Software Assisted Scratch Visibility Measurements

The SavvyInspector ™

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Motivation

- Most optics produced in the world today are made to a MIL-PRF-13830B scratch and dig specification
  - e.g. “80/50 Scratch-Dig”
  - Based on inspector evaluation of “visibility”
  - Methods of evaluation vary in lighting, angles, an interpretation
  - Subjectivity of test is the killer
- Surface imperfections by far the most cited cause of optics rejection
  - Almost all are cosmetic or workmanship specifications only
- The confusion about surface imperfections costs our industry tens of millions of dollars each year
  - MRB decisions
  - Returned optics
  - Reworked optics
  - Overmanufactured parts

Conventional visibility inspection is performed by a skilled operator under controlled lighting conditions

- The trained human eye is quite good (repeatable) in making accurate side by side comparisons.
- Disagreements from inspector to inspector and shop to shop due to differences in:
  - Training
  - Interpretation
  - Illumination
  - Visibility of comparison standards.

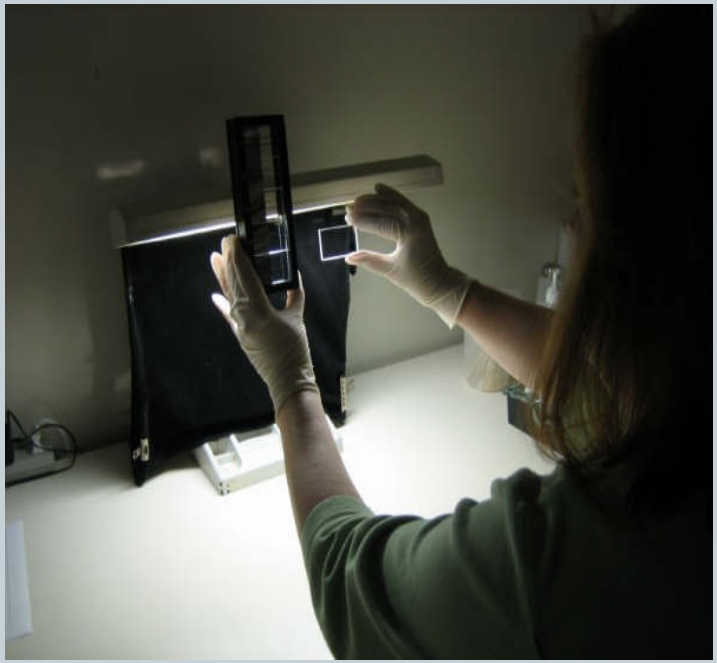


Photo from "taking variability out of scratch inspection", presentation to OEOSC by Ari B. Siletz

- Due to geometry, reflectivity of optics, most inspections actually done in reflection rather than transmission, as shown.

Geometry for standard reflectance visibility measurement from OP1.002:2009

- Illumination with a broad spectrum of angles
- Viewed with a smaall band of angles
- Part is rotated to achieve maximum visiblity

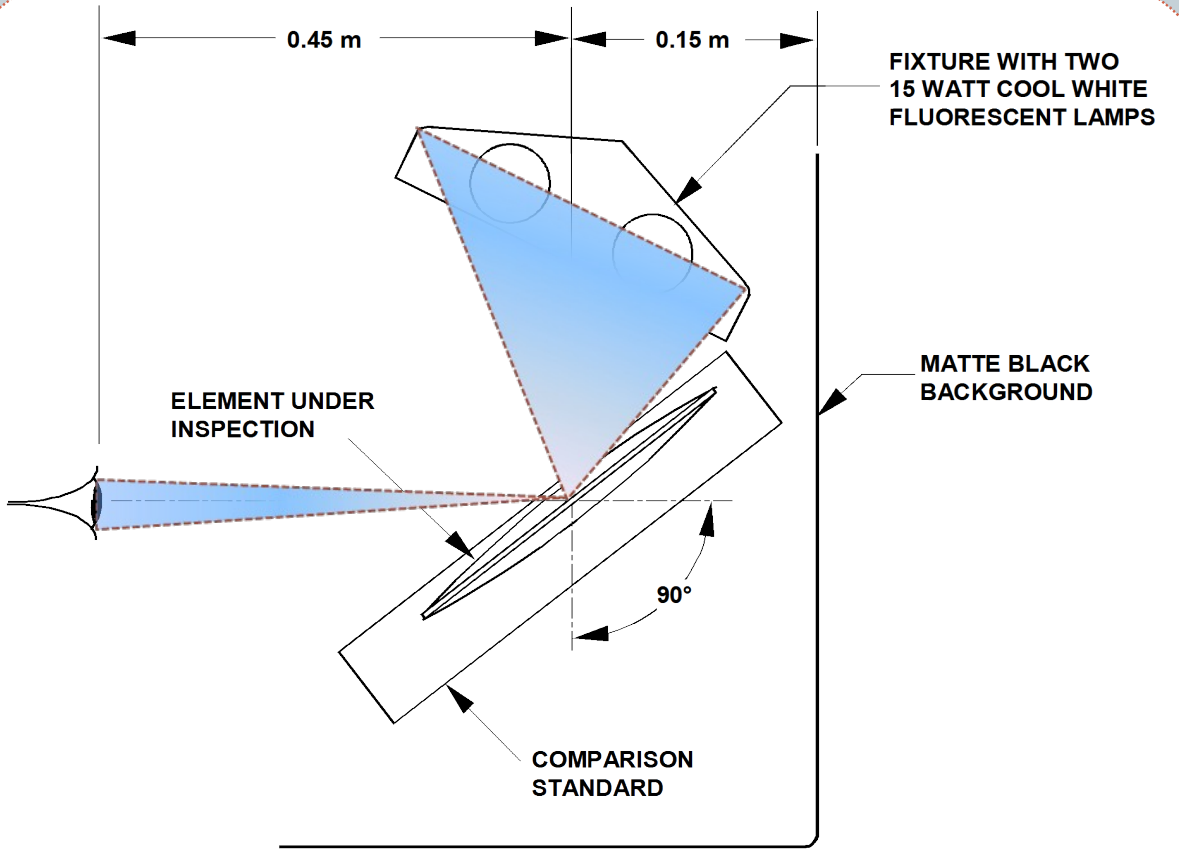


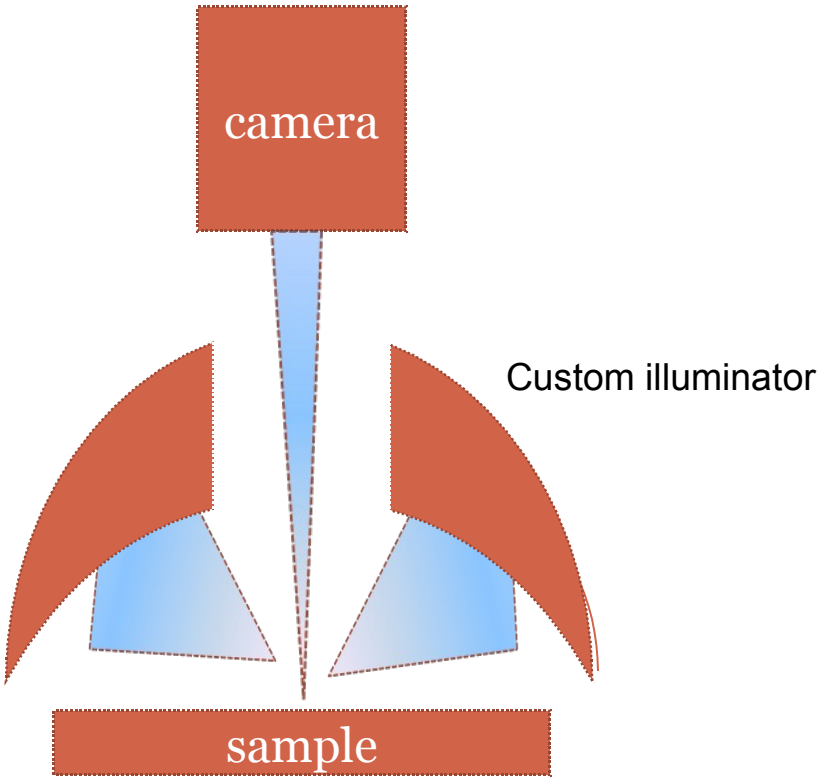
Figure 4 Reflected Light Inspection

Software assisted scratch inspection

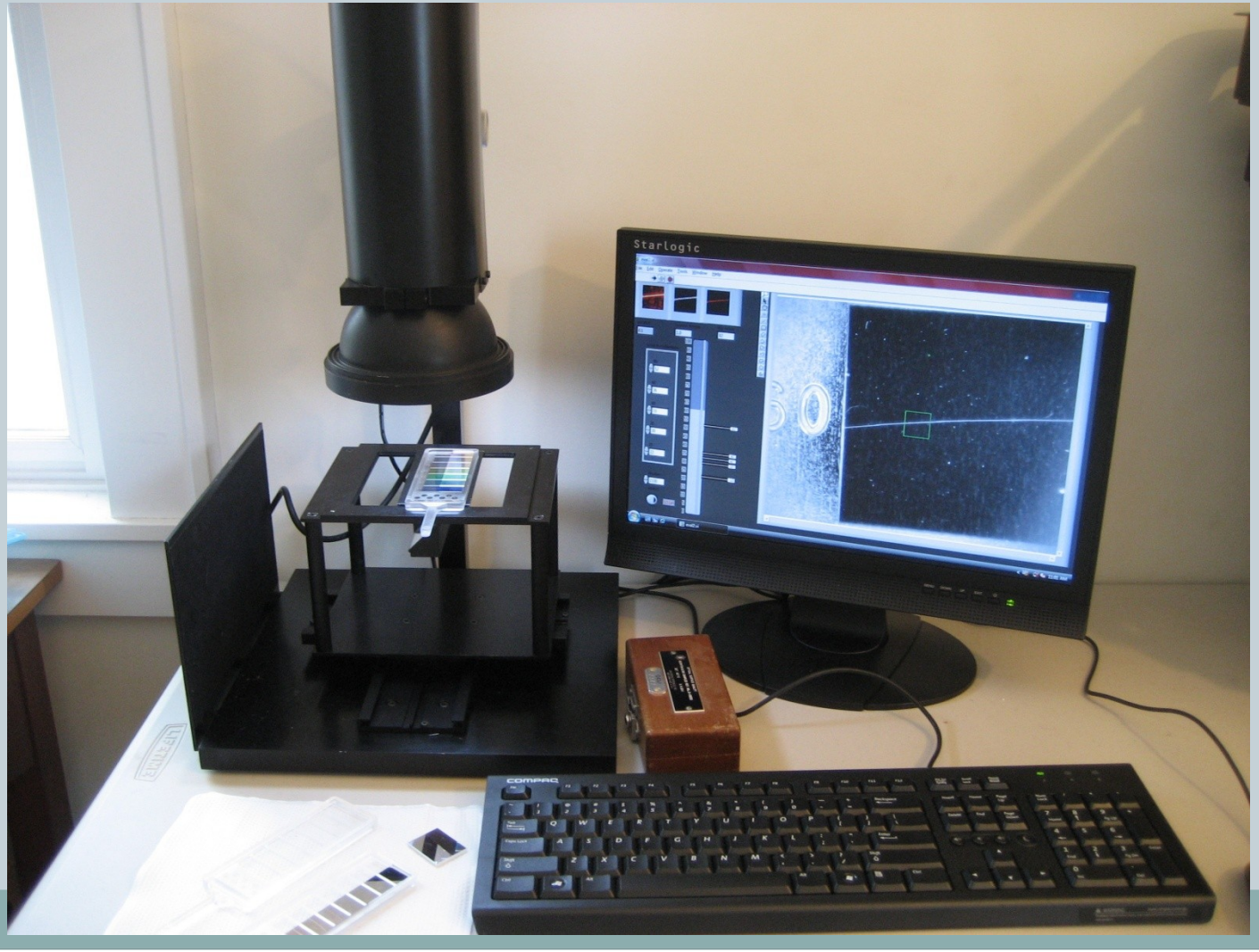
- CCDMetrix and Savvy Optics have developed an instrument to remove the subjectivity from scratch visibility inspection
- Simulates the visibility test from MIL-PRF-13830B
  - Based on digital CCD, custom illumination
  - Angles of detection close to human observer
  - Angles of illumination to highlight differences between small scratches
- Factory calibrations based on Jenoptik paddle, and Davidson Optronics and FLIR/Brysen standards
  - Both clear and metalized
  - Can calibrate in situ with any standard set
- Allows operator to move sample beneath integral head
  - Unit reports scratch value
  - Operator does length and accumulation rules
  - Spreadsheet provided for quick calculation of pass/fail
  - Image and data files saved for future reference

SavvyInspector™ recreates the reflection visibility conditions, over 360 degrees of rotation

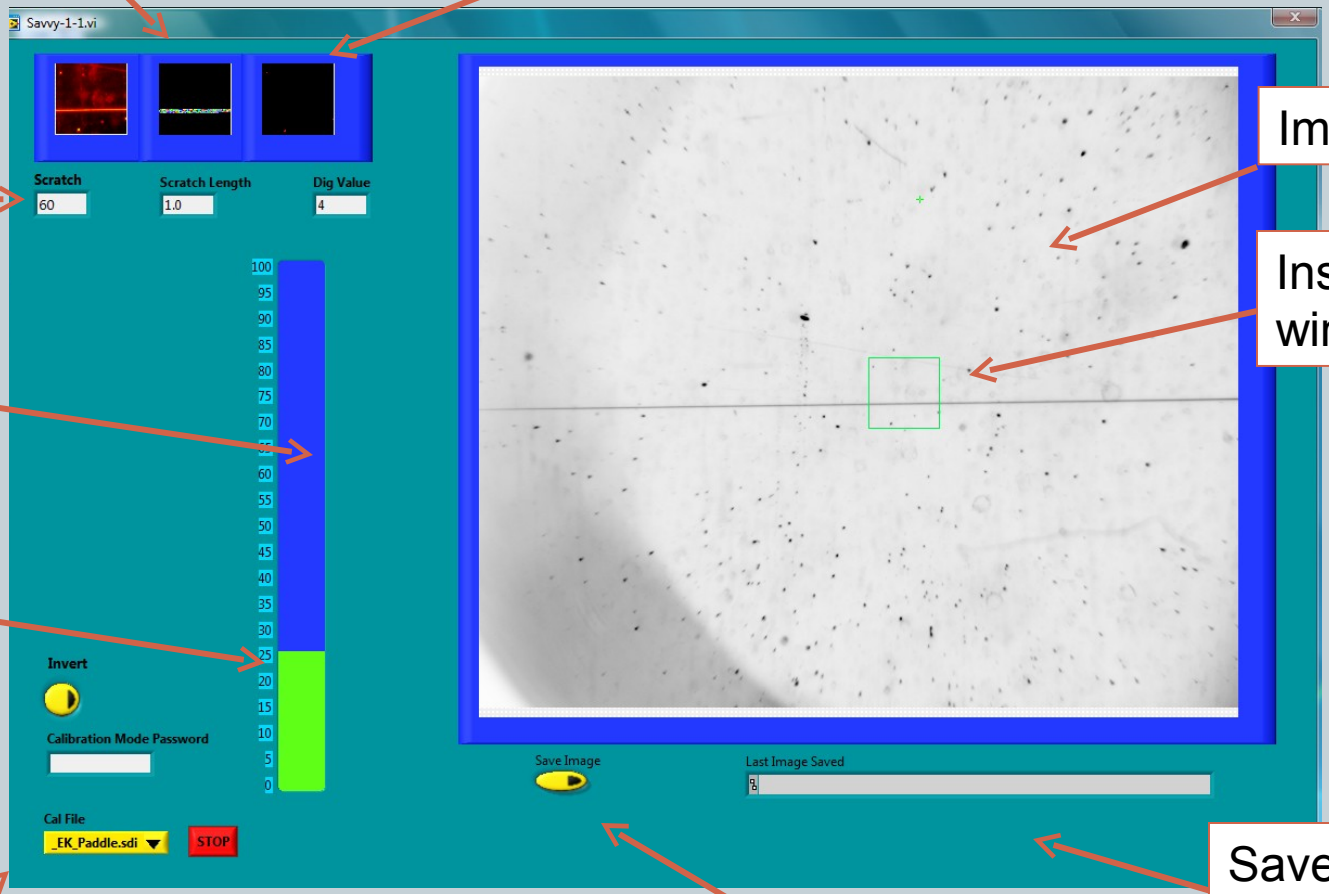
- Increased illumination angles slightly to improve repeatability
- Tailored brightness and integration to make #10 just visible on camera



The Savvy Inspector ™

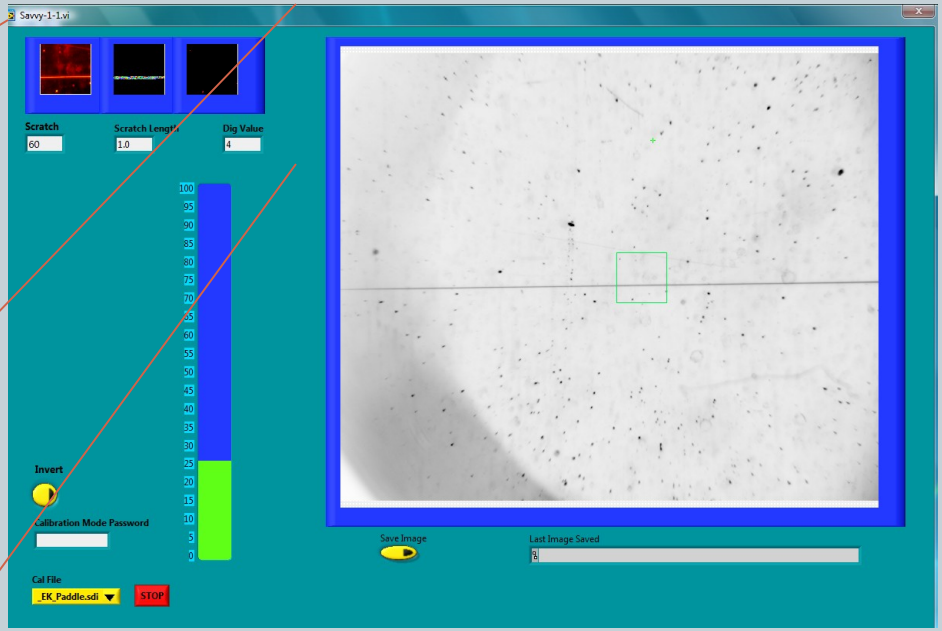


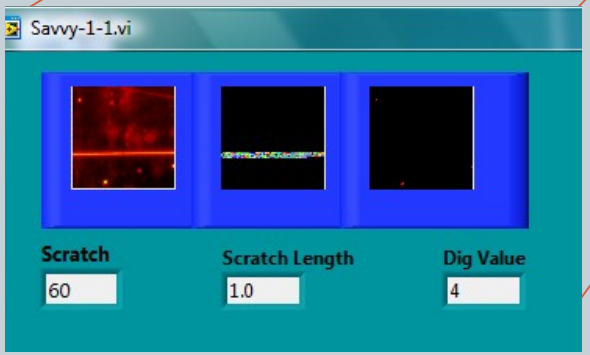
The Savvy Inspector™ Software is the key to the inspection



Inspection mode

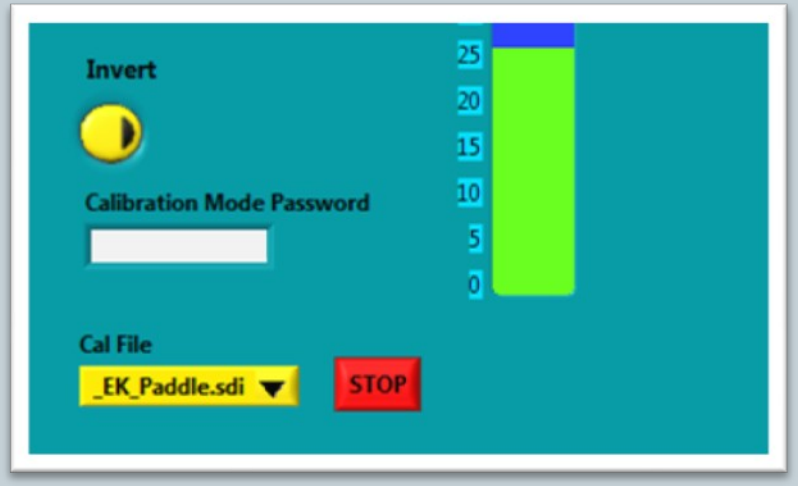
- Part is visually inspected to generate rough map
- Imperfections are viewed with Savvy Inspector™
- SavvyInspector™ is used to determine scratch and dig values



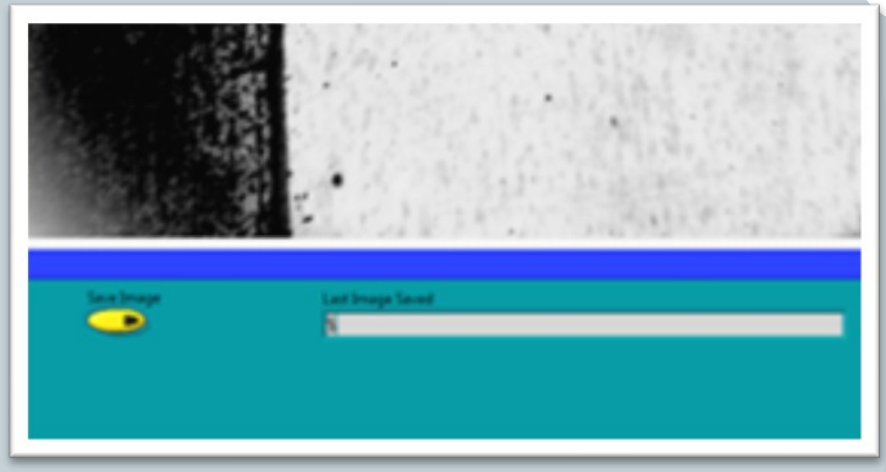


Inspection mode, continued

- User can select from menu of calibration files for scratch evaluation
  - Factory calibrations which cannot be altered
  - Custom calibrations generated by tool owner
- Factory calibrations based on sequestered set of all important comparison artifacts
  - Davidson, transmissive and reflective
  - Brysen, transmissive and reflective
  - Jenoptik (current revision paddle)
  - Eastman Kodak paddle



Inspection mode, continued



- Image files are saved to a folder with part information for future reference
- Values for scratches and digs entered into Savvy Accumulator spreadsheet for pass-fail determination

Scratch and Dig Accumulation Spreadsheet © 2009 Savvy Optics Corp

Part number	asdflkasdflkj
Serial number	123
Comment	this is a cool spreadsheet

Specification (e.g. 80-50) Scratch: 80 Dig: 50

Part diameter in mm: 25.0

allowed digs: 2
Allowed dig sum: 200 over part
Allowed concentration: 100 in 20 mm

Allowed max scratch total length: 6.25 in mm
Allowed total scrach accumulation: 80 if max scratch present
160 if no max scratch present

Concentration rule does not apply: N/A <-- leave this cell blank

Scratch inspection data

Scratches	Scratch grade	length in mm	relative length
Scratch #1	80	0	0.00
Scratch #2	60	0	0.00
Scratch #3	40	0	0.00
Scratch #4	20	0	0.00
Scratch #5	10	0	0.00
Scratch #6	0	0	0.00
Scratch #7	0	0	0.00
Scratch #8	0	0	0.00
Scratch #9	0	0	0.00
Scratch #10	0	0	0.00

Dig inspection data

Digs	Dig grade	within worst 20mm dia?
Dig #1	50	n
Dig #2	40	n
Dig #3	30	n
Dig #4	20	n
Dig #5	10	n
Dig #6	5	n
Dig #7	0	n
Dig #8	0	n
Dig #9	0	n
Other digs	0	n

Max scratch: pass
Max scratch length: pass
Scratch Accumulation: pass
Concentration: pass
Scratch pass/fail overall: pass

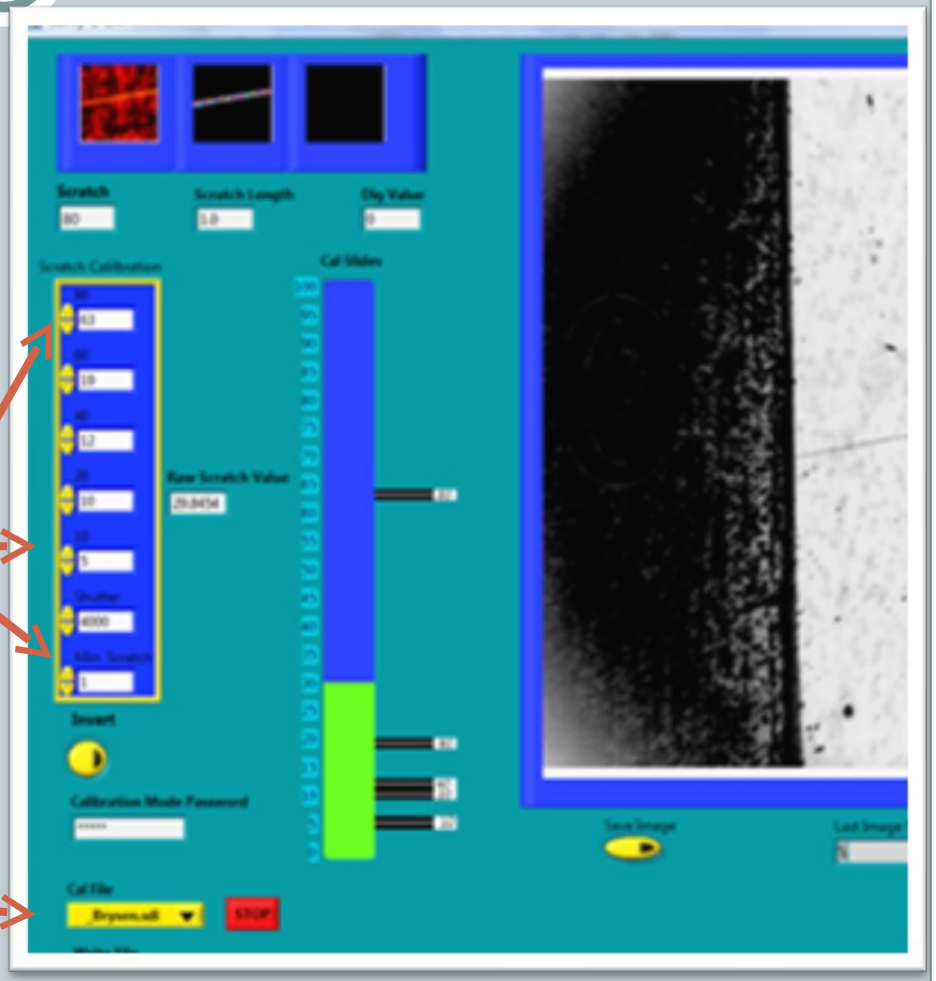
Max dig: pass

Dig accumulation: pass
Dig concentration: pass
Dig pass/fail overall: pass

(user enters data in all cells marked in green:)

Calibration Mode

- User can enter calibration mode password to create new calibration files
- A comparison artifact of a given number (e.g. #20) is loaded, and the relative visibility is recorded here
- The calibration file is stored
- The new calibration appears on the calibration file pull-down menu



Alpha testing observations

- Very little sensitivity to ambient light
  - Tested room lights, full sun
  - No issue for most measurements
  - Darkened room preferred for calibration
- Signal level
  - Can see digs < 5 microns diameter
  - Can see the #10 scratch for all sample sets tested
- Different comparison samples show significant difference in visibility
  - In worst cases, more than a factor of 4 in signal level (#10)
  - Typically about a factor of 2
- In all cases, sensitivity to dust, lint indicates clean hood operation will be preferred

Preliminary performance testing results

- Jenoptik paddles
  - Excellent scratch differentiation and repeatability
  - Great set-to-set reproduceability
  - Expect GRR of < 10% for most inspections
- FLIR/Brysen samples
  - Good repeatability
  - Excellent results for all but #40
  - #20 and #40 very close in visibility; difficult to differentiate them
    - Correlates with visual inspection, however
  - Need to check set-to-set variability
- Davidson Optronics comparison samples
  - Initial results excellent for all scratch values
  - Signals similar to those for Jenoptik paddles
  - Set to set variability may be an issue

Calibration mode has been used to compare different comparison artifact standards

Scratch	Brysen	Davidson	EK Paddle	Jenoptik Paddle
#10	5	9	13	23
#20	10	12	16	29
#40	12	15	24	35
#60	19	50	28	39
#80	63	58	48	48

- Measurements done under identical illumination conditions
- Camera integration time set to make Brysen #10 visible
- Multiple samples were averaged where available
- Conclusion; there is weak correlation in reflective visibility between different makes of comparison artifact standards

Product Development Status

- Product development is complete for now
  - Software and documentation development will continue
  - System proven to provide reliable, repeatable results with all available comparison standards
- Unit #1 currently available for demonstrations
  - Requested to bring unit to Picatinny for evaluation in June
- Unit #2 to be deployed at two beta sites, in series
  - Anticipate that further software improvements will result
- Currently booking production orders for July shipment
  - Pricing and availability will be provided on request

Summary

- Software assisted scratch inspection is an excellent solution to the scratch visibility problem
  - Very repeatable
  - Easy to calibrate
  - Easy to operate
  - Permanent record and traceability
- Current configuration is manual, flat-only
  - Curved surface version under development next
  - Motorized version can be developed on request
- SavvyInspector™ takes the subjectivity out of the scratch inspection process
  - Scratches are easy to “see” with this instrument
  - Gets the same answer every time under normal conditions
  - Expect excellent GR&R results for this measurement