S INTERNATIONAL MICROWAVE SYMPOSIUM</p>	<p>11-16 JUNE CONVENTION CENTER San Diego, California</p>	The San Diego 2023 logo, featuring a stylized car and the text 'The Coolest Ideas Under the Sun' and 'SAN DIEGO 2023'.
The IEEE logo, featuring the letters 'IEEE' in a bold, sans-serif font.	The MTT-S logo, featuring a stylized 'M' and 'T' inside a circle, with the text 'MTT-S' and 'IEEE MICROWAVE THEORY & TECHNOLOGY SOCIETY' below it.		

## The problem – Contaminants can affect planarity

- In WinCal XE the probe geometry is set at a single reference location in terms of XYZ
- During calibration, the system steps using its co-ordinates assuming the planarity is perfect
- Contaminants under the substrate can cause planarity to change, and results in more or less overtravel affecting probe final position at the standards away from the reference

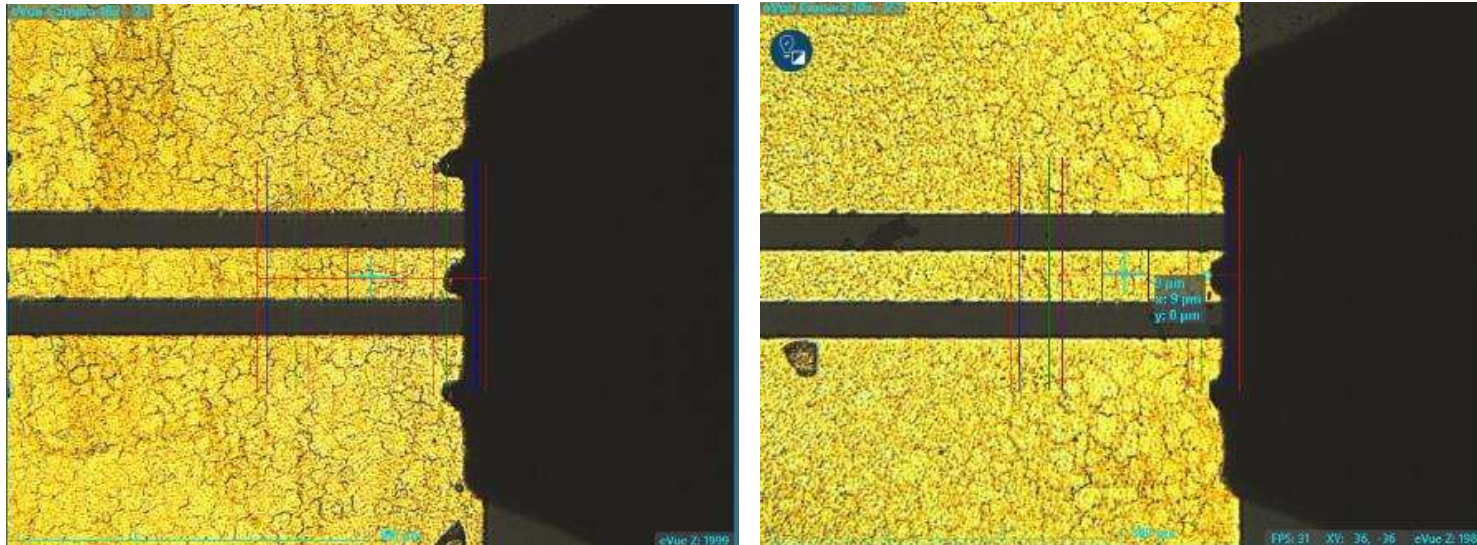


- Augmented alignment  
Green lines set to be 130  $\mu\text{m}$  – probe geometry set to this spacing at alignment Mark A
- Stage move to location H –  
Less skate and probes now spaced to 140  $\mu\text{m}$





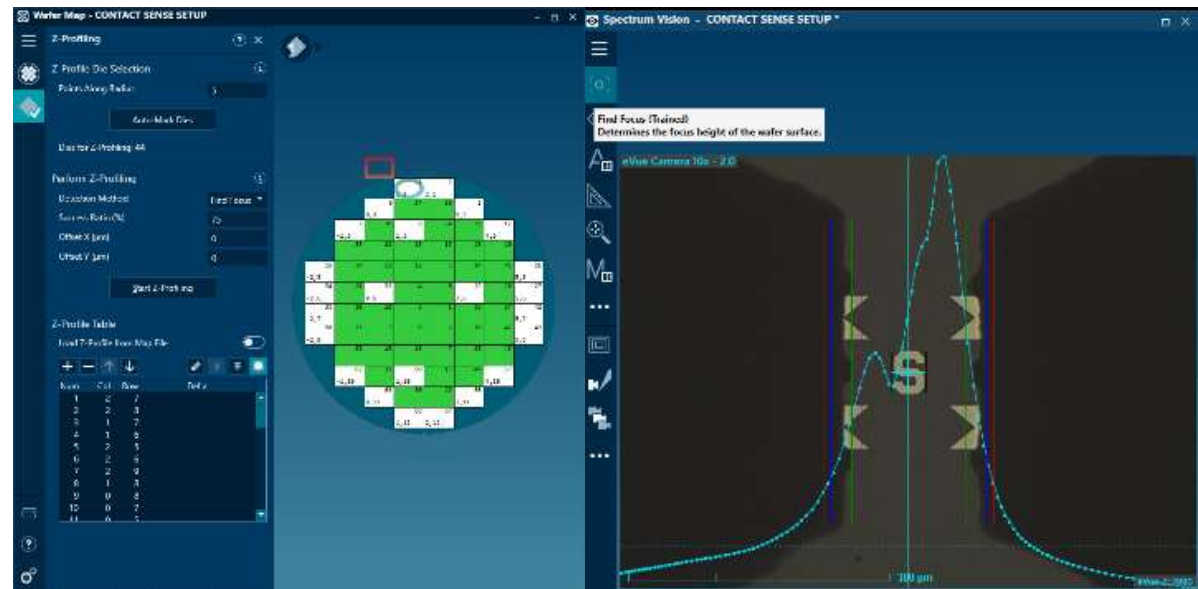
## The problem – planarity of iss and positioner runout



- Final placement error seen here is 10  $\mu\text{m}$  – A combination of small positioner planarity error and iss planarity error and small X offset
- Note height of scope Z reference was changed by 16  $\mu\text{m}$  to get best focus

## Alternative solutions to contact sensing?

- Velox supports Z profiles to the main wafer chuck but doesn't do this at the auxiliary chucks
- Lookup table for Z that could be applied at calibration time ,breaking into the automatic calibration routine but needs calculated initially
- Dynamic height adjustment could be done using the FindFocus algorithm and height adjusted this way but there is potential for failure with contaminants on iss itself.
- Find focus wouldn't detect probe changes or tiny positioner runout.

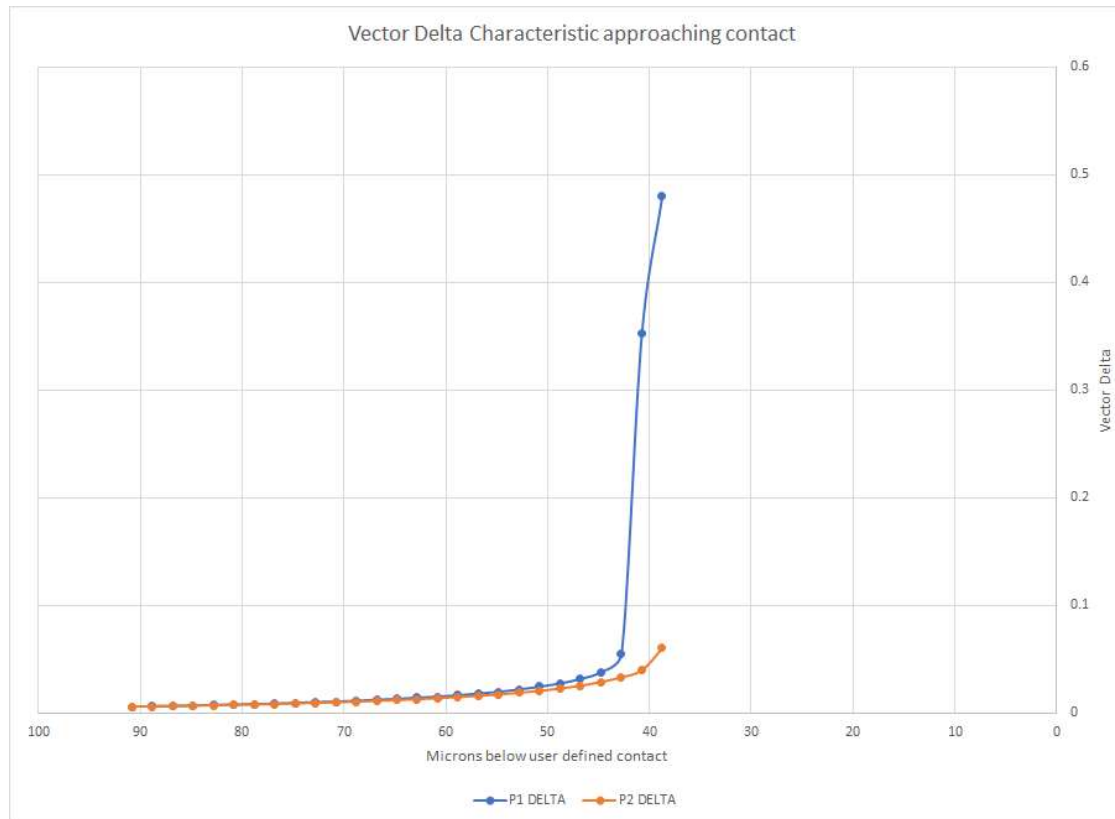


## Contact sensing



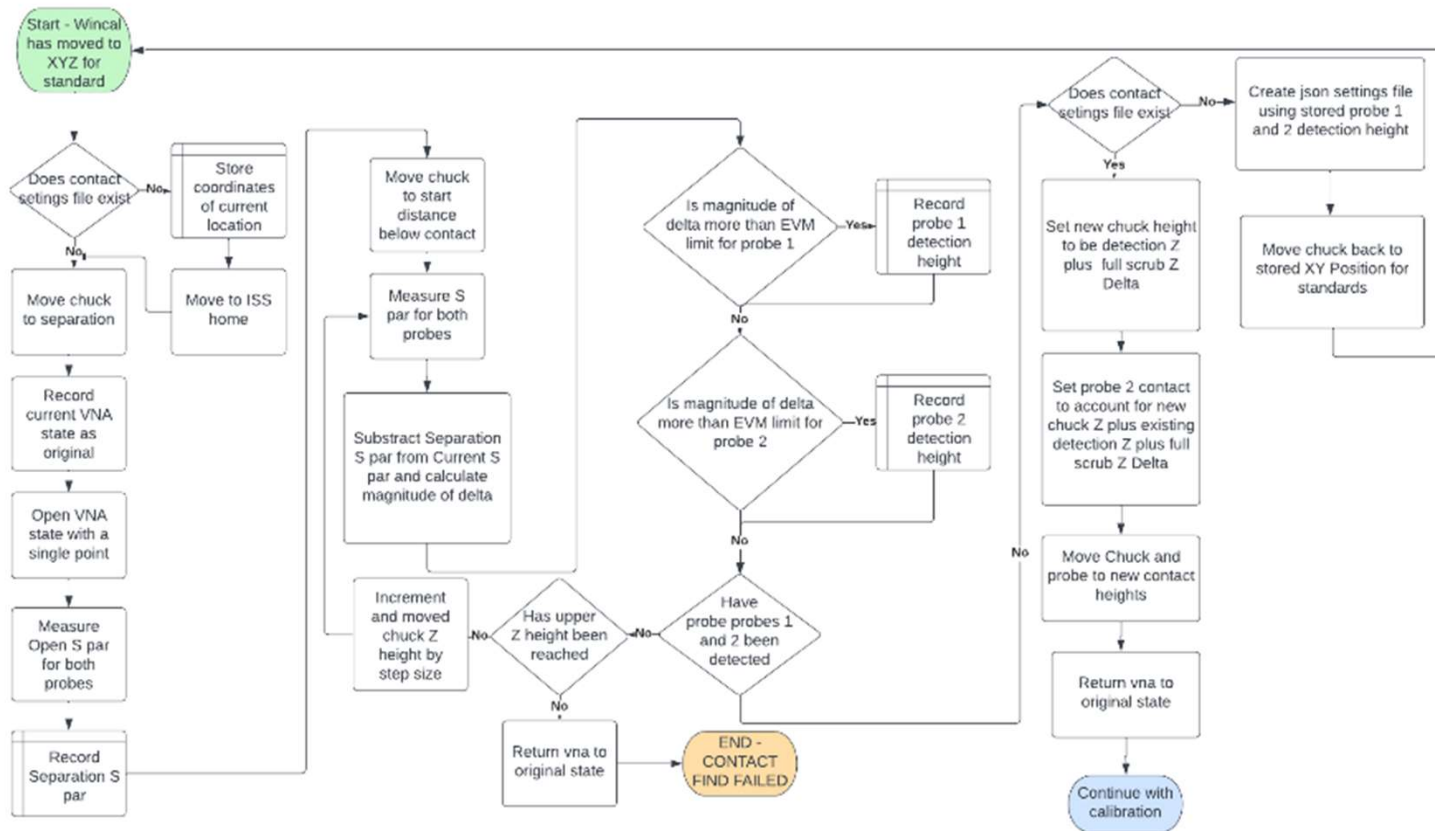
- Very repeatable and uses the measurement system itself
- Is dynamic and reflects the height of the probe at the actual time of calibration (as probes cool the height can change)
- Can be very quick when communicating directly with the vna via tcp (as we did)
- Drawback of direct approach is a driver is needed per instrument type additional to Wincal's own
- Can be compatible with Autonomous RF setups
- Is simple – probes need setup for the iss anyway....
- $\Delta \text{ Magnitude} = ((\text{Real\_current} - \text{Real\_Open})^2 + (\text{Imag\_current} - \text{Imag\_Open})^2)^{0.5}$

# Contact detection Threshold



- Steps are in 2 um here
- It takes off typically at 0.05 delta
- Here the stopping point is 0.05 – probes barely kissing pad

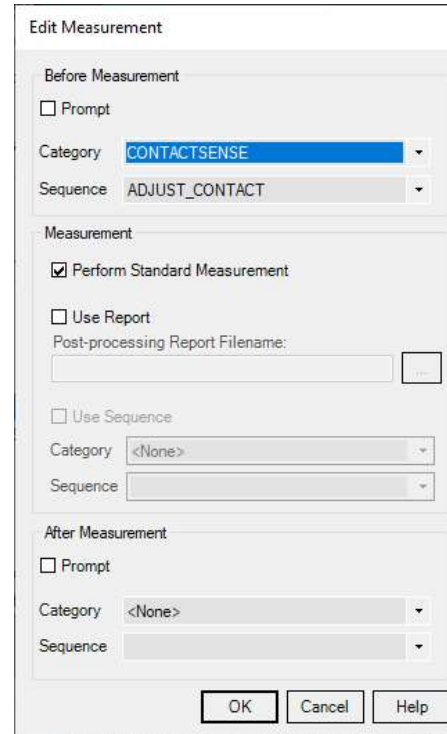
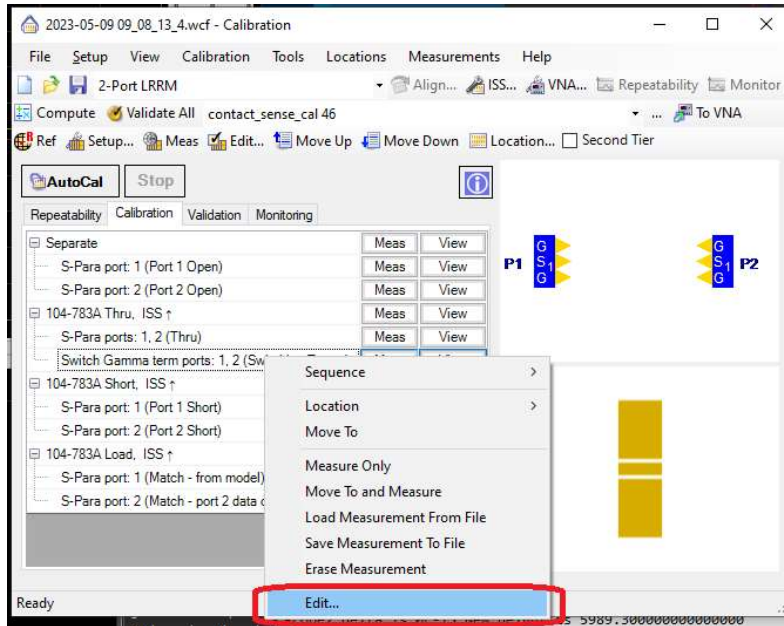
# How does it work in general inside Python script?



This is a flowchart of the general contact sense python script logic

This script is run during the calibration process

# How to make python scripts work within Wincal



- Python direct approach could use Wincal as a slave but preference is to sense in the normal cal approach
- Wincal can invoke a “sequence” during the calibration sequence
- Calibration sequence can in turn invoke a python script using DoScript command
- Each measurement can have a sequence run before and after and even use a specified report for process work

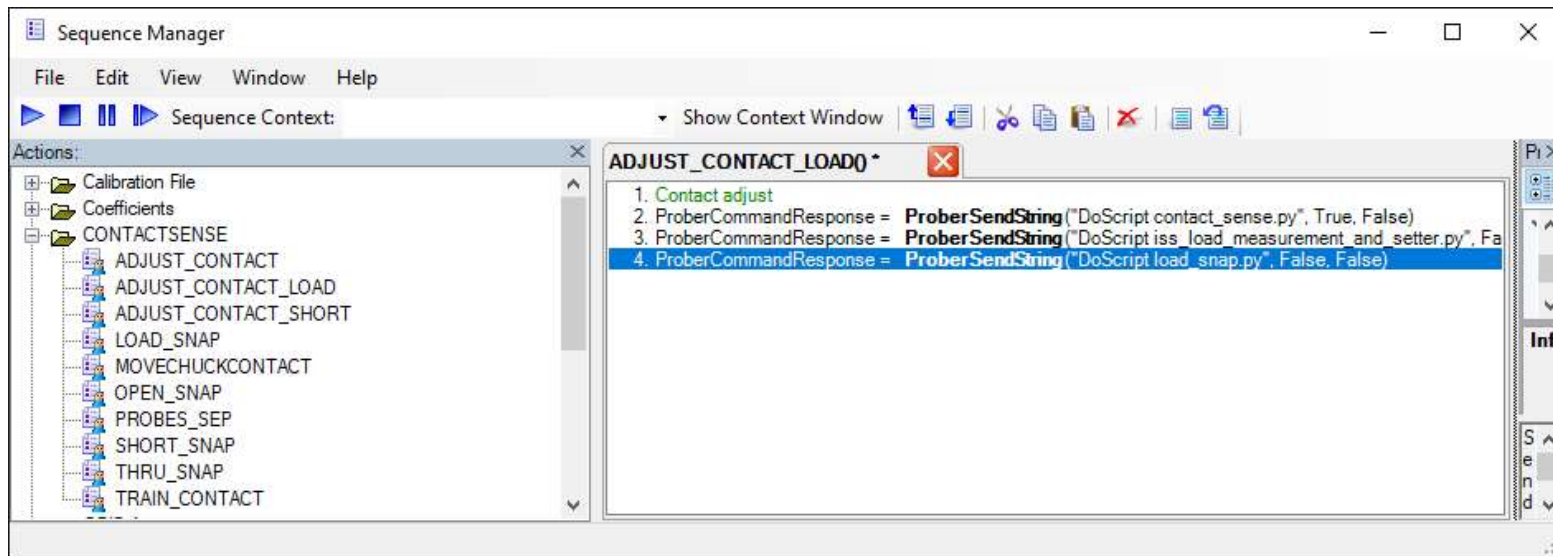


## A few tricks regarding implementation

The 'Edit Measurement' dialog box is divided into three main sections: 'Before Measurement', 'Measurement', and 'After Measurement'.  
- **Before Measurement:** Includes a 'Prompt' checkbox (unchecked), a 'Category' dropdown menu set to 'CONTACTSENSE', and a 'Sequence' dropdown menu set to 'THRU\_SNAP'.  
- **Measurement:** Includes a 'Perform Standard Measurement' checkbox (checked), a 'Use Report' checkbox (unchecked) with a 'Post-processing Report Filename' text field and a browse button, and a 'Use Sequence' checkbox (unchecked) with 'Category' and 'Sequence' dropdown menus set to '<None>'.  
- **After Measurement:** Includes a 'Prompt' checkbox (unchecked), a 'Category' dropdown menu set to 'CONTACTSENSE', and a 'Sequence' dropdown menu set to 'PROBES\_SEP'.  
At the bottom are 'OK', 'Cancel', and 'Help' buttons.

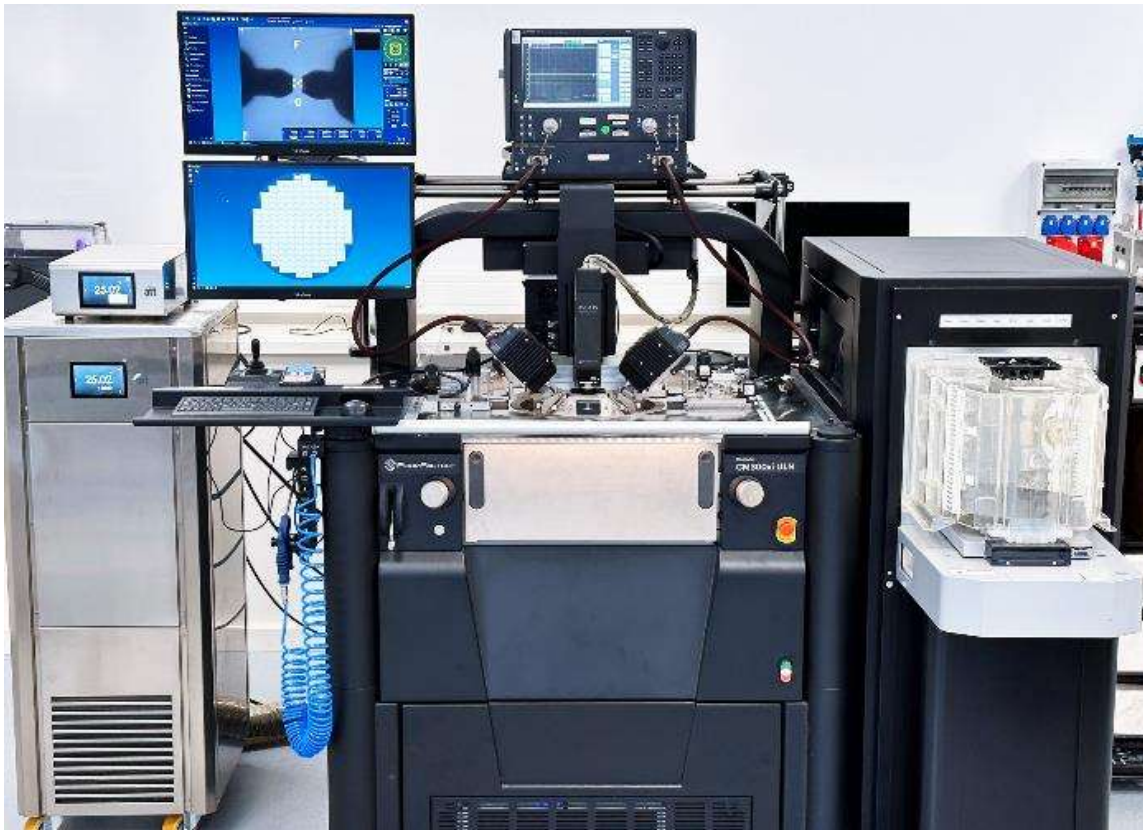
- By default Wincal will do all the movement activities prior to reaching the standard including movement to contact
- However it will not bring positioners to contact if they were previously at separation
- Multiple touchdowns avoided to reduce pad wear
- For this reason the ProbeSeperation sequence is done after the standard measurements
- In this case this is the second standard in the pair of reflect standards

## Sequence manager being used to call Python scripts



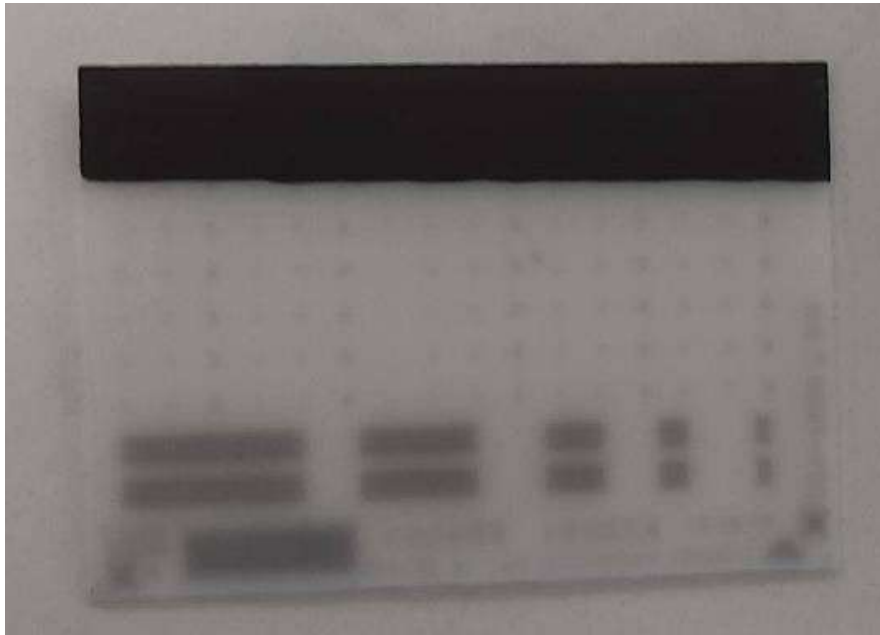
- The set of sequences is seen in the list

## System used for evaluation



- WinCalXE™ 4.9
- Velox™ 3.4
- CM300xi ULN
- Keysight N5291A VNA
- I110-AM-GSG-100
- 104-783 ISS (deliberately contaminated or rear)
- RPP504 Motorised positioners
- Remote Author was in UK machine in Germany

## Iss deliberate contamination



- Permanent Sharpie™ marker layered over a few coats ON ISS rear face
- This created a delta of approximately 18 um from the upper edge of the iss to the lower edge
- We have have added more but this is likely to be in the level of typical “annoyance” levels of contamination which doesn’t necessarily warrant remedial action



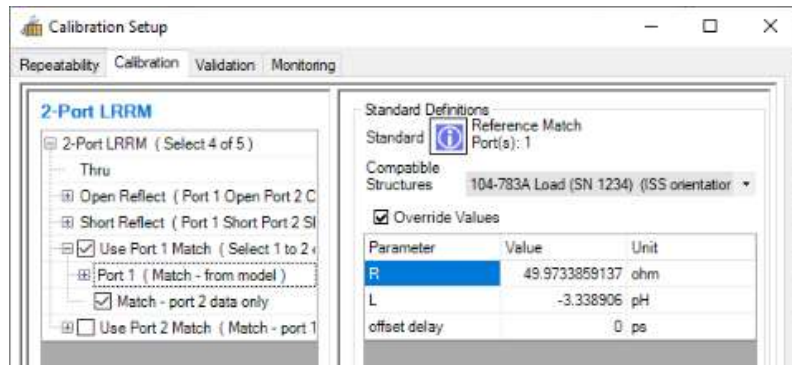
## Testing methodology

- Use a script to perform calibrations at 25 locations on 104-783 – upper set of loads are totally untrimmed and so excluded
- Perform calibration set with load compensation and contact correction
- Record error sets for all locations tested and photos of probe contact.
- Measure Open in air and same thru as used for the test
- Carry out calibrations on same iss and setup but only use load compensation and no contact correction
- Compare spread of error sets
- 20 um skate used to maintain standard but also to improve contact sense – with 25 skate the probe doesn't quite touch standard initially

# Load resistance measurement and adjustment

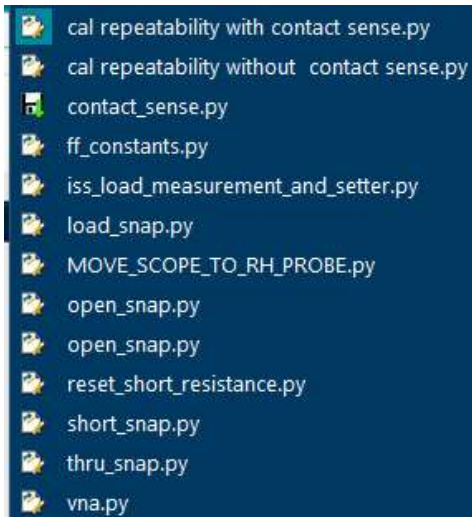


- ISS Map was not readily available so we needed to measure the load resistance – we used B1500 via instrument bias tees
- The ability to add sequences to calibration made direct measurement and compensation appealing
- Short was measured at .1 volts and used as offset reference
- Load was measured a 1 volt and resistance of short subtracted
- Corrected load value is automatically applied during calibration process
- `WinCalExecuteCommand("CalSetCoefficient, 1, Match - from model, Reference Match, R, {}".format(rload1_corrected))`



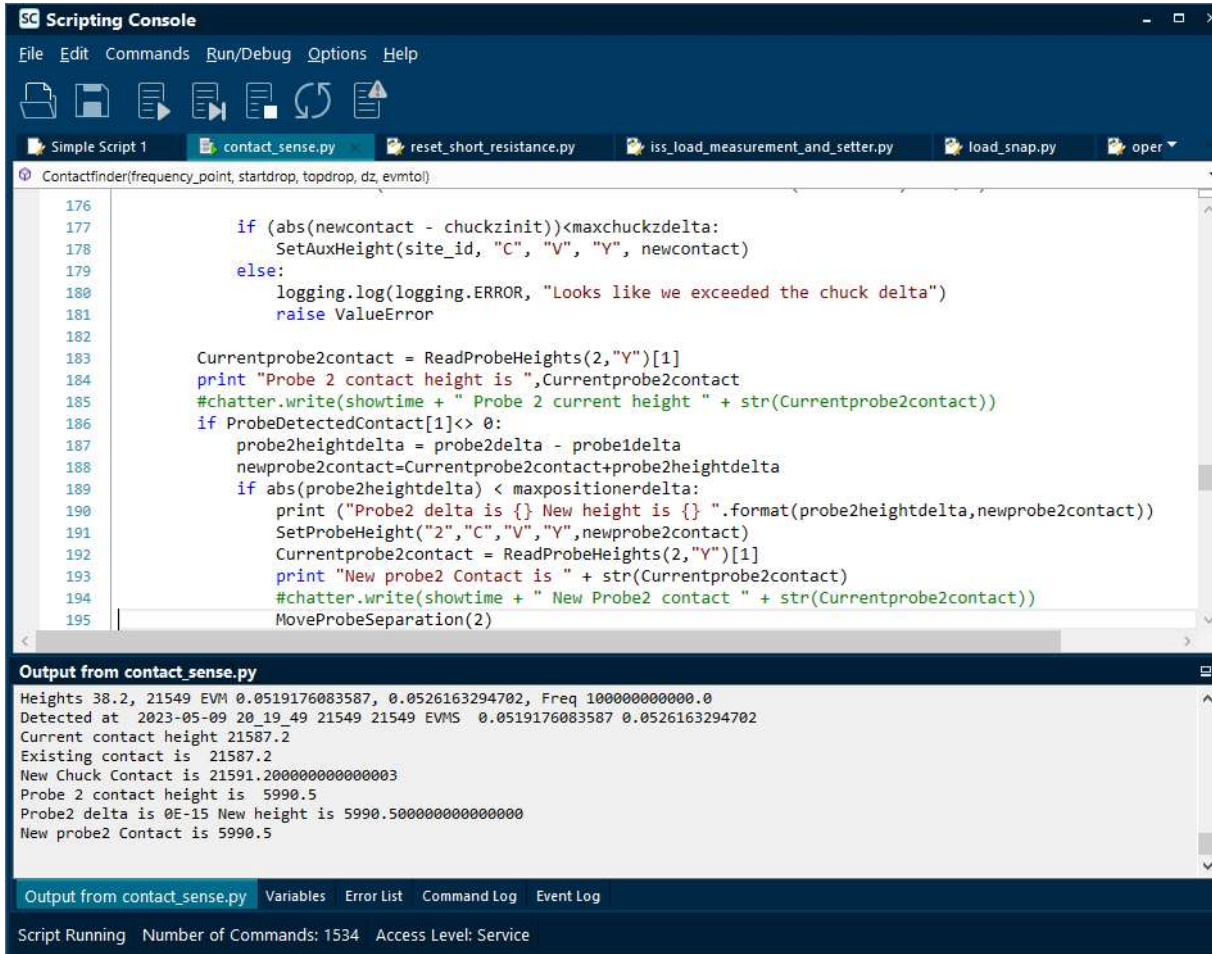
	1-P1	1-P2	2-P1	2-P2	3-P1	3-P2	4-P1	4-P2	5-P1	5-P2
<b>D</b>	50.16738	49.97174	50.108	49.94734	50.07572	49.92857	50.05479	49.96162	50.07692	49.96095
<b>E</b>	50.06263	50.02269	50.09324	49.99304	50.26224	50.25585	50.04498	49.96696	50.1972	49.96872
<b>F</b>	50.0823	49.92257	50.04715	49.96062	50.02146	49.92824	49.97339	49.99766	50.02857	49.93536
<b>G</b>	50.05876	49.96696	50.00833	49.95592	49.99709	49.92257	50.10094	49.92424	50.13753	49.93255
<b>H</b>	50.08611	49.96229	50.02901	49.893	50.10251	49.92391	50.0209	49.9485	50.07824	49.93803

## Scripts used



- Main script is contact\_sense which either determines the required overdrive per probe set by the user from sensing or corrects the chuck and probe2 contact based on contact sensing of current standard
- VNA is crucial to communicate to the vna directly over socket
- Ff\_constants are the primary control variables
- Iss Load measurement and setter measure the short resistance and if on a load measures and compensates the load and sends to WinCal XE
- Cal repeatability scripts are used to run the tests
- Reset\_Short\_Resistance removes the short data file to force measurement of a short rather than a load

# Scripting console



The screenshot displays the 'Scripting Console' application window. The top menu bar includes 'File', 'Edit', 'Commands', 'Run/Debug', 'Options', and 'Help'. Below the menu is a toolbar with icons for file operations and execution. The main editor area shows a Python script with line numbers 176 to 195. The script defines a function 'Contactfinder' and contains logic for reading probe heights, calculating deltas, and updating contact information. The bottom panel, titled 'Output from contact\_sense.py', shows the execution results, including probe heights, detected times, and calculated deltas. The status bar at the bottom indicates 'Script Running', 'Number of Commands: 1534', and 'Access Level: Service'.

```
176
177
178     if (abs(newcontact - chuckzinit)) < maxchuckzdelta:
179         SetAuxHeight(site_id, "C", "V", "Y", newcontact)
180     else:
181         logging.log(logging.ERROR, "Looks like we exceeded the chuck delta")
182         raise ValueError
183
184     Currentprobe2contact = ReadProbeHeights(2, "Y")[1]
185     print "Probe 2 contact height is ", Currentprobe2contact
186     # chatter.write(showtime + " Probe 2 current height " + str(Currentprobe2contact))
187     if ProbeDetectedContact[1] < 0:
188         probe2heightdelta = probe2delta - probe1delta
189         newprobe2contact = Currentprobe2contact + probe2heightdelta
190         if abs(probe2heightdelta) < maxpositionerdelta:
191             print ("Probe2 delta is {} New height is {}".format(probe2heightdelta, newprobe2contact))
192             SetProbeHeight("2", "C", "V", "Y", newprobe2contact)
193             Currentprobe2contact = ReadProbeHeights(2, "Y")[1]
194             print "New probe2 Contact is " + str(Currentprobe2contact)
195             # chatter.write(showtime + " New Probe2 contact " + str(Currentprobe2contact))
196             MoveProbeSeparation(2)
```

Output from contact\_sense.py

```
Heights 38.2, 21549 EVM 0.0519176083587, 0.0526163294702, Freq 1000000000000.0
Detected at 2023-05-09 20:19:49 21549 21549 EVMS 0.0519176083587 0.0526163294702
Current contact height 21587.2
Existing contact is 21587.2
New Chuck Contact is 21591.200000000000000003
Probe 2 contact height is 5990.5
Probe2 delta is 0E-15 New height is 5990.5000000000000000
New probe2 Contact is 5990.5
```

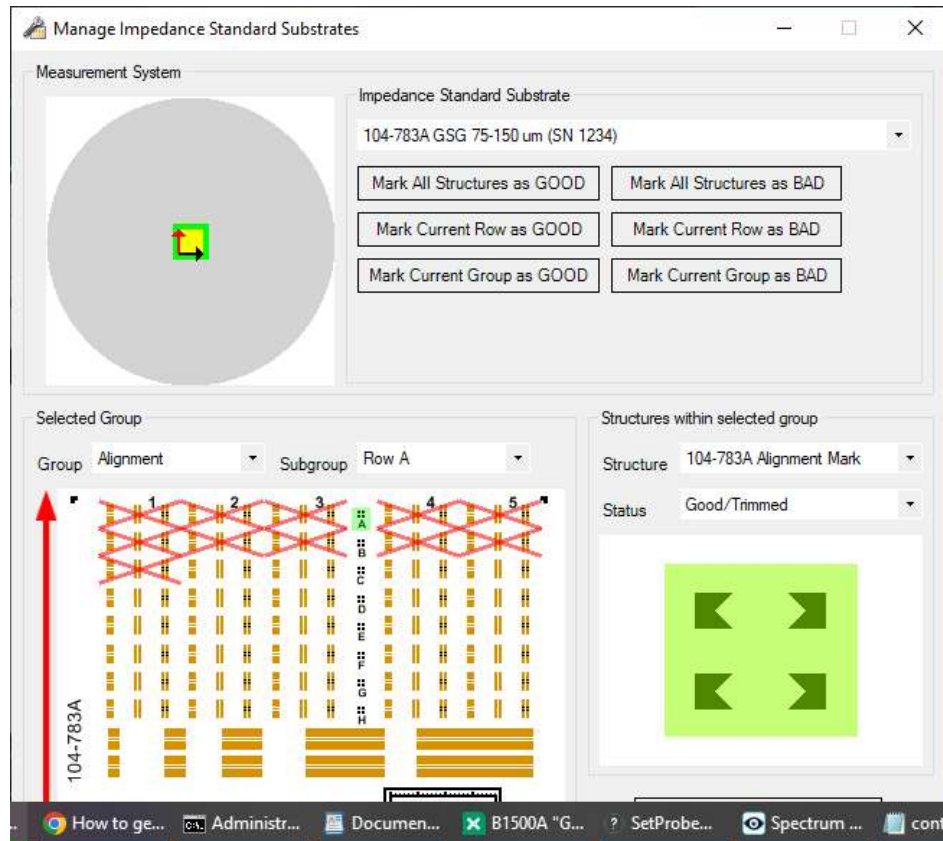
Output from contact\_sense.py Variables Error List Command Log Event Log

Script Running Number of Commands: 1534 Access Level: Service

- The python scripts used were run via the scripting console but other approaches could also have been used
- Console is advantageous that the command choose and Intellisense for all the Velox commands makes coding fairly straightforward



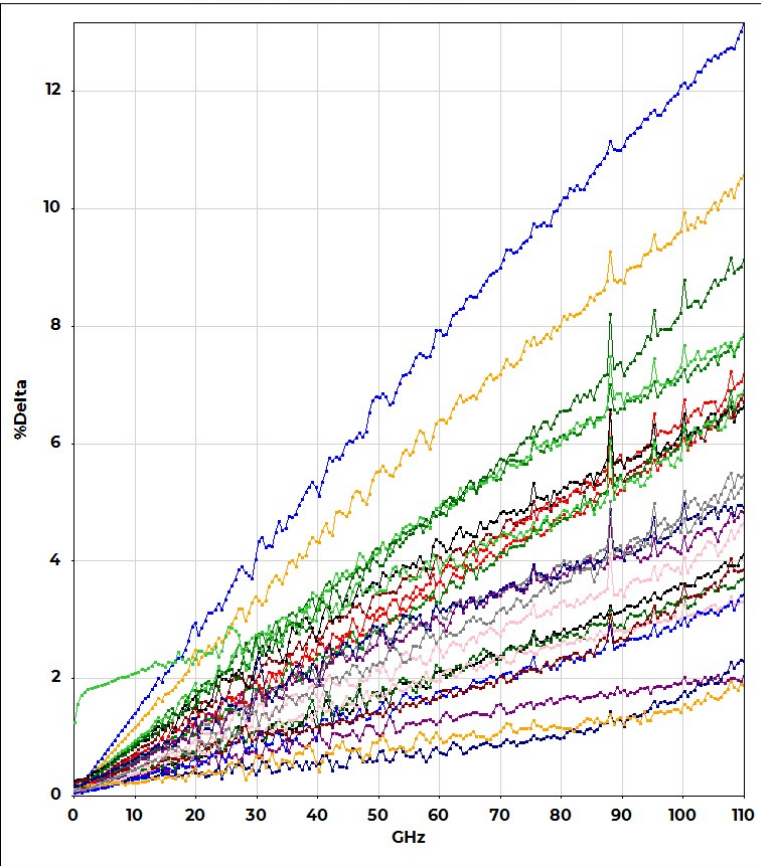
# Adjusting the Cal group for measurement



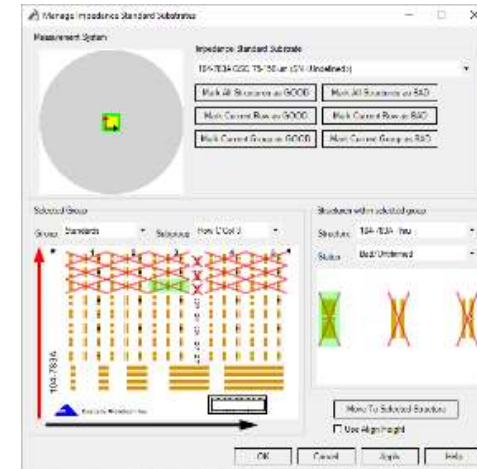
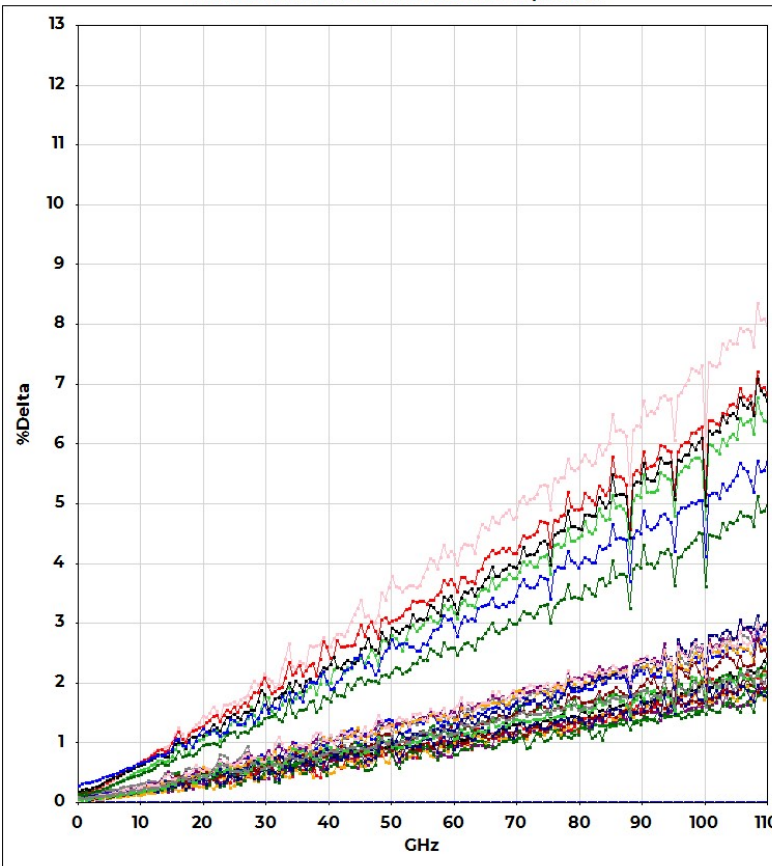
- This is often done manually but there is a command to progress to next cal group  
w.CalUseNextGoodGroupOnIss()

# Error set comparison – Left graph without Z compensation

No Z Sense but Load resistance compensated

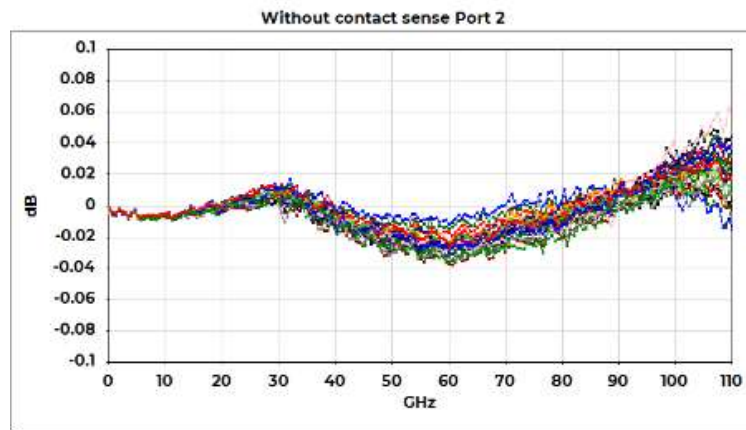
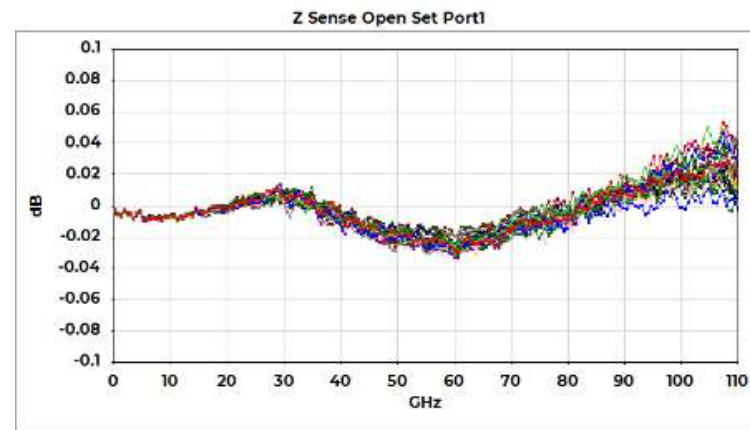
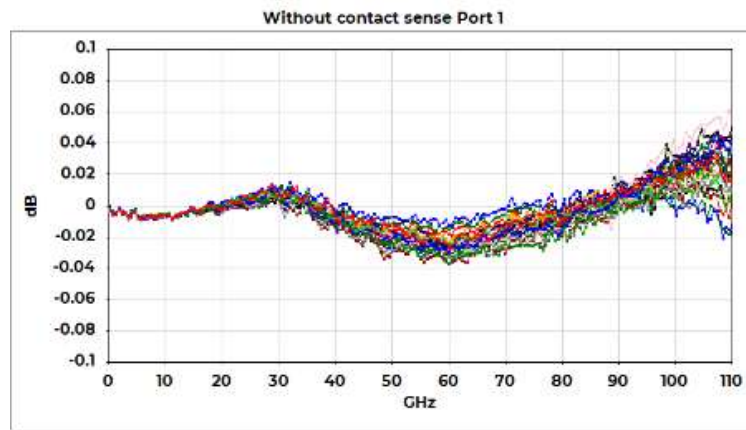


With Z Sense and Load resistance compensated

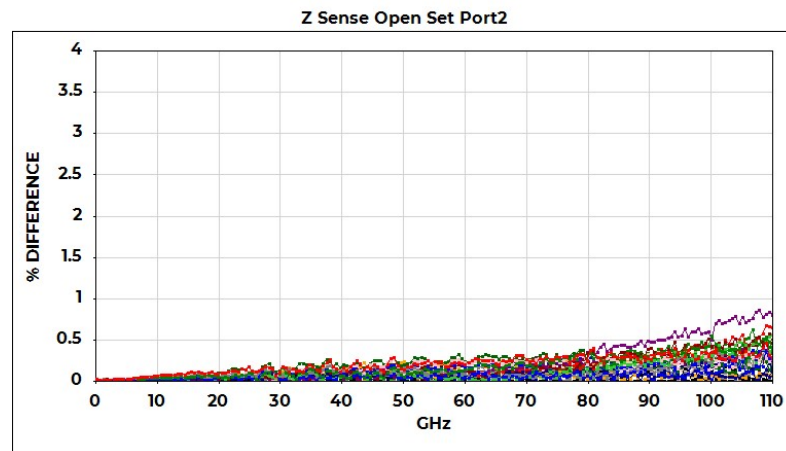
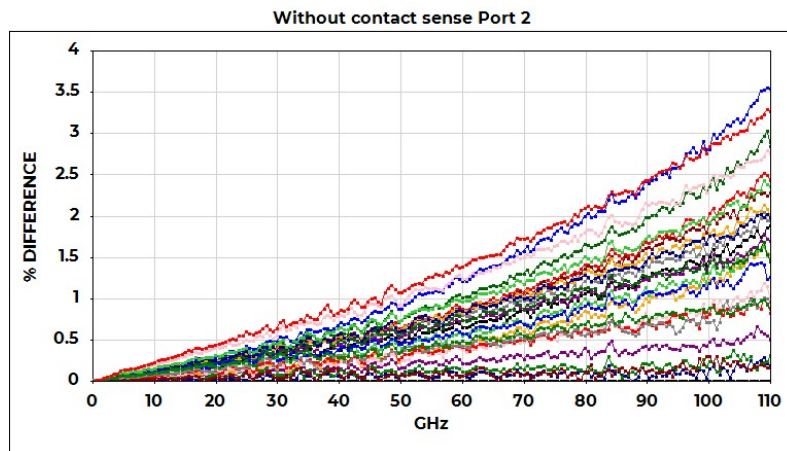
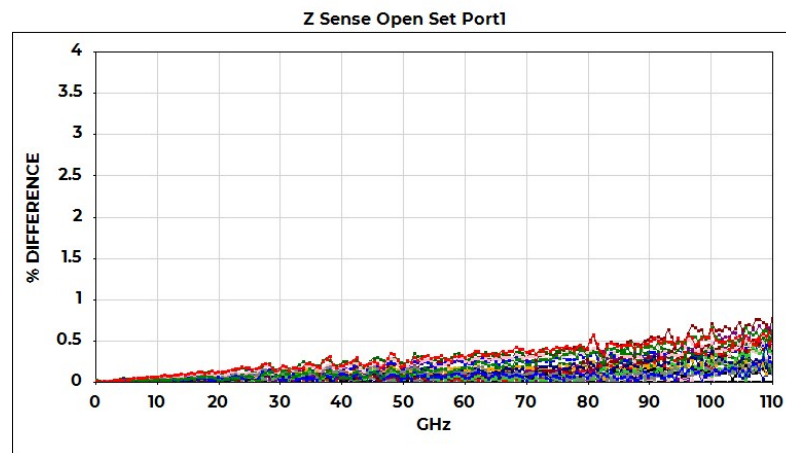
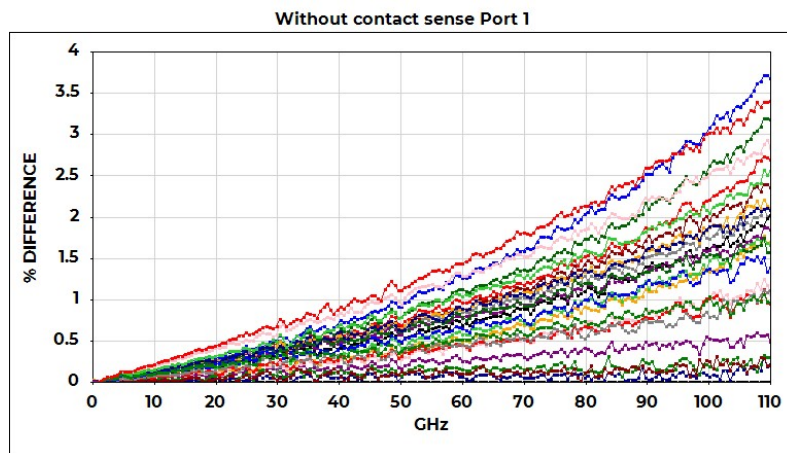


- Data shown compares location 16 thru 40 from topleft
- Much tighter grouping in the 2.5% range

# Post calibration Open Magnitude Variation



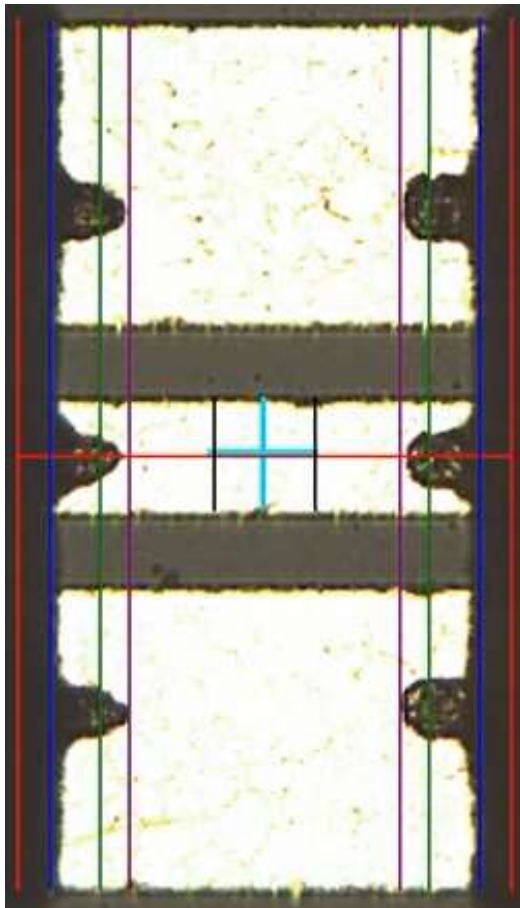
# Post calibration Open EVM Delta (x100)



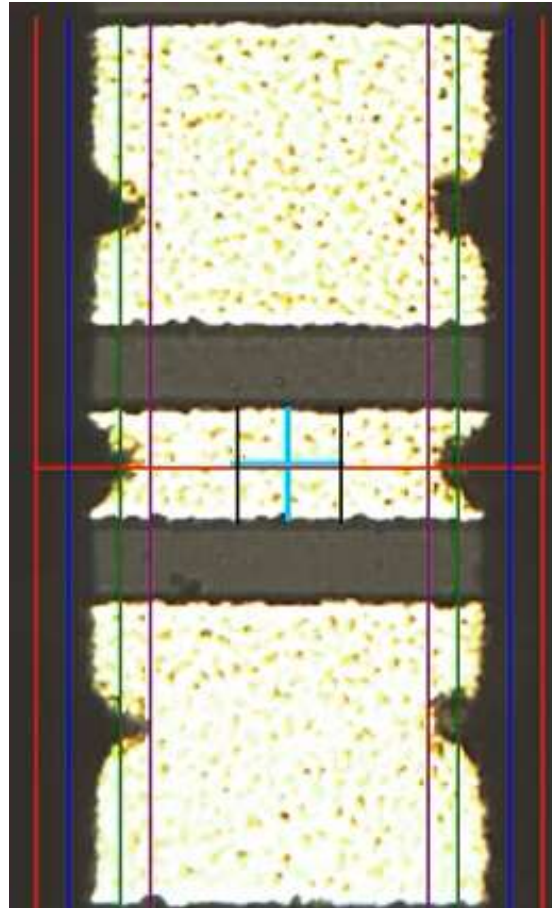


# Comparing standard in the same location with and without sensing

WITHOUT SENSE



USING SENSE



- Note relationship of dark leading edge of probe wrt blue lines (170 um apart)
- Tips clearly retracted from the green 130 um lines

**Video of operation – video removed to fit inside 25 MB**

## Conclusion

- Contact Z adjustment via RF electrical sensing is a readily achievable enhancement to FormFactor probers equipped with WinCal XE 4.9 using existing software with the addition of some scripting
- Using a Z sensing approach, we can improve upon the spread of error sets for a given iss and for a given environmental instrument drift
- Dynamic measurement of load resistance and on the fly compensation can be performed for customers who also have a B1500 parametric instrument.