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

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Thanks also to Pranav Shrivastava

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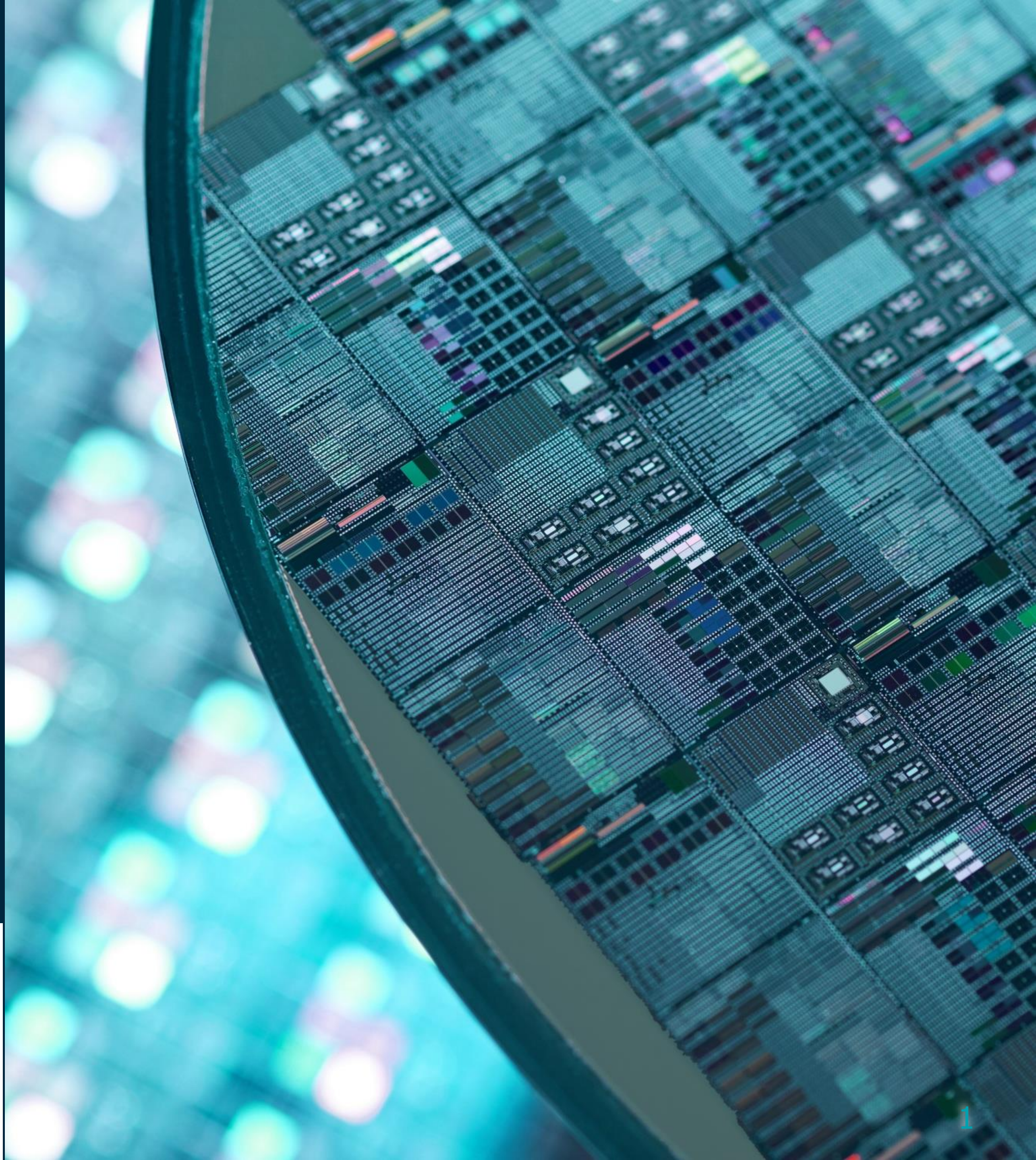
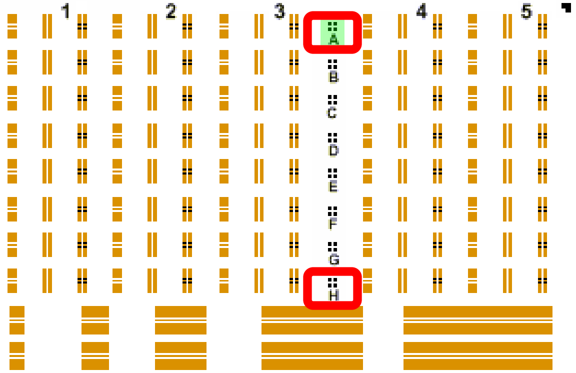
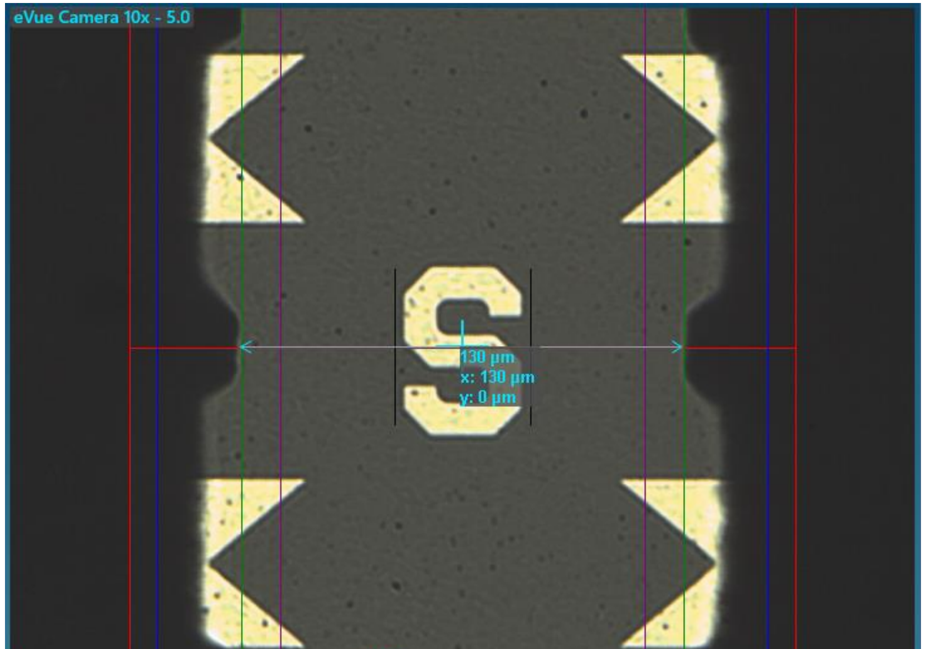


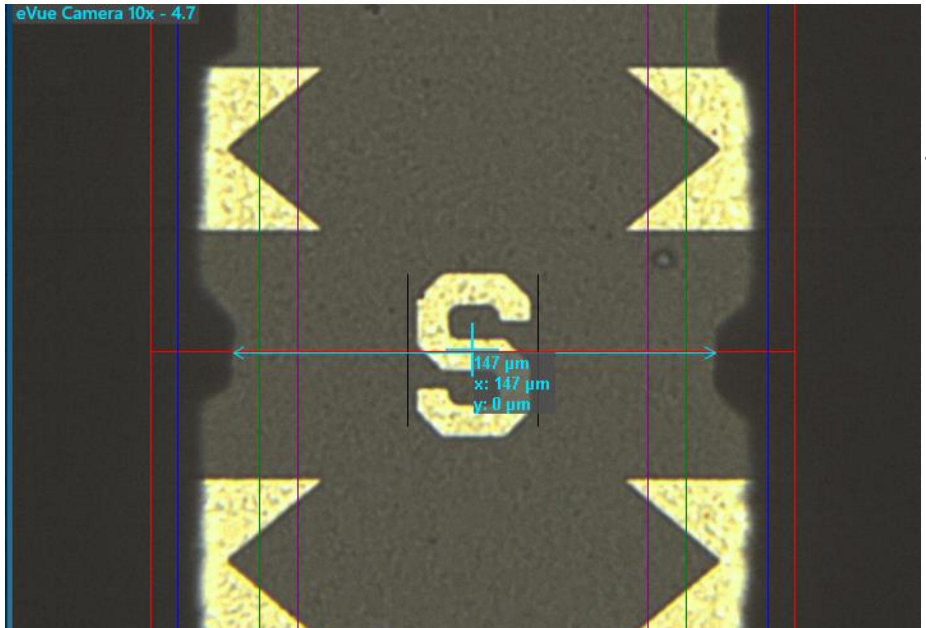
The problem – Contaminants can affect planarity

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



- Augmented alignment Green lines set to be 130 um – probe geometry set to this spacing at alignment Mark A
- Stage move to location H – Less skate and probes now spaced to 140 um





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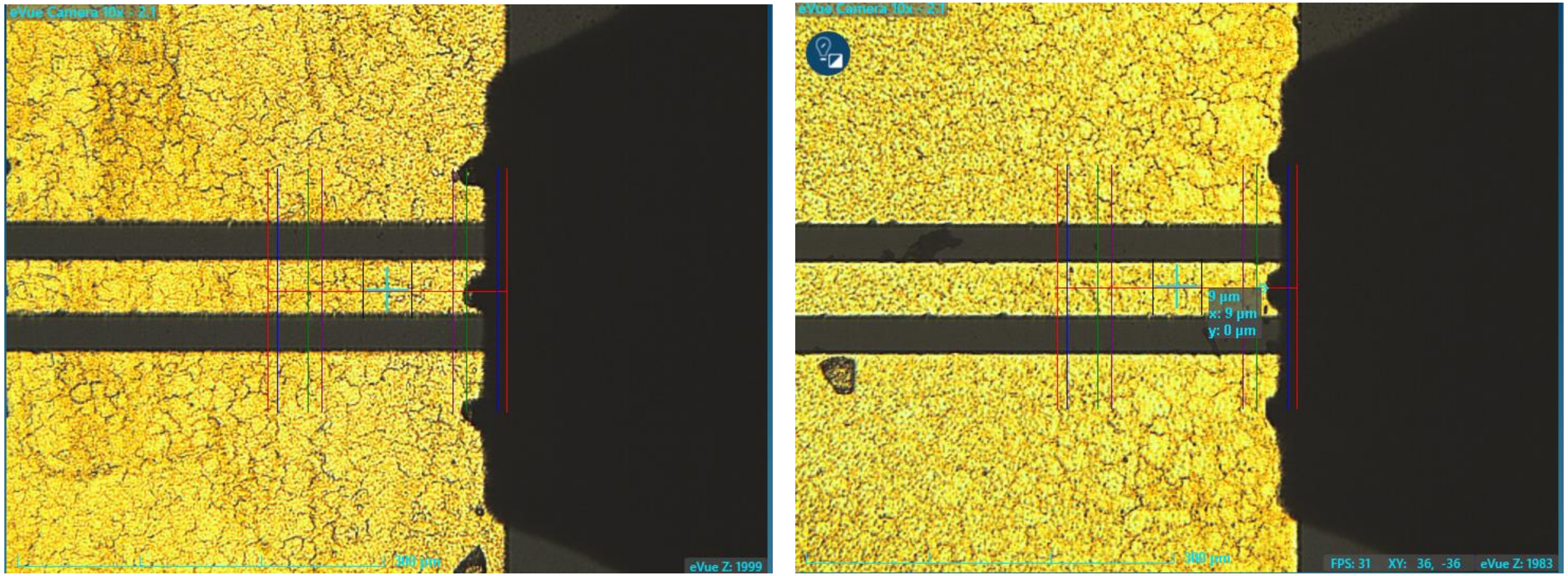
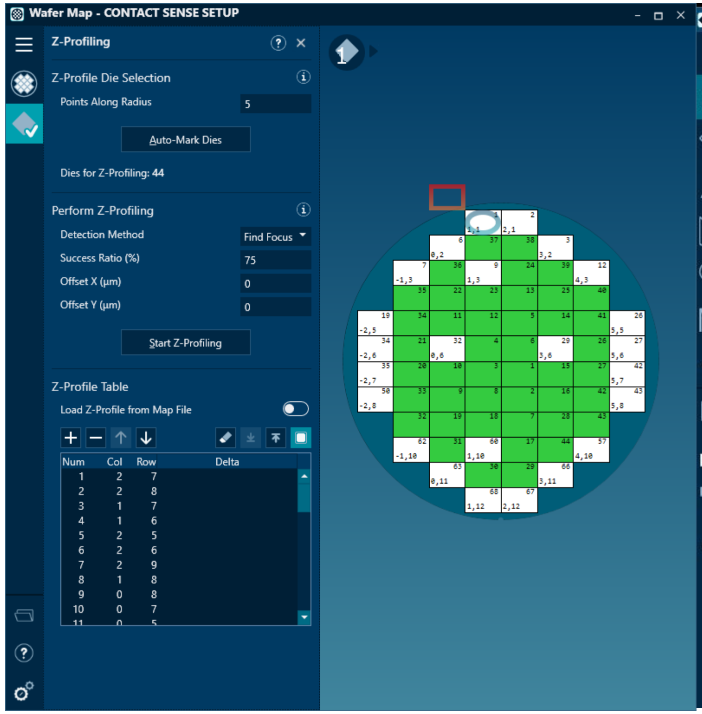
The problem – planarity of iss and positioner runout

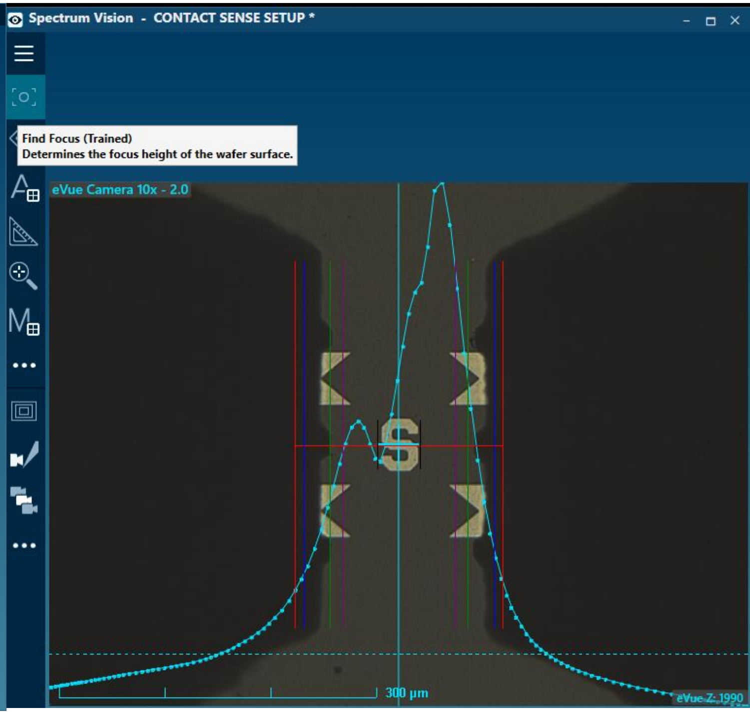


- Final placement error seen here is 10 um – A combination of small positioner planarity error and iss planarity error and small X offset
- Note height of scope Z reference was changed by 16 um to get best focus

Alternative solutions to contact sensing?

- Velox supports Z profiles to the main wafer chuck but <u>doesn't do this </u>at the auxiliary chucks at present
- 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 as it stands without use of Vuetrack and this is more difficult to implement in calibration sequence





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 Magnitude = ((Real_current – Real_Open)^2+(Imag_current – Imag_Open)^2)^0.5

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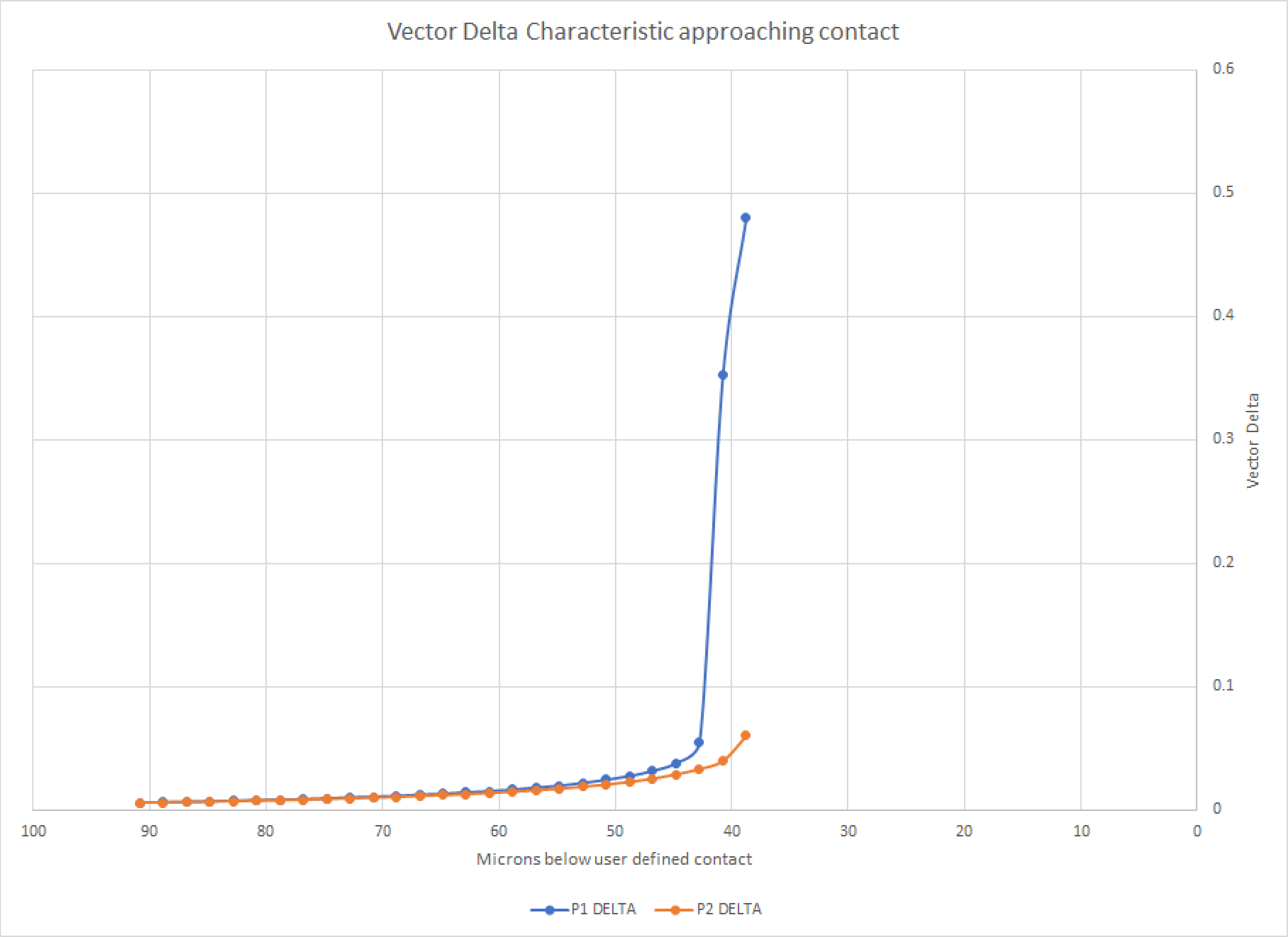
Contact detection Threshold



- Steps are in 2 um here
- Rate of change of Vector delta hanges rapidly typically at 0.05 delta
- Here the stopping point is 0.05 – probes barely kissing pad

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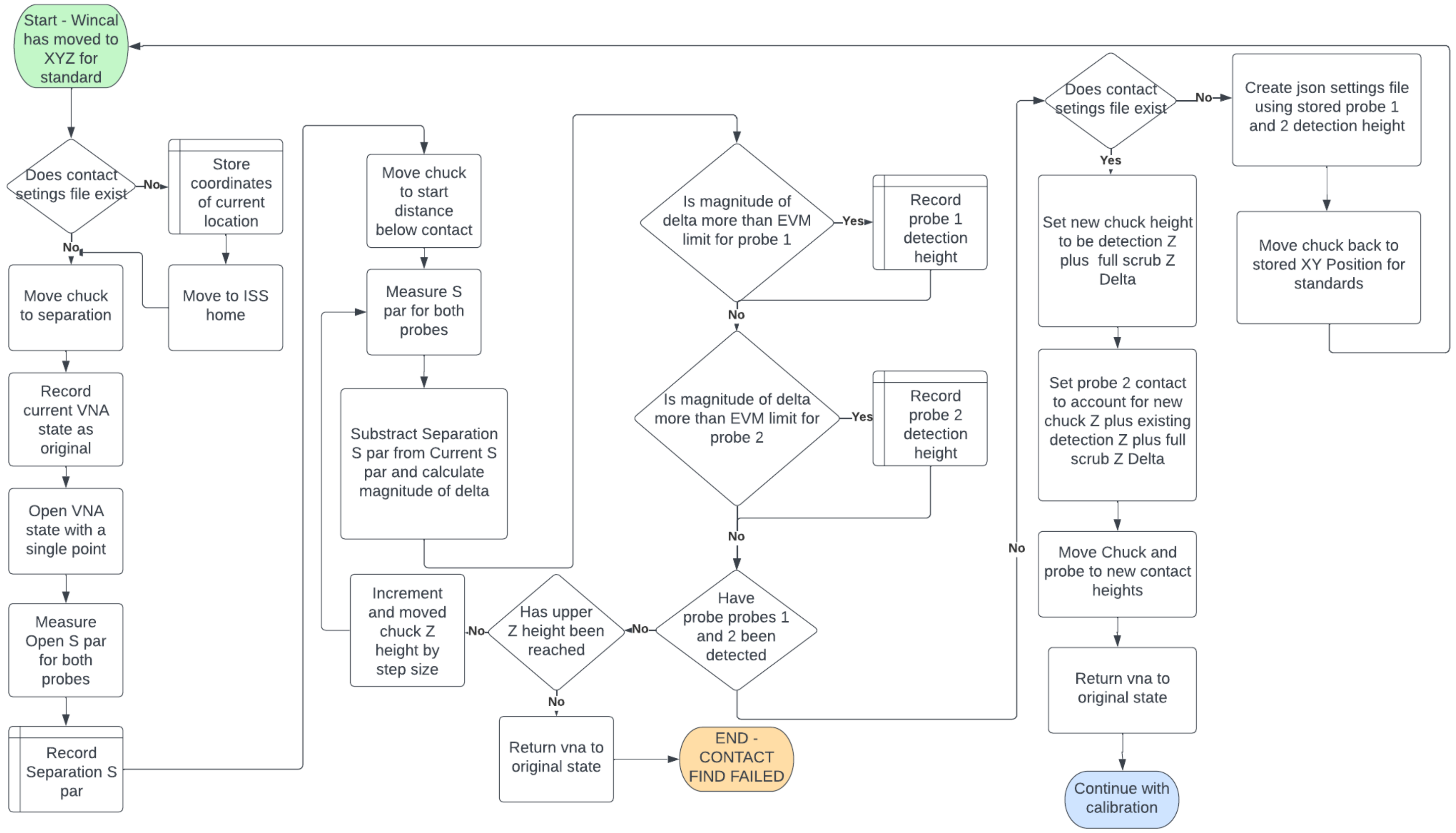
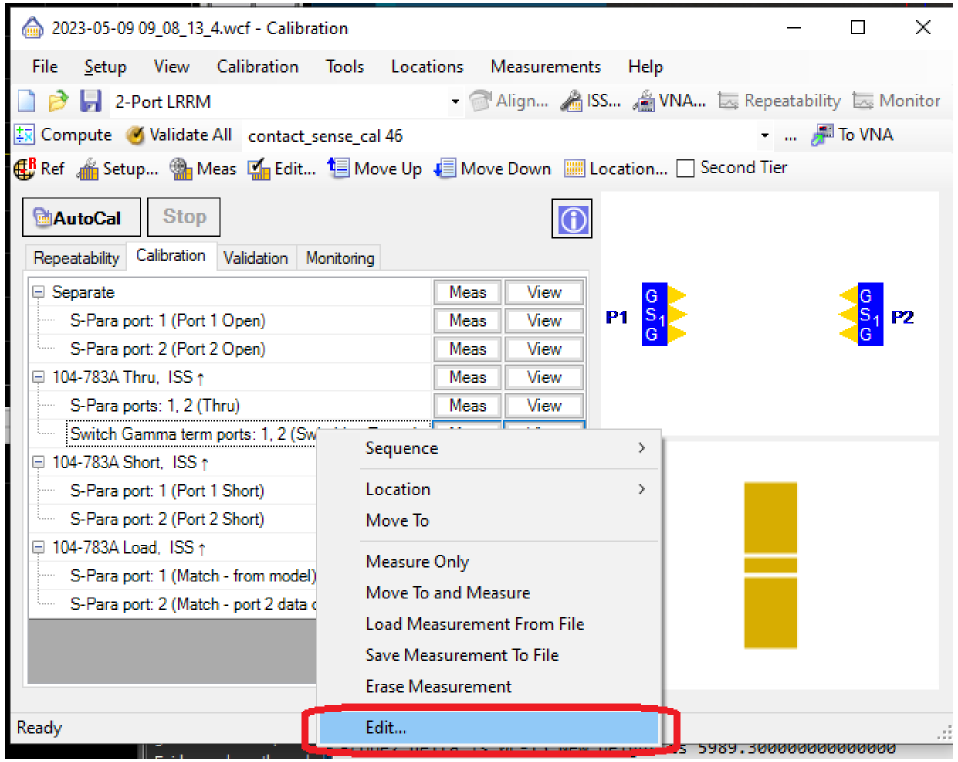
How does it work in general inside Python script?

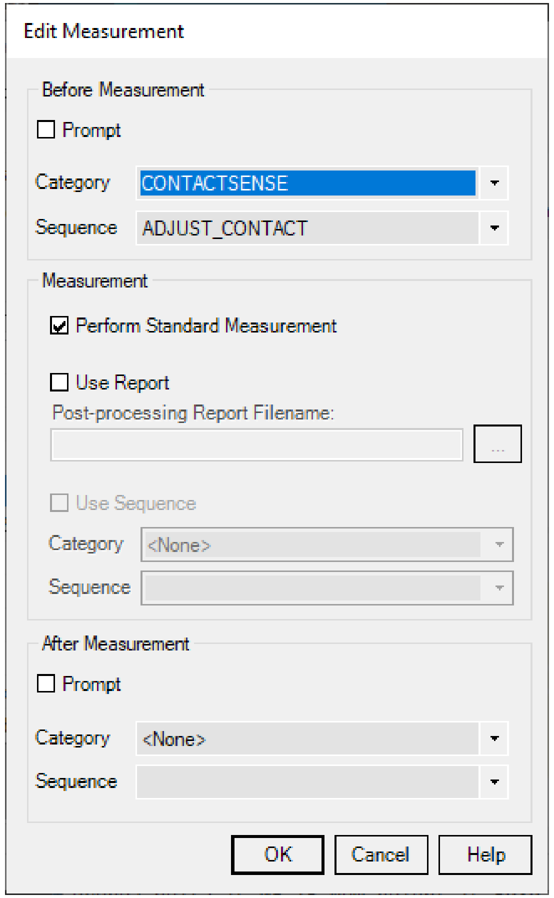


This is a flowchart of the general contact sense python script logic

This script is run during the calibration process

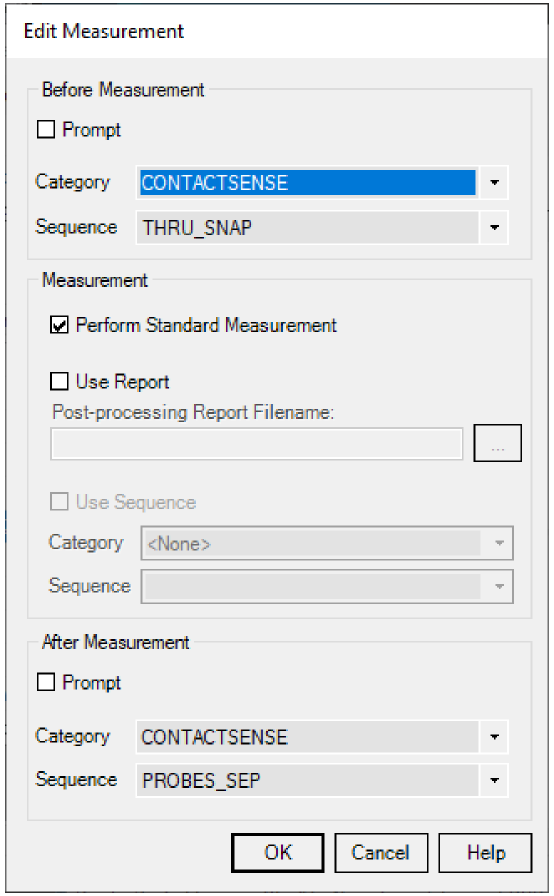
How to make python scripts work within WinCal





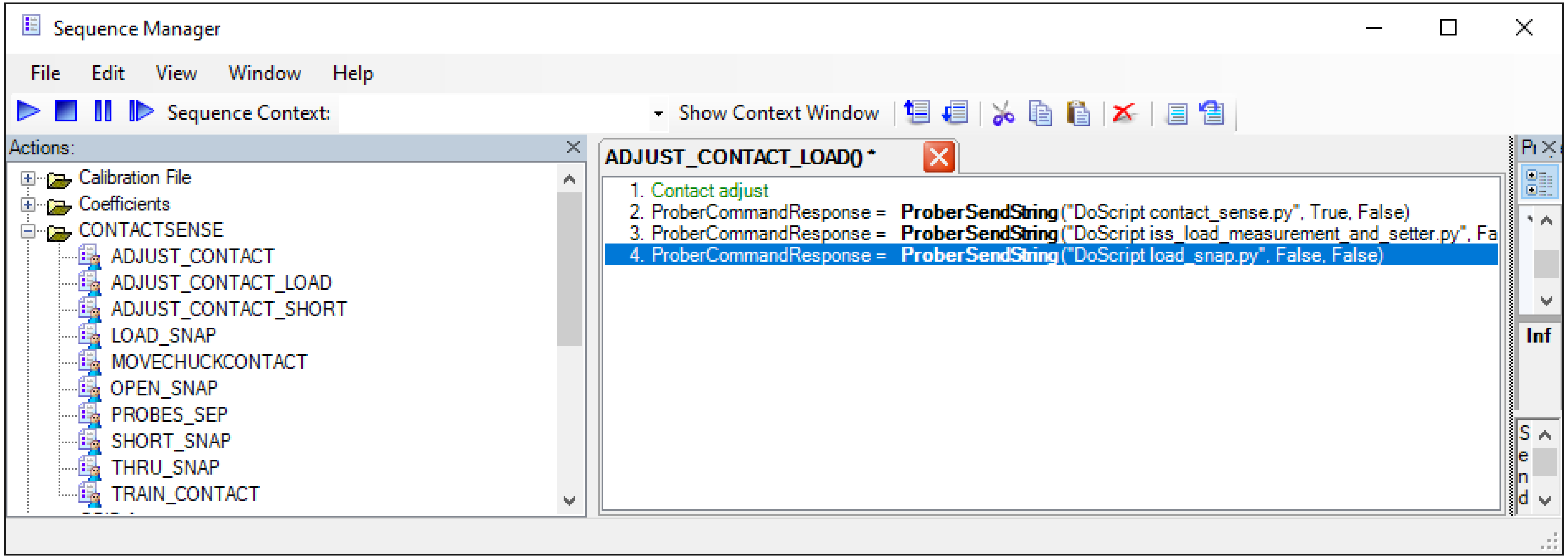
- Python direct approach could use WinCal as a slave, but preference is to sense in the normal calibration approach
- WinCal can invoke a “sequence” during the calibration as an activity carried out prior or post standard measurement
- Calibration sequence can in turn invoke a python script using DoScript 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



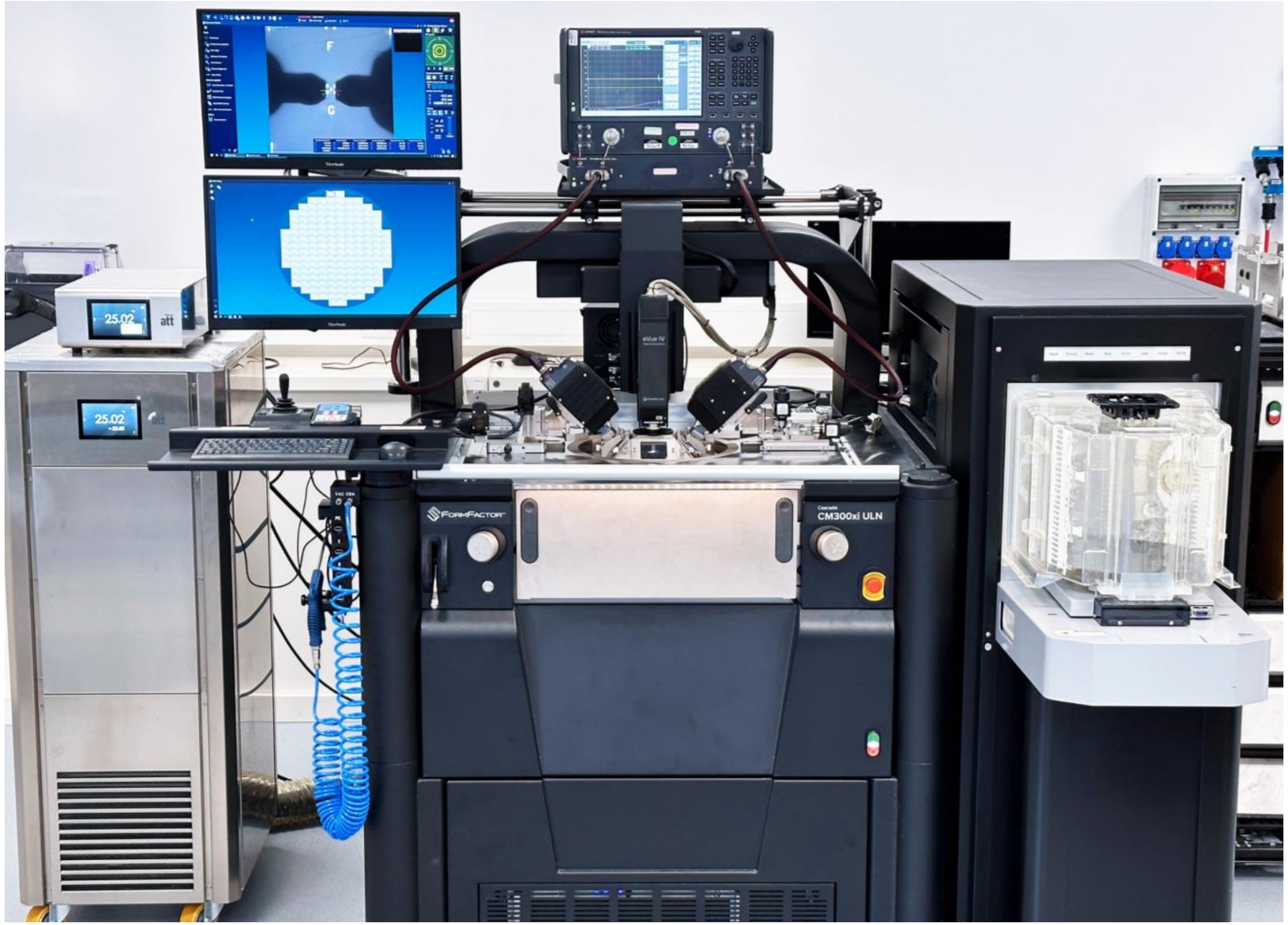
- By default, WinCal will perform all the movement activities prior to reaching the standard including movement to contact
- However, it will not bring positioners to contact if they were previously at separation before the movement
- Multiple touchdowns avoided to reduce pad wear
- For this reason, 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



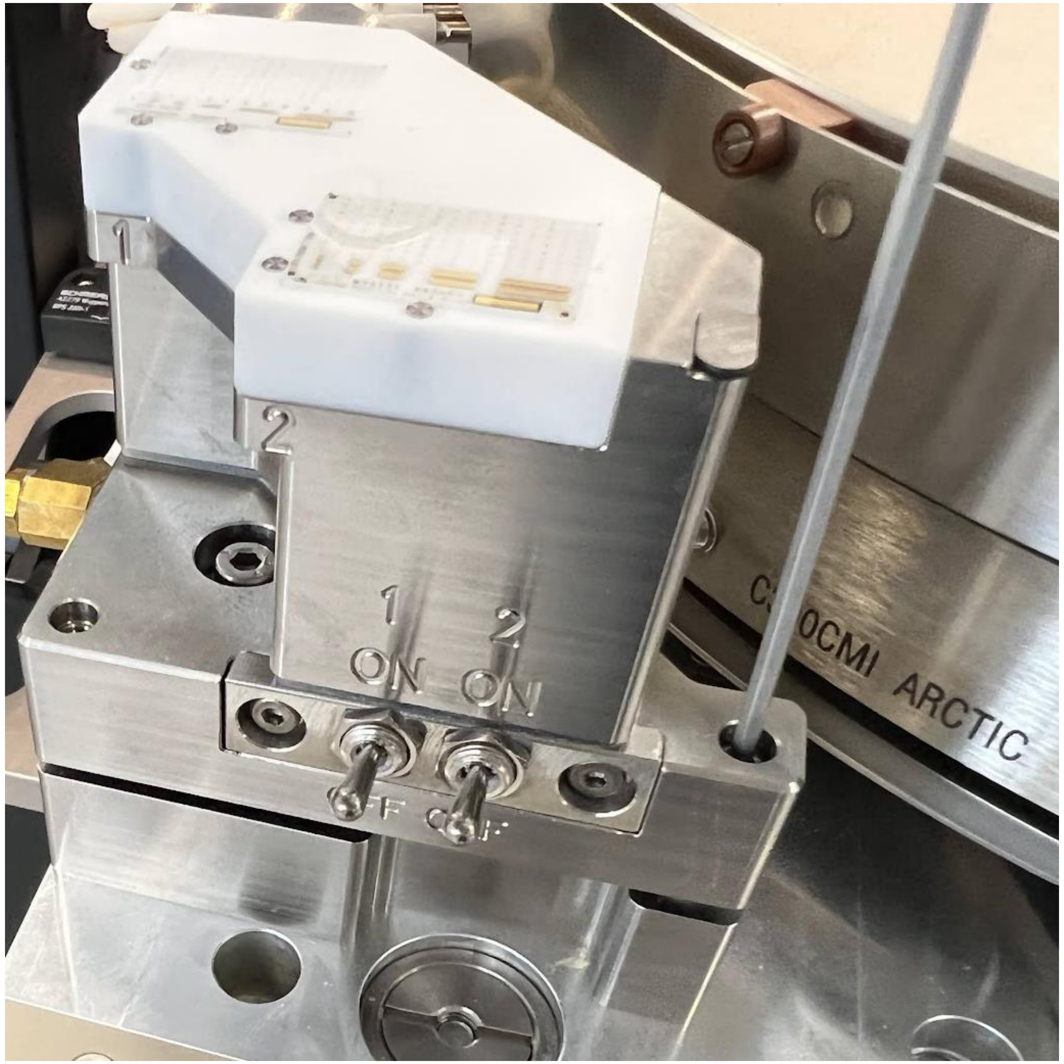
- The set of sequences is seen in the list

System used for evaluation



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

Iss contamination simulation

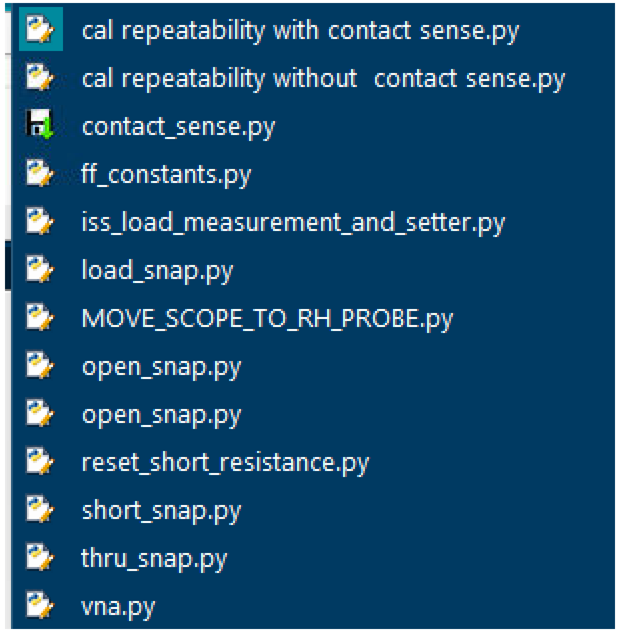


- ISS Chuck was deliberately mis-adjusted to simulate errors from contaminants or other sources
- This was done using mechanical adjustment of planarity screws

Testing methodology

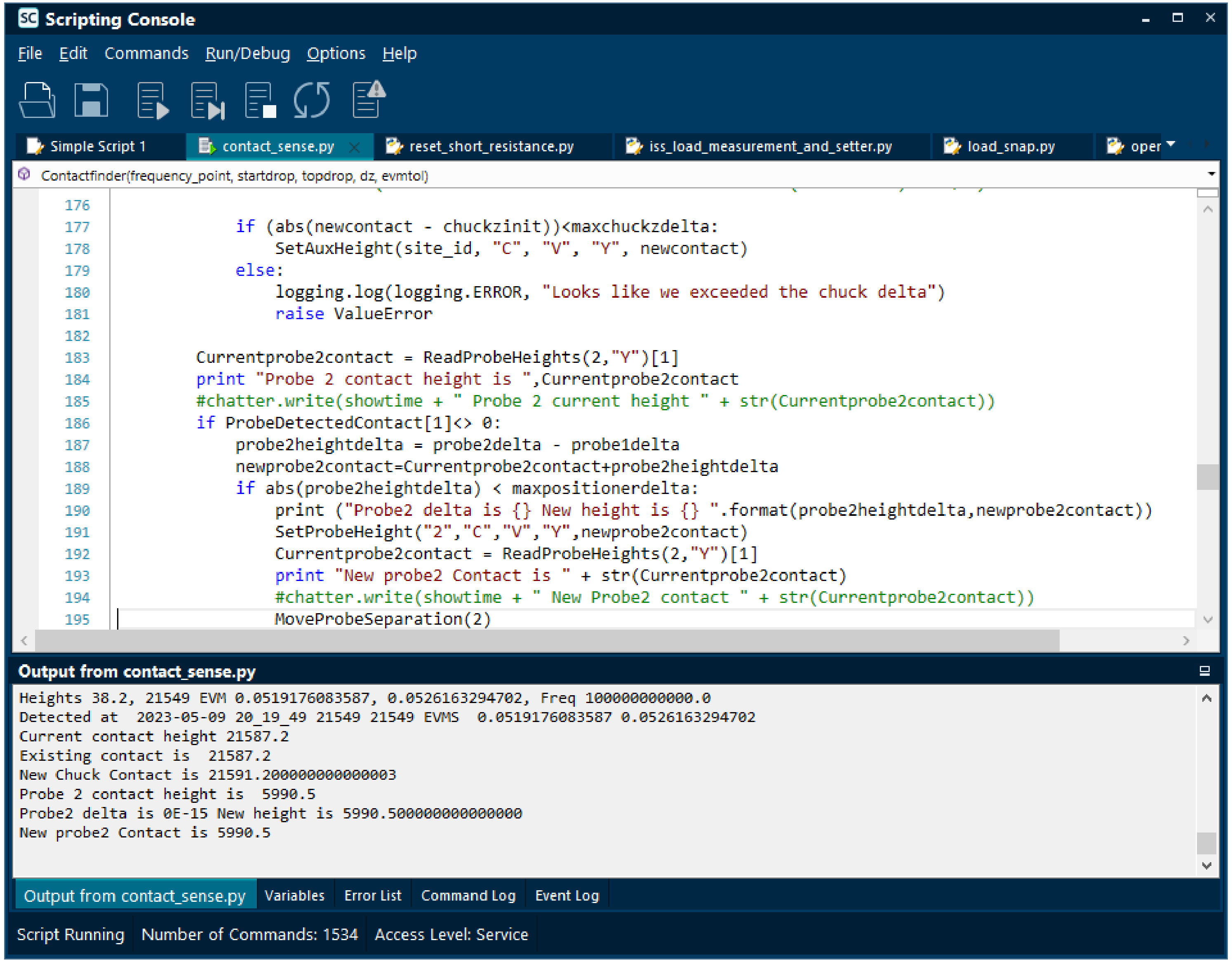
- Use a script to perform calibrations at 16 locations on 104-783
- Perform calibration set with load resistance compensation and contact correction
- Record error sets for all locations tested and photos of probe contact.
- Measure Open in air and same thru as used for the test
- Carry out calibrations on same iss and setup but only use load compensation and no contact correction
- Compare spread of error sets and Open measurements
- 25 um skate used
- Iss was a unit that had failed trim process but fine for our needs

Scripts used



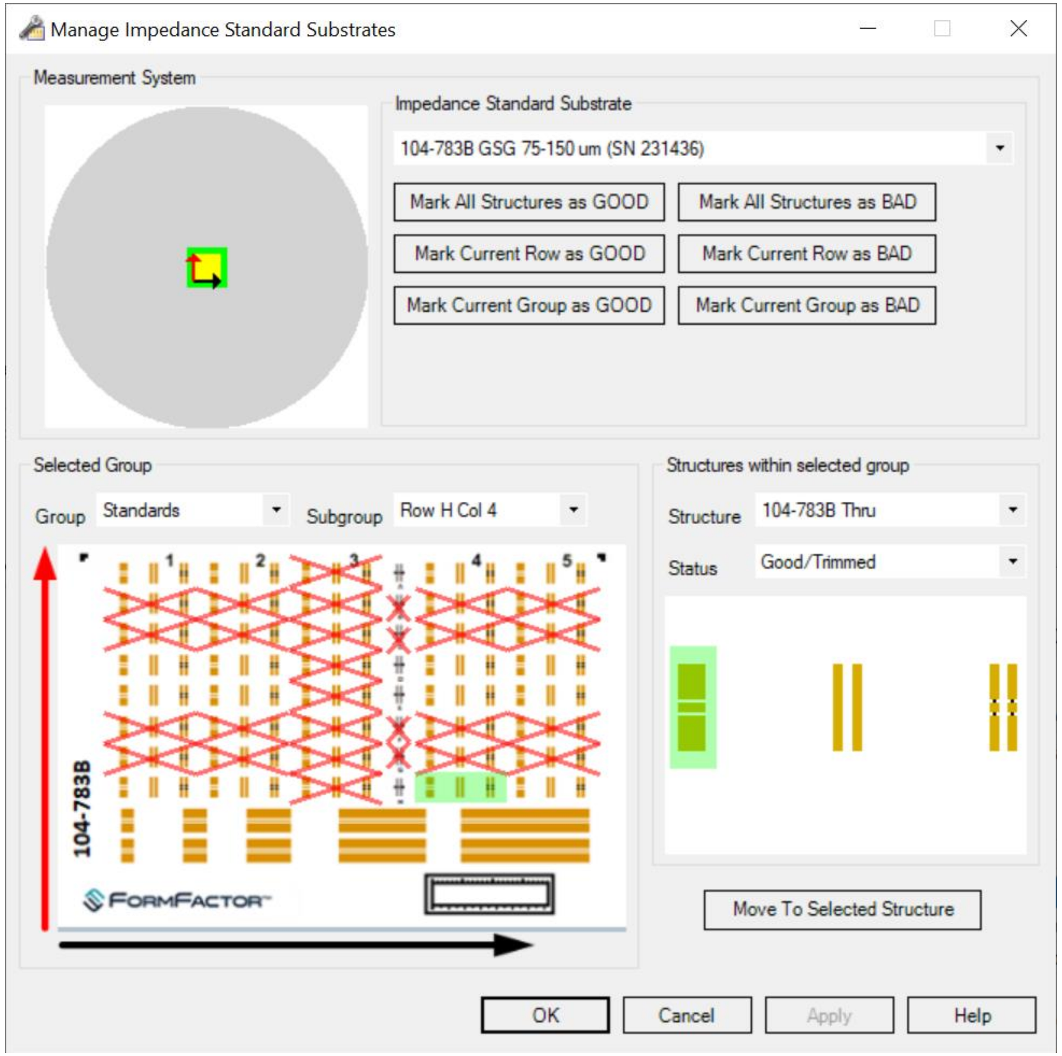
- Main script is contact sense, which either determines the required overdrive per probe set by the user from sensing or corrects the chuck and probe2 contact based on contact sensing of current standard
- VNA is crucial to communicate to the vna directly over socket
- FF_constants are the primary control 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 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 Calibration group for measurement



- During test procedure we automatically index the cal groups using following command w.CalUseNextGoodGroupOnIss()
- Groups shown were used
- We deliberately ran a run through all locations prior to capture of data – experience shows significant variation from very first contact to the next

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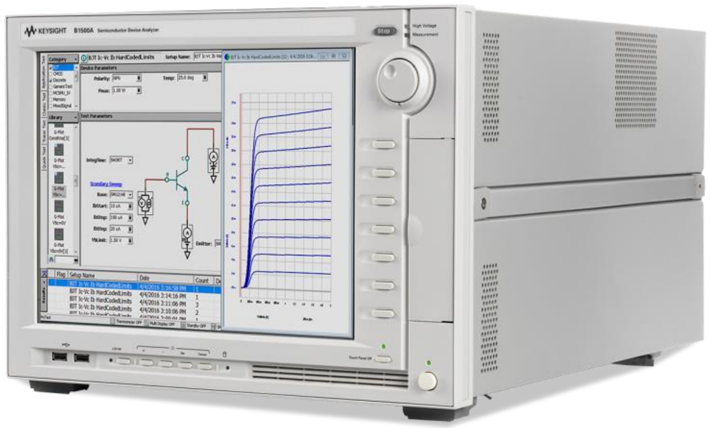
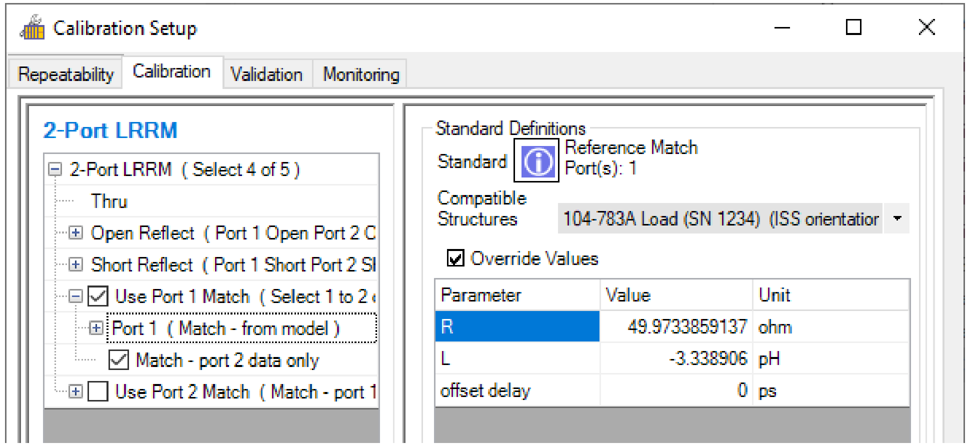
Load resistance measurement and adjustment on the fly

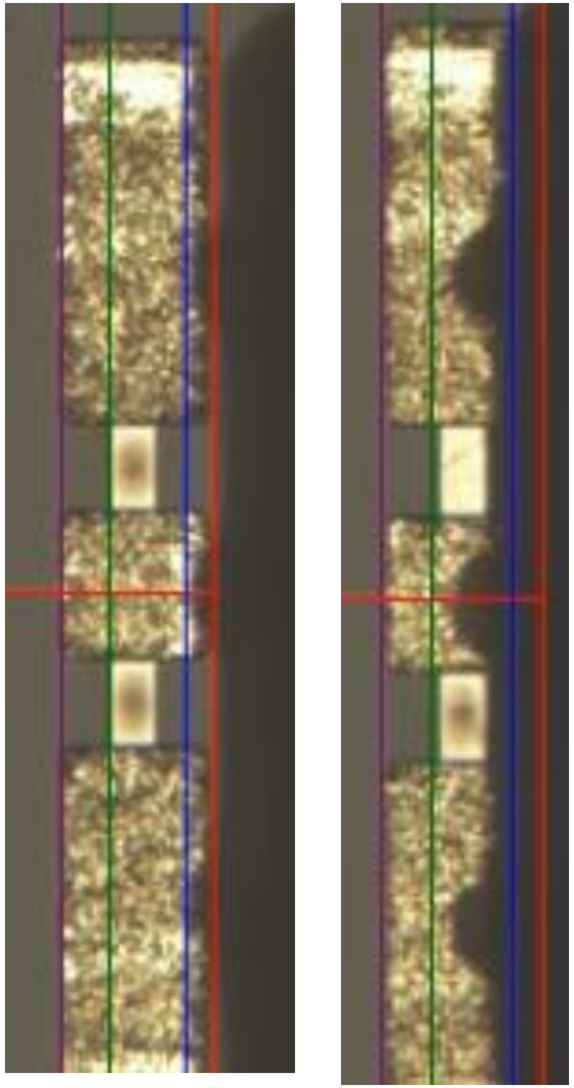


- ISS Map was not readily available so we needed to measure the load resistance – we used B1500 via N5291A instrument bias tees
- The ability to add sequences to calibration process made direct measurement and compensation appealing
- Short was measured at .1 volts and used as offset reference and written to file
- Load was measured a 1 volt bias and resistance of short subtracted
- Corrected load value is automatically measured and applied during calibration process
- WinCalExecuteCommand("CalSetCoefficient, 1, Match - from model, Reference Match, R, {}".format(rload1_corrected))
- One resistor appears to have failed in 5R location..



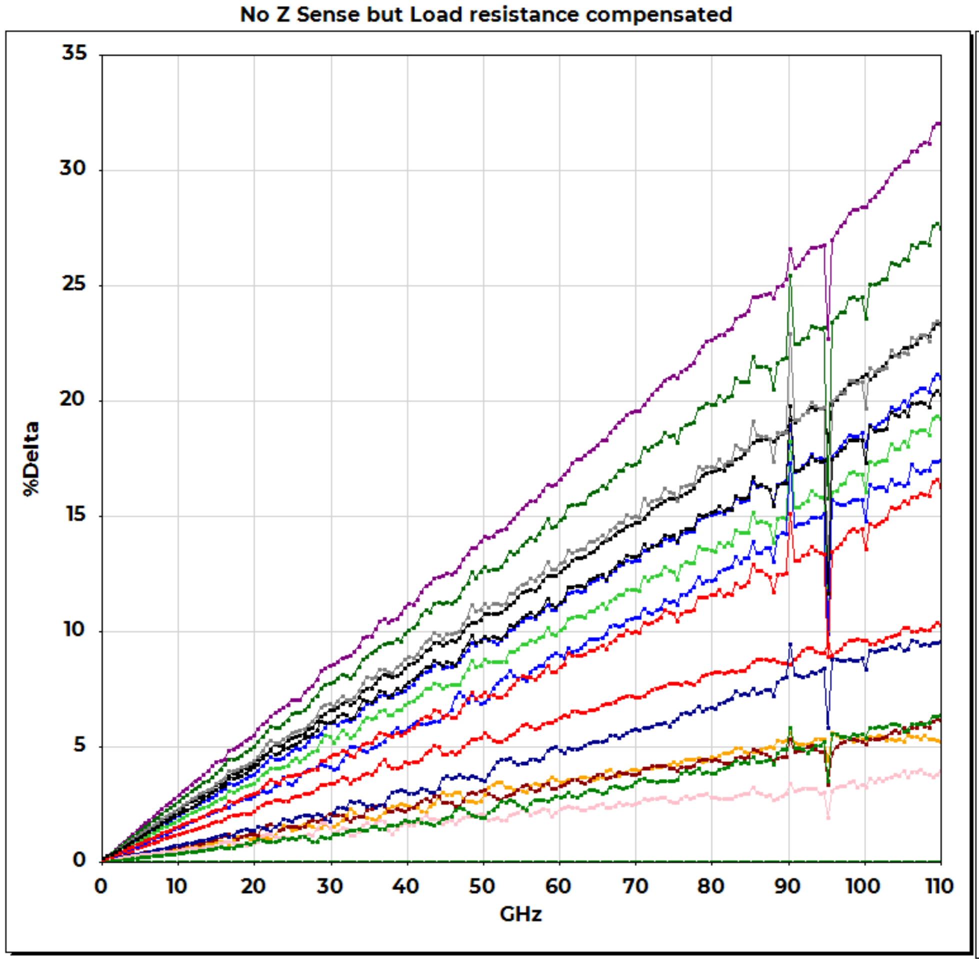
	1L	1R	2L	2R	4L	4R	5L	5R
A	50.12321	50.00223	48.33143	48.24285	47.79855	50.57794	47.00259	47.02301
D	50.20838	49.94828	50.14571	49.90843	50.19265	50.05771	50.2203	49.96821
E	50.24733	50.01891	50.12752	49.90194	50.20219	50.01985	50.19329	49.96933
H	50.28777	50.04244	50.12788	49.95298	50.25752	50.08616	50.1595	100.0728

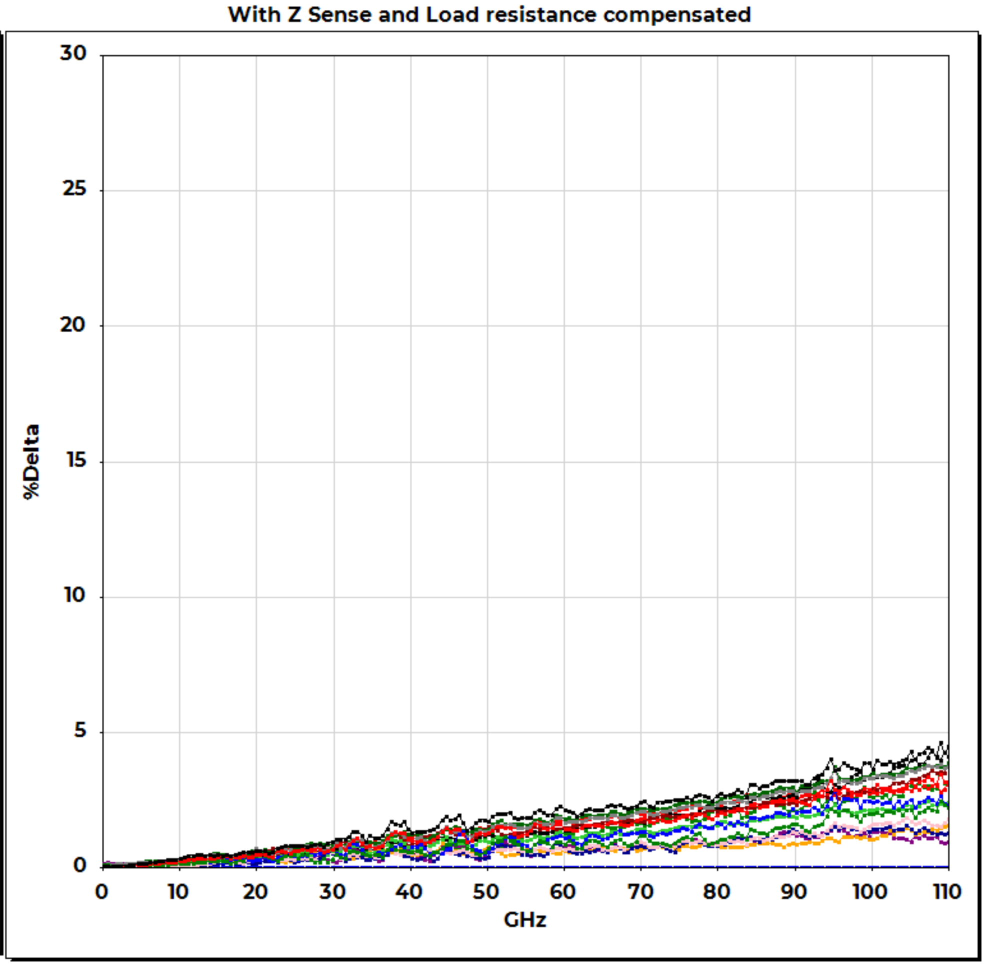
Resistor 5R Mistrim

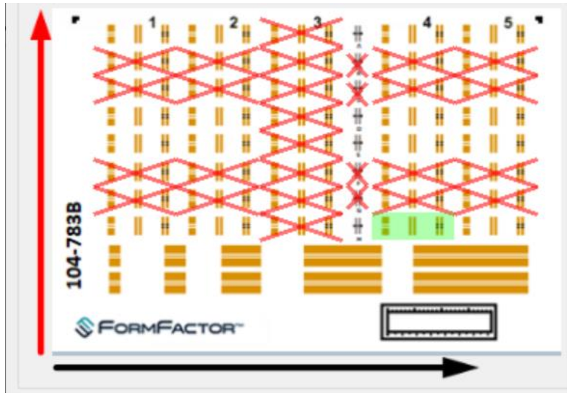


- This iss was not of saleable quality and was scrapped
- Location 5R was detected as 100 Ohms and it can be seen that the resistors are burnt assymetrically indicating it is suspected an open circuit to upper resistor
- Resistor on the left is in normal trim state

Error set comparison – Left graph without sensing







- Much tighter grouping when contact sensing is use
- All locations are the same
- Source of 95 GHz glitch during unsensed run not known

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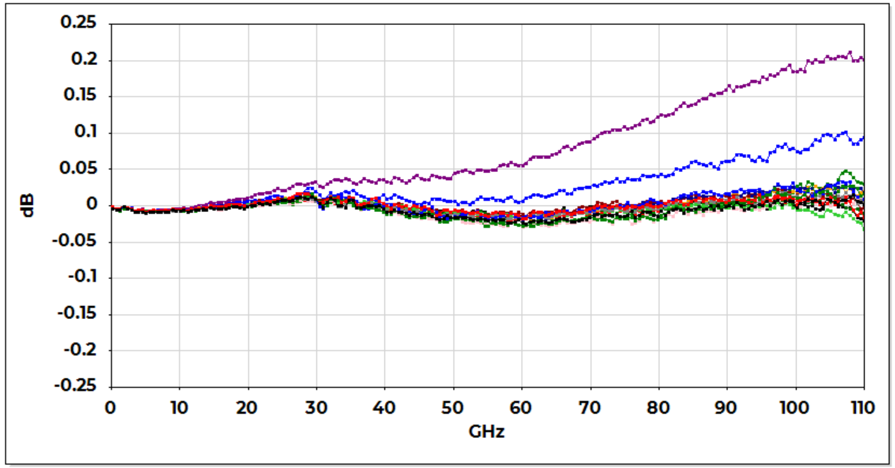
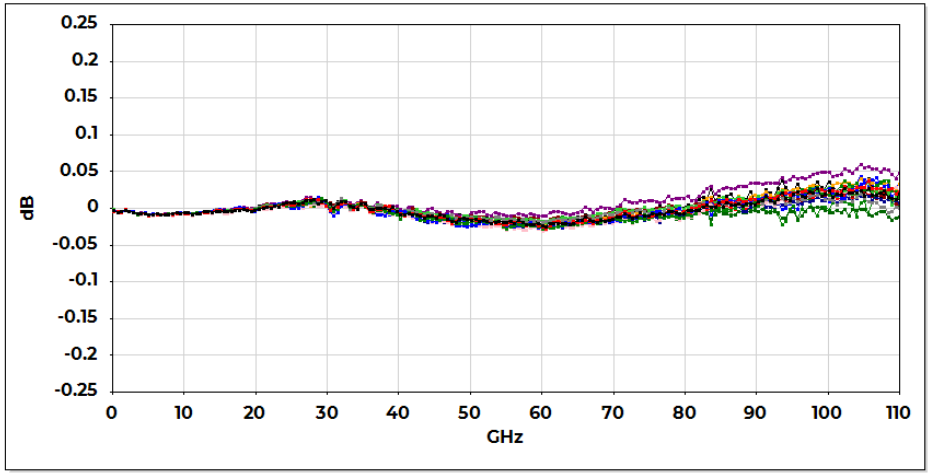
Post calibration Open Magnitude Variation

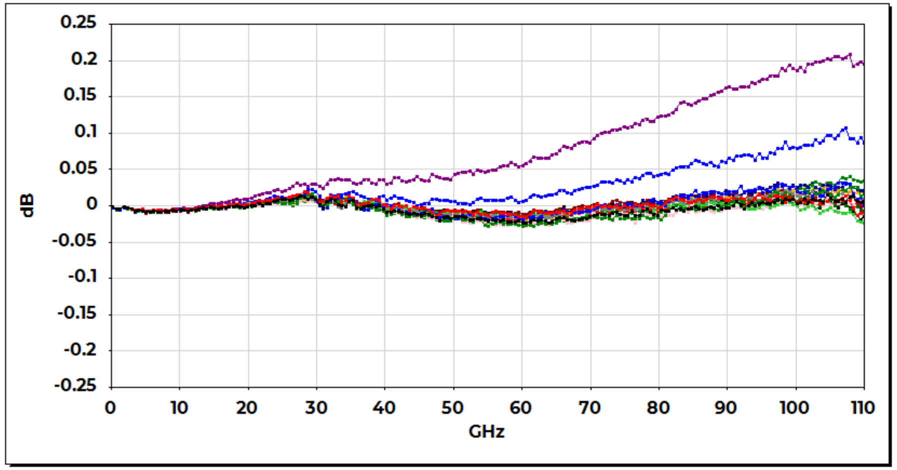
No Contact Sense Open Masnitude S11



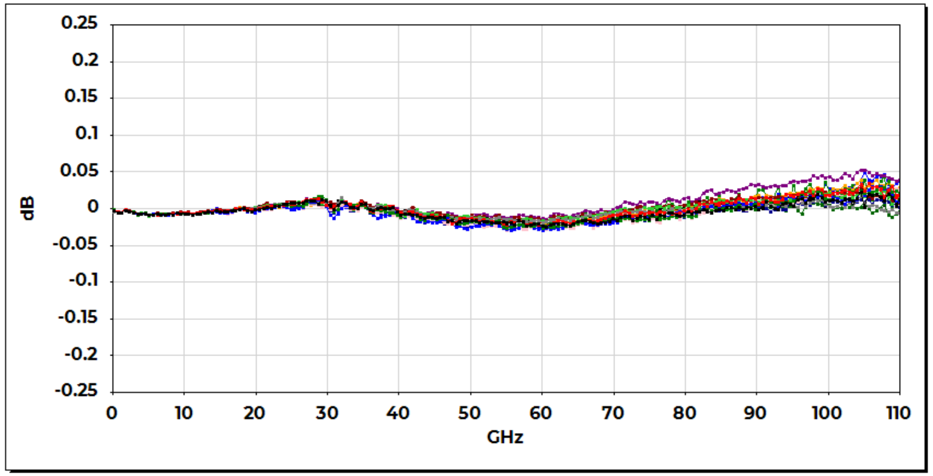
Using Contact Sense Open Masnitude S11



No Contact Sense Open Magnitude S22



Using Contact Sense Open Magnitude S22



- Magnitudes fairly similar apart from outliers which may have had limited contact

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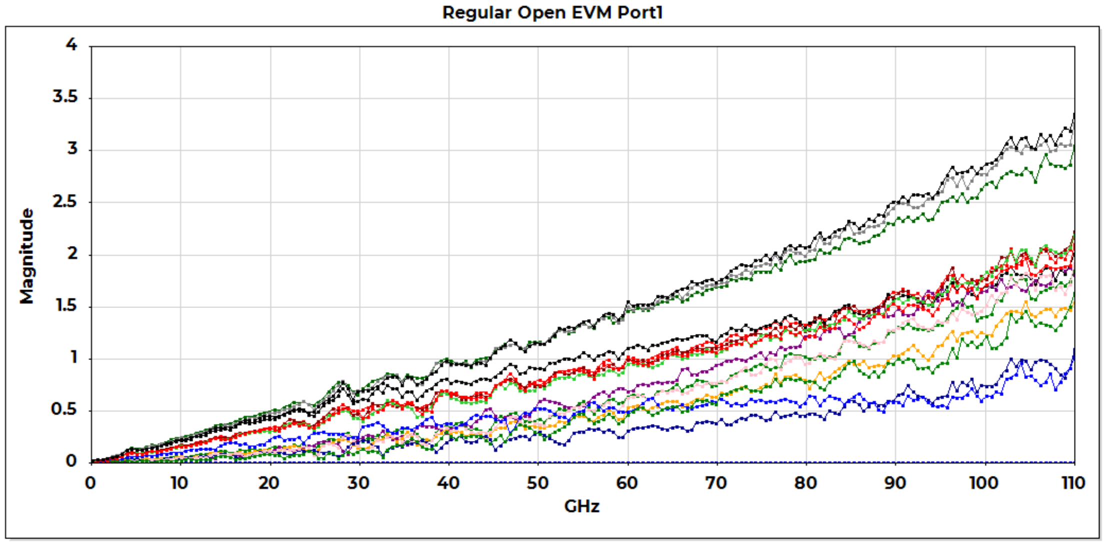
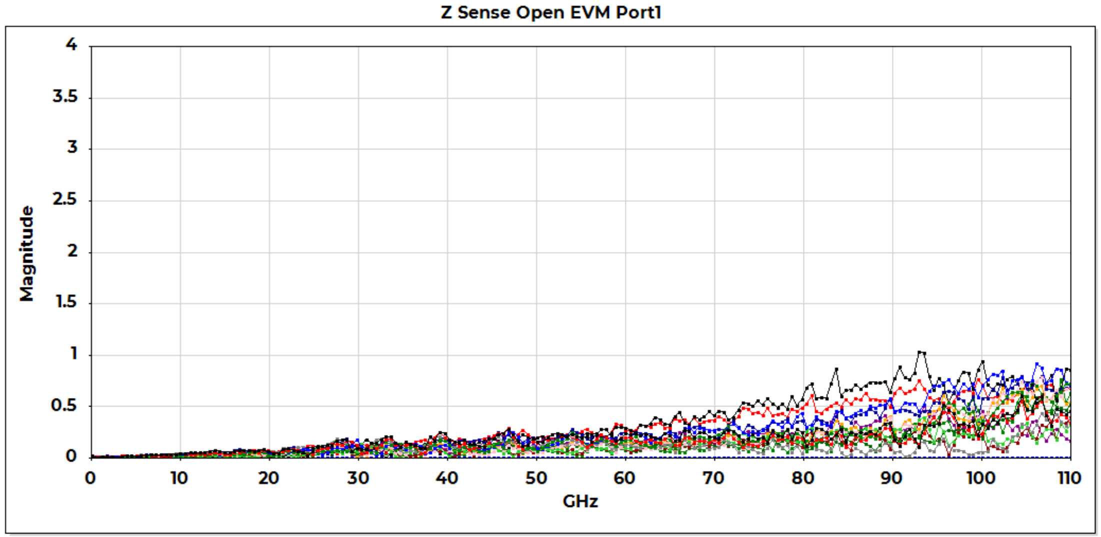
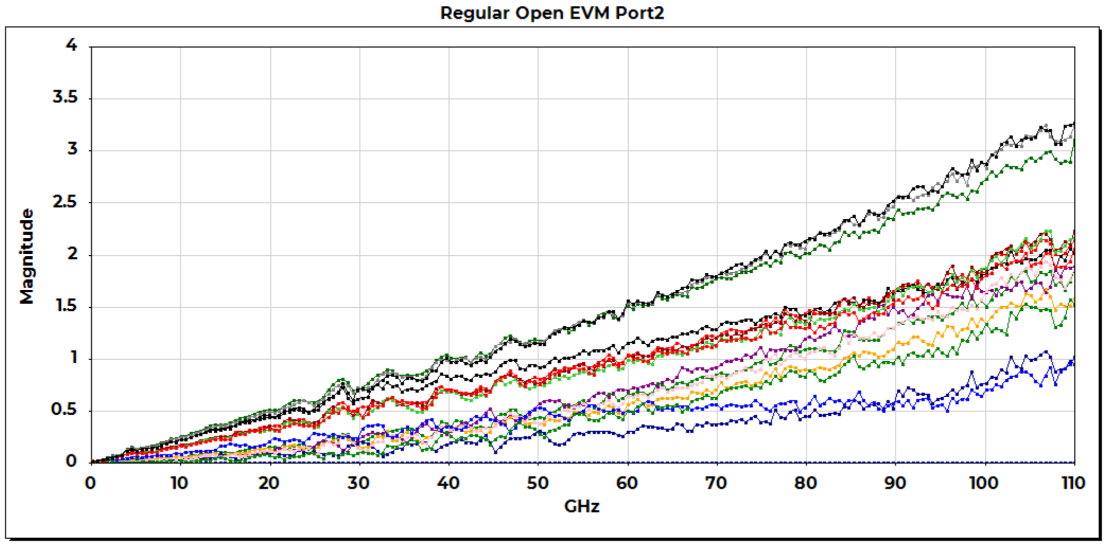
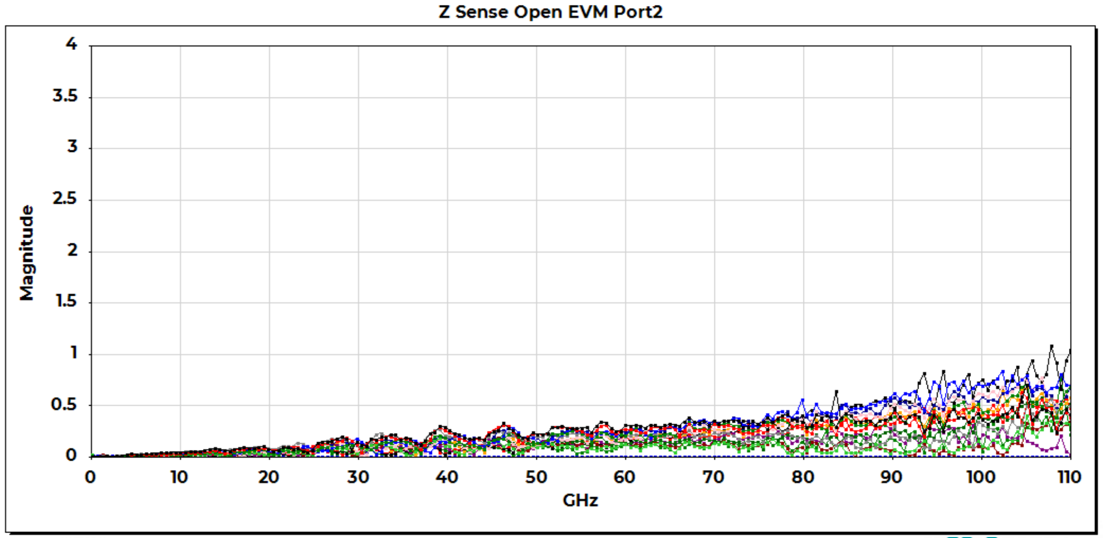
Post calibration Open EVM Delta (x100) – This shows effects or varying capacitance









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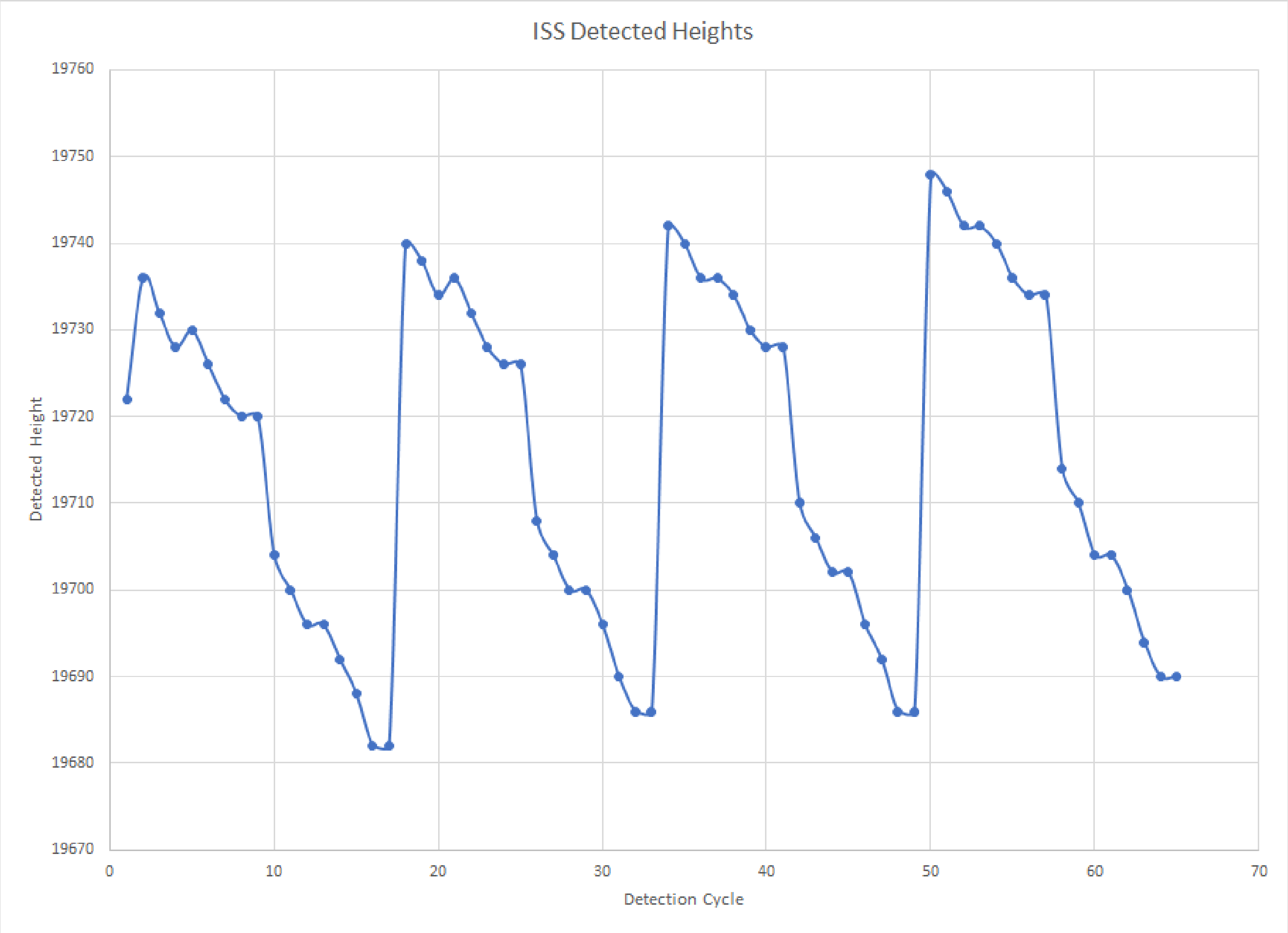
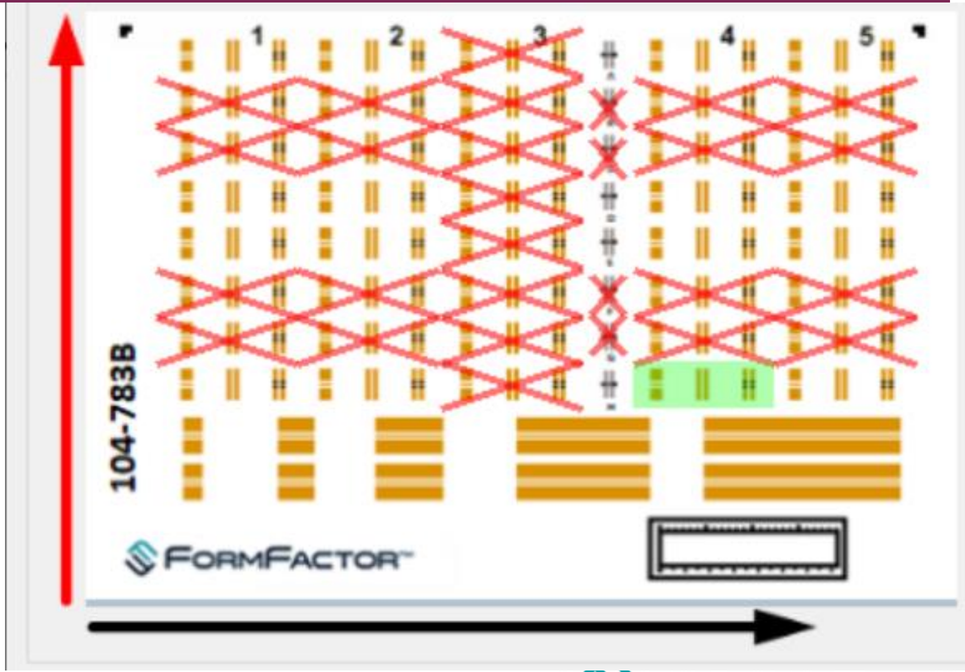
Contact height deltas across iss – Load to left of R-H is zero

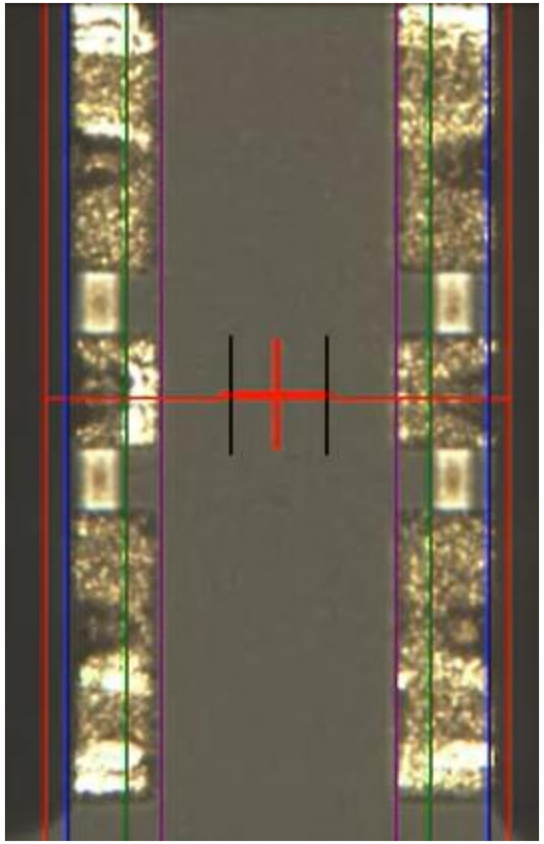


	1	2	3	R	4	5
A	14	4			-18	-30
B						
C						
D	18	10			-14	-26
E	20	12			-12	-26
F						
G						
H	26	18			-8	-22

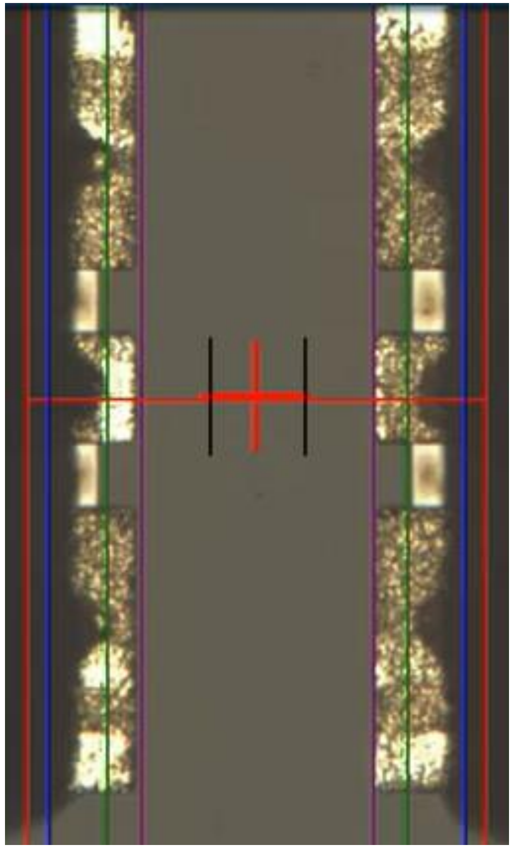


Comparing standard in the same location with and without sensing

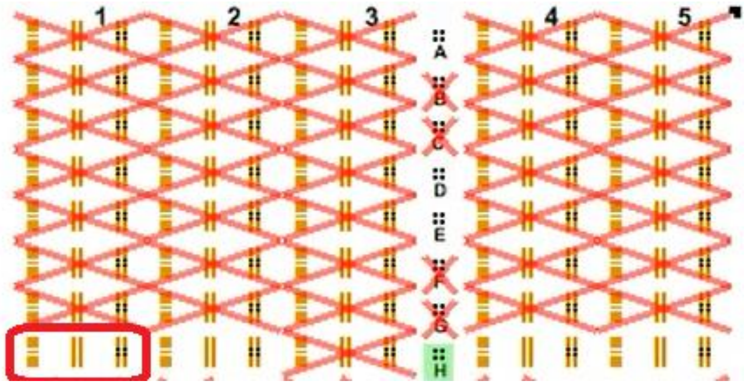
WITHOUT SENSE



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



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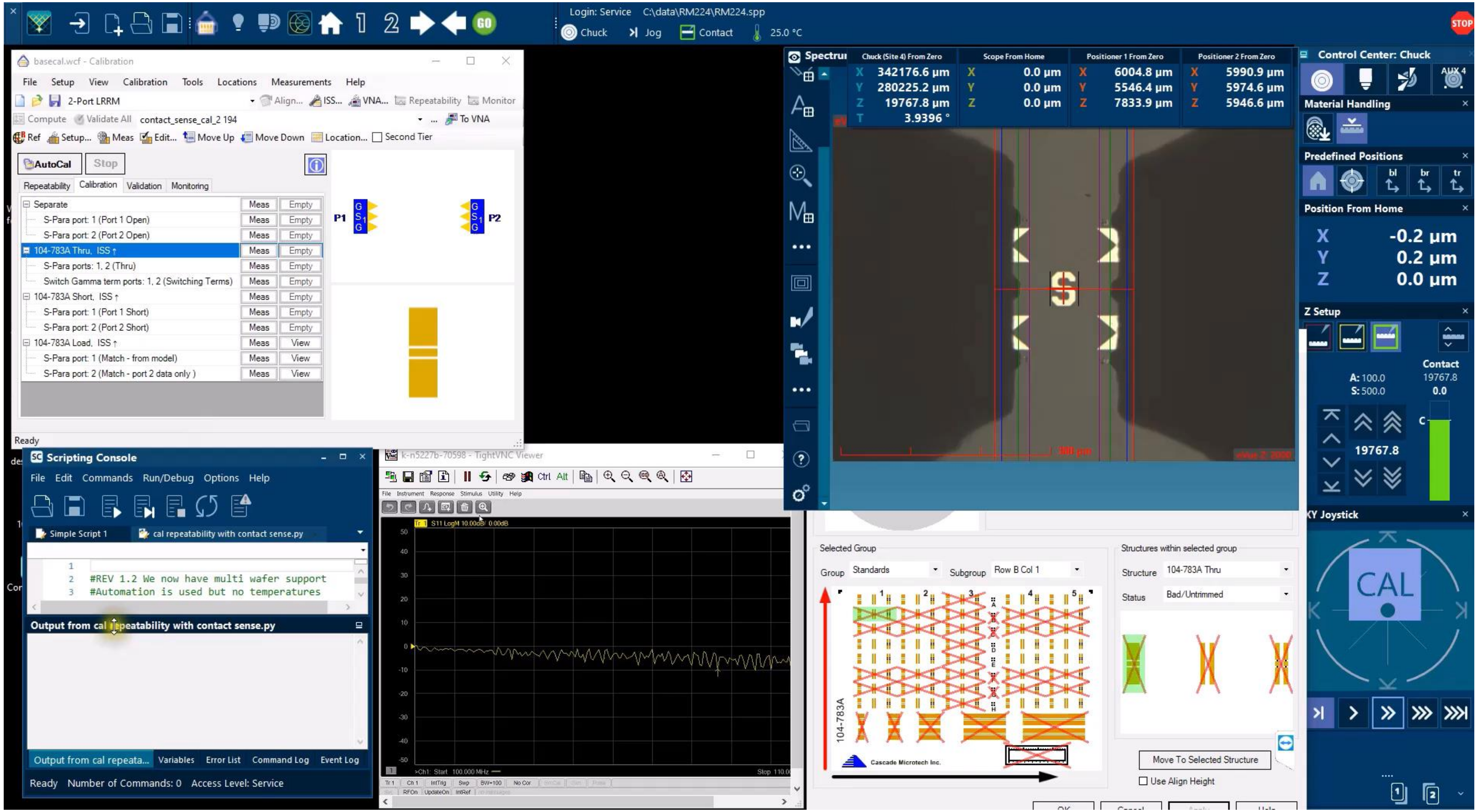
Video of operation



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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 and sequences
- Using a Z sensing approach, the error set variation is greatly improved
- Dynamic measurement of load resistance and on the fly compensation can be performed for customers who also have a DC measurement instrument
- Although we used motorised positioners also the approach could simply adjust contact using chuck variation. Motorised positioner addition useful to compensate potential positioner planarity variation also