Investment Casting Metrology Growth and Sustainability

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Hitchiner Manufacturing Inc.

2022

15th WCIC 2022
INVESTMENT CASTING
It's A Small World After All

Introduction

Investment casting process is timely and costly, so dimensional integrity is vital to the success of delivering a quality part on time. Metrology must strategize and purchase equipment to maintain dimensional growth parallel with its customers to be competitive. This being stated, the field of equipment can be very broad and confusing, but the staple of this field is the Coordinate Measuring Machine (CMM), having various manufacturers and in different configurations.

This timeline of growth focuses on the foremost of contact to non-contact inspection and how Hitchiner derived to utilize castings for Aerospace, Automotive and Military.

Early Years of Metrology

- Early to mid-2000, numerous machines were being used in Metrology.
  - Manual and DCC CMM – used for calibration, FAIRs, Deltas, production machining, and part sorting
    - ✓ Line scripting was used with part print.
    - ✓ Block editing – DOS or UX-UNIX, Linx
    - ✓ To correlate and verify programming. two software languages were used.
  - Some of the numerous CMM software.
  - - MM3, MM4, UMESS, COSMOS, and AVIL.
  - Parametric scripting was very helpful as it kept the operator within the program.

```
MAIN_MENU  = TEXT/PROMPT; {
1.PROBE_CAL
2.MULT_FIXTURE_ALIGN
3.PART_RUN_MENU
4.EXIT_MENU
```

```
            BRANCH/TEST; MAIN_MENU, EQ, 1, PROBE_CAL
            BRANCH/TEST; MAIN_MENU, EQ, 2, MULT_FIXTURE_ALIGN
            BRANCH/TEST; MAIN_MENU, EQ, 3, PART1
            BRANCH/LABEL; EXIT_PROGRAM
```

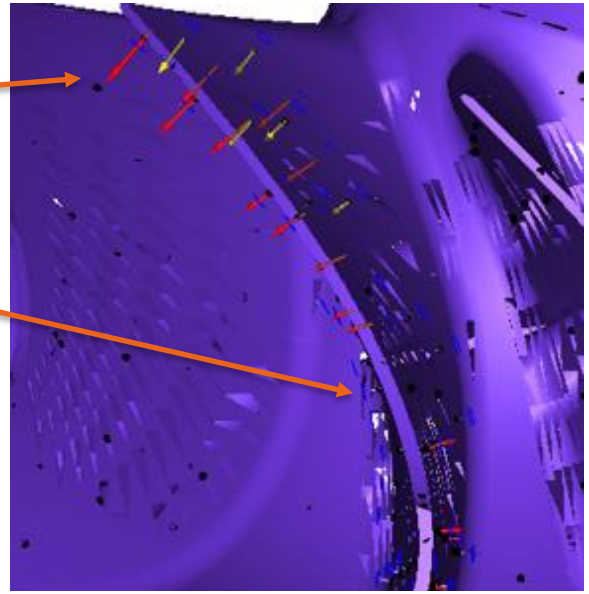
```
! #######PROBE CALIBRATION START##################################
```

```
PROBE_CAL  = LABEL/;
             TEXT/WRITE; SCREEN, {
%USE A MOTORIZED HEAD PH9A W/ TPS-5WAY+BLACK EXT
%5MM STYLUS+5MM EXT OR EQUAL S/U
%MASTER BALL SPHERE CLUSTER IN PLACE AND CLAMPED
                                                        }
```

```
            UNITS/ANGLES; DEG, DEG
            UNITS/ENGLISH;
            SETUP/MEASUREMENT; MANUAL, AUTO_OFF
            TEXT/WRITE; SCREEN, {
%USE A MOTORIZED HEAD PH9A W/ TPS-5WAY+BLACK EXT
%5MM STYLUS OR EQUAL S/U
%MOUNT MASTER SPHERE CLUSTER IN CENTER OF PLATE
```

CMM programming with Models

- Late 2000s Introduction of Model Based CMM Programming
  - CAD programming was being done and new updates were coming each year
  - CMM graphics software integrated:
    - IJK surface recognition
    - Model deviation with graphical reports
    - Iterative Alignment – 6-Point movement
    - Best-Fit alignment – weighted 2D or 3D
  - Customer models can be imported and used for FAIR:
    - CAD to print evaluations
    - Interrogation of section rotations
    - Graphical report and excel freedom



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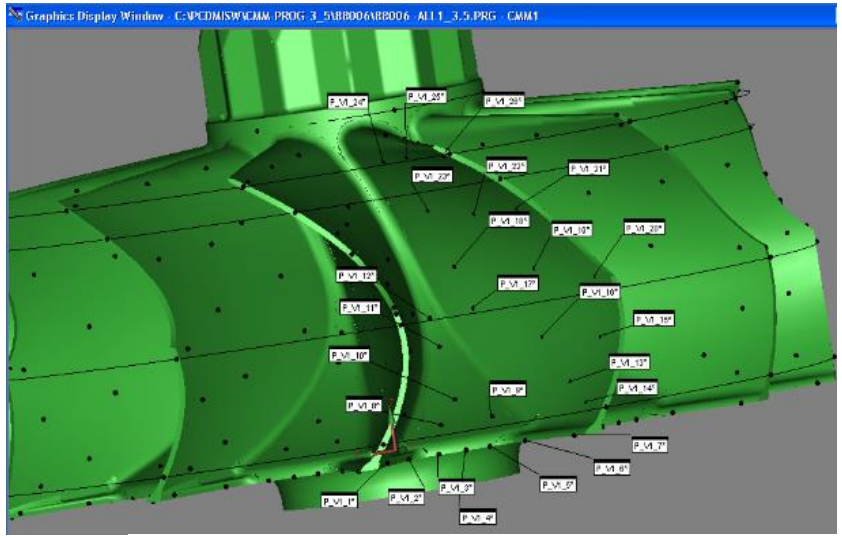
	DIM_ANG_020	Dim Loc (CON_A1)	Y	-0.006	-0.001	0.009	-0.002	-0.012	1.000	-0.012	0.009			
	DIM_ANG_020	Dim Loc (CON_A1)	Z	47.888	47.888	47.888	47.888	47.888	1.000	47.888	47.888	47.888	47	
	DIM_ANG_020	Dim Loc (CON_A1)	A	29.554	29.487	29.669	29.539	29.641	0.000	29.487	29.669	29.487	29	
	DIM_TOP_HEX1	Dim Loc (PNT_TOP_HEX_1)	Z	52.418	52.452	52.467	52.489	52.438	1.000	52.418	52.489			
	DIM_TOP_HEX1	Dim Loc (PNT_TOP_HEX_1)	T	-0.082	-0.048	-0.033	-0.011	-0.062	1.000	-0.082	-0.011			
	DIM_TOP_HEX3	Dim Loc (PNT_TOP_HEX_2)	Z	52.422	52.463	52.470	52.474	52.432	1.000	52.422	52.474	52.418	52	
	DIM_TOP_HEX3	Dim Loc (PNT_TOP_HEX_2)	T	-0.078	-0.037	-0.030	-0.026	-0.068	1.000	-0.078	-0.026	-0.082	(0	

CMM Flexibility and Growth in 2009

- Programming with CAD was now a staple
  - Manual CMMs were used for quick setups and calibration
  - DCC CMM were updated, and FAIR/Delta were being processed with customer models
  - Correlations were clearer and had more visual deviation
  - Running programs needed less instructions as model showed the points to hit in setup mode
  - Copy, rotation, increment showed on the model once completed.

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''DATE INSP _' : 11/4/2009

STATS/ON

DIM DIM_ANG_020= LOCATION OF CONE CON_A1  UNITS=MM
AX    NOMINAL       +TOL       -TOL       MEAS        DEV     OUTTOL
X       0.000       0.050      0.050     -0.001      -0.001      0.000 ---#----
Y       0.000       0.050      0.050     -0.006      -0.006      0.000 ---#----
Z      47.888       0.050      0.050     47.888       0.000      0.000 ---#----
A      30.000       0.500      0.500     29.554      -0.446      0.000 #-------

DIM DIM_TOP_HEX1= LOCATION OF POINT PNT_TOP_HEX_1  UNITS=MM
AX    NOMINAL       +TOL       -TOL       MEAS        DEV     OUTTOL
Z      52.500       0.150      0.150     52.418      -0.082      0.000 -#------
T       0.000       0.150      0.150     -0.082      -0.082      0.000 -#------


Z      52.500       0.150      0.150     52.422      -0.078      0.000 -#------
T       0.000       0.150      0.150     -0.078      -0.078      0.000 -#------

DIM DIM_BASE_HEX1= LOCATION OF POINT PNT_BASE_HEX_1  UNITS=MM
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Z      49.000       0.150      0.150     48.956      -0.044      0.000 --#-----
T       0.000       0.150      0.150     -0.044      -0.044      0.000 --#-----

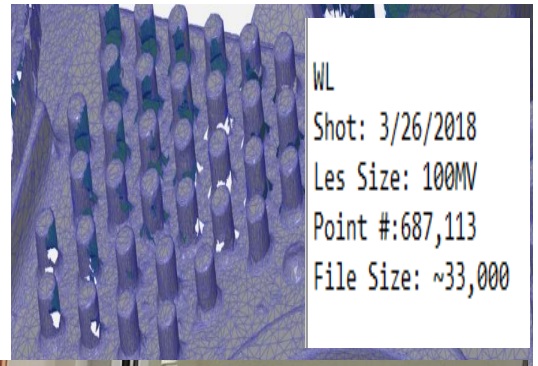

Z      49.000       0.150      0.150     48.929      -0.071      0.000 --#-----
T       0.000       0.150      0.150     -0.071      -0.071      0.000 --#-----

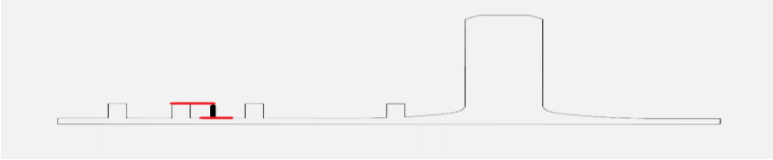

Z      49.000       0.150      0.150     48.914      -0.086      0.000 -#------
T       0.000       0.150      0.150     -0.086      -0.086      0.000 -#------


Z      49.000       0.150      0.150     48.927      -0.073      0.000 --#-----
T       0.000       0.150      0.150     -0.073      -0.073      0.000 --#-----
```

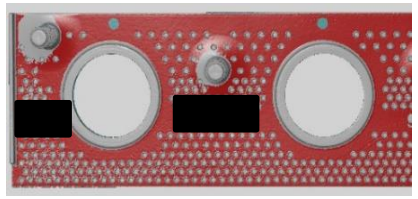
2010 – Customers Required More

- CMM technology and software had made great strides in advancement but with limitations
- Complex floatwall castings posed a definite dimensional problem for the CMM
  - Customer wanted all surfaces to be checked – pin height of all pin arrays
  - Floatwall castings could have hundreds of pins at different heights
- Various inspection systems reviewed
  - Laser, Optical, Structured Light, & Vision System
- Metrology selected single system
  - White Light 4MP System
  - Non-Contact 3D Inspection
  - CAD based programming and inspection
  - Produced Color Maps for 3D Surface inspection

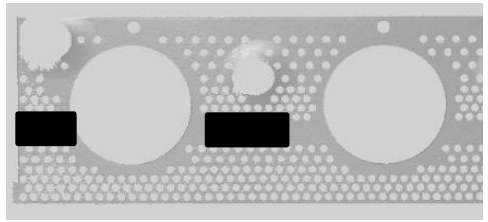




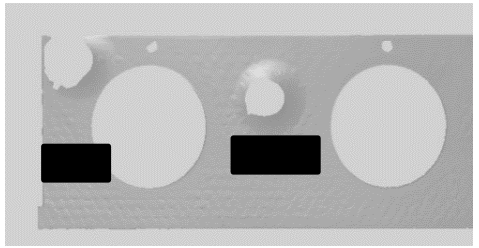
2011 – Problem to a Resolve – Technology Inspection Strategy



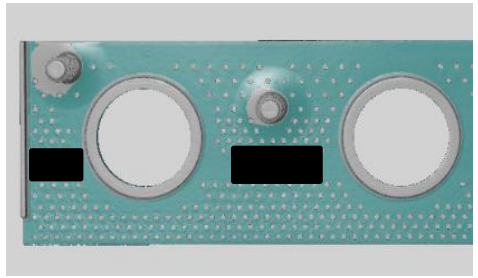
The irregular pin base is show here in RED. *Note this is not overlayed to a plane or cone feature.*



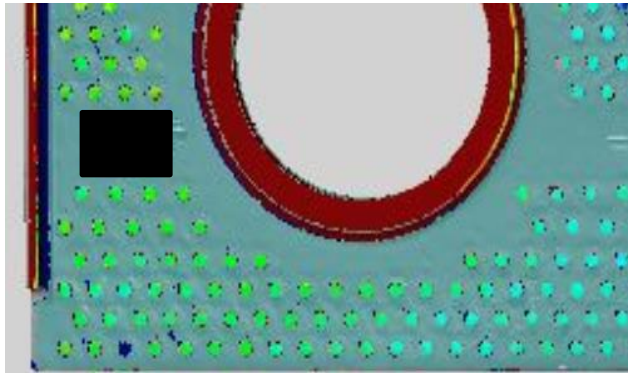
Foil is segregated from the mesh and is rendered as a separate mesh – pin holes are visible



Foil pin holes are filled - you can see the filling of the pin holes



Foil and original mesh are then combined. Foil is set to ensure the software calculates correctly.

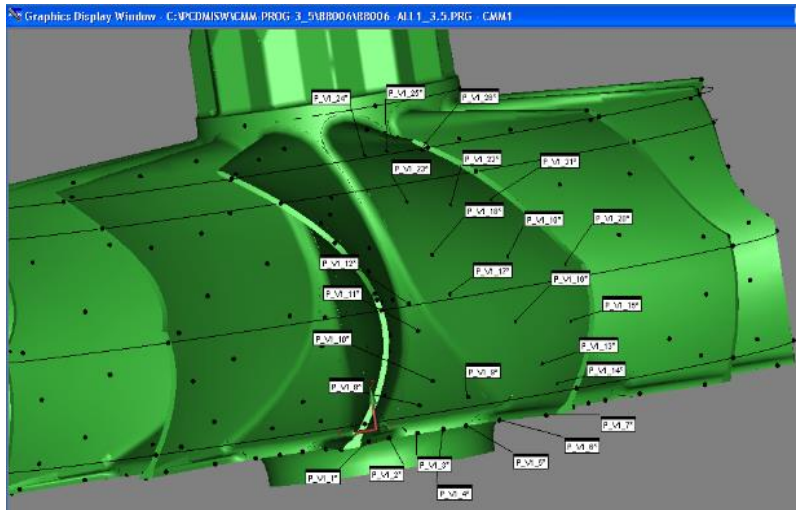


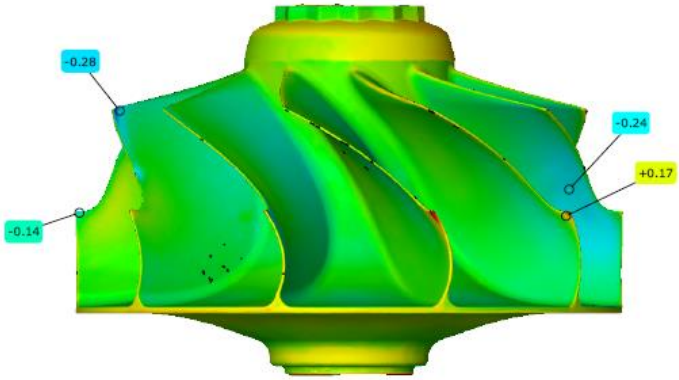
Original mesh is now combined, and now a full 3D pin base is available to create a full deviation color map with actual accurate readings.

Metrology's pin height issue was resolved, and all pins are now evaluated using this method

Customer Approval and Integration

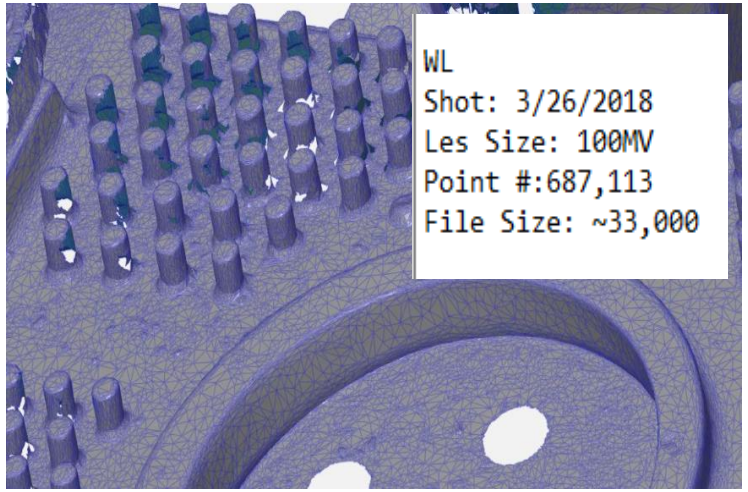
- Customer approved WL inspection method.
  - Fully integrated into FAIR procedure
- Increasing internal inspection demand
  - WL correlation to CMM programs
  - Check tool rework for confirmation
  - Color Map castings for inspection/R&D
- White Light Inspection became bottleneck
  - Slow shooting process
  - Increased demand
  - Large Cycle Times
- Secondary Sensor needed to break bottleneck.

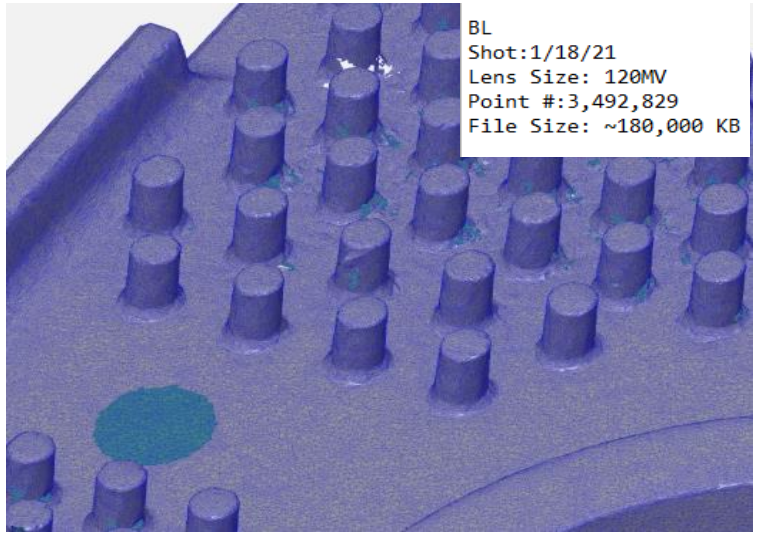




Introduction of Blue Light

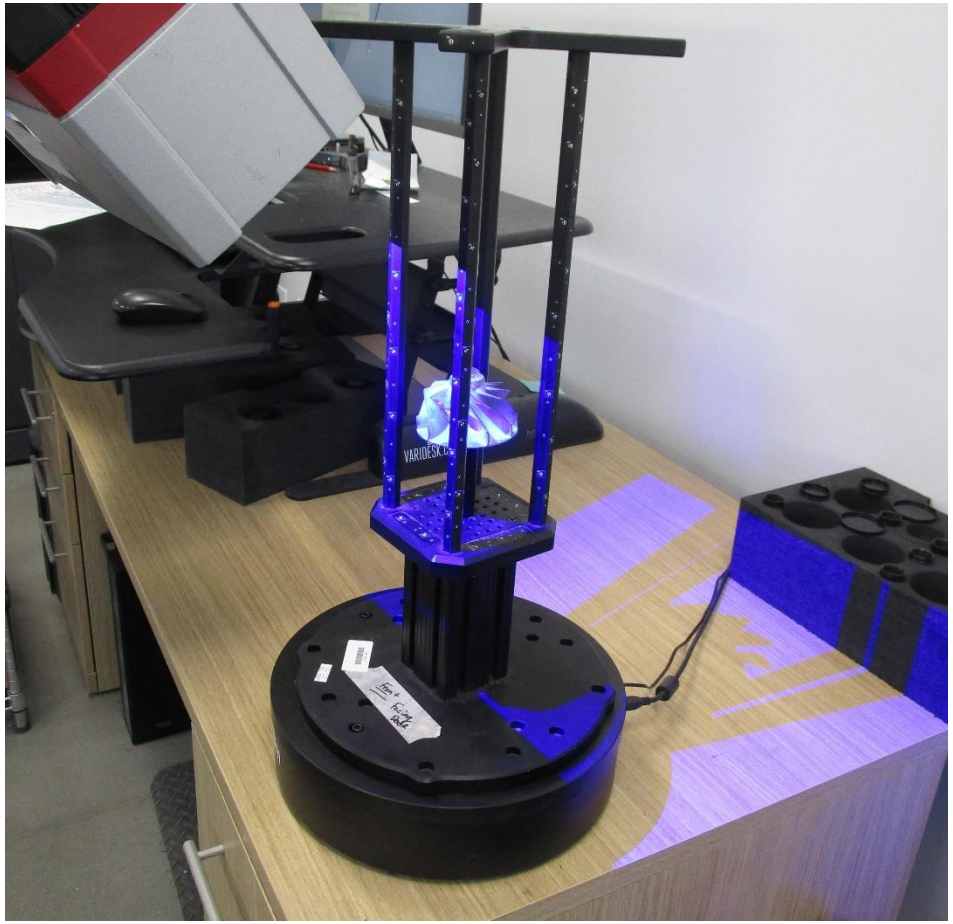
- Metrology purchased new system to meet demand
  - ATOS Capsule 12MP BL Sensor
  - 3x more resolution than WL Sensor
- Improvements
  - BL produced 3x higher point density
    - Reproduce finer details
  - Captured more data per shot
    - Less shots = shorter cycle time
  - Less affected by ambient light
  - Stereo – mono point capture





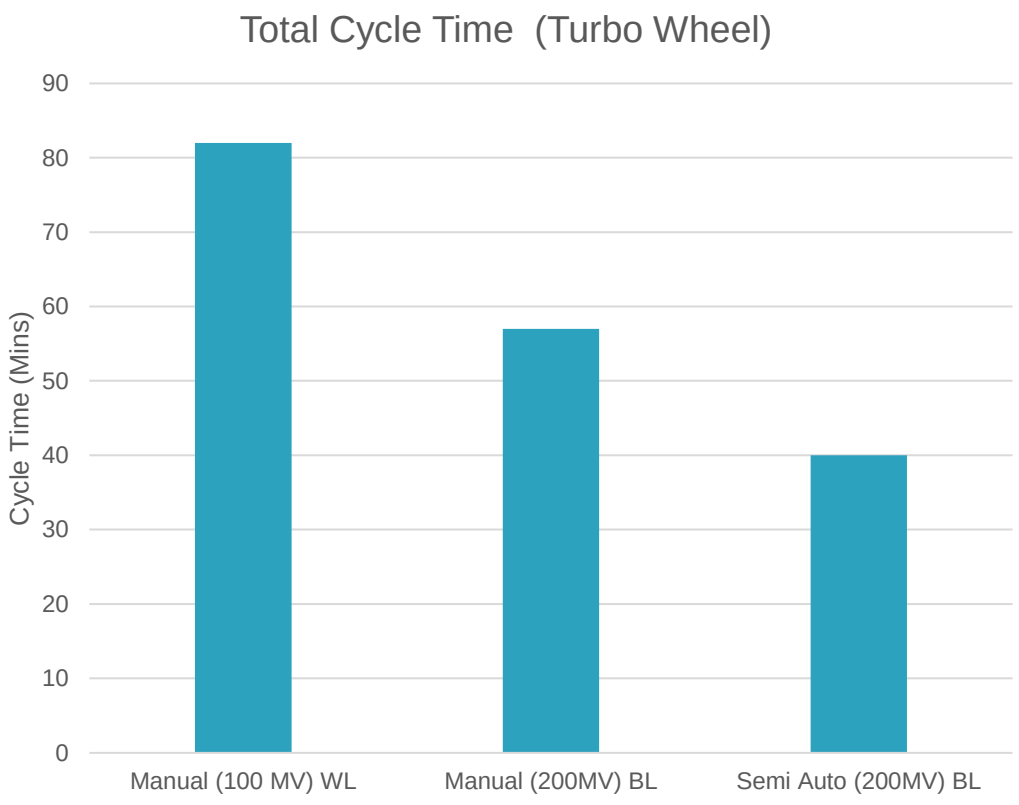
WL to BL – Doubling Capacity

- Increasing demand created second bottleneck
  - Decreased Cycle Time from WL to BL
  - FAIR Demand/Tool Inspection increased dramatically as a result
- Metrology purchased second BL system
  - Replace WL system to help meet demand
- Added two rotary tables
  - Turned manual BL systems into semi-auto
  - Attempt to decrease cycle time to increase throughput



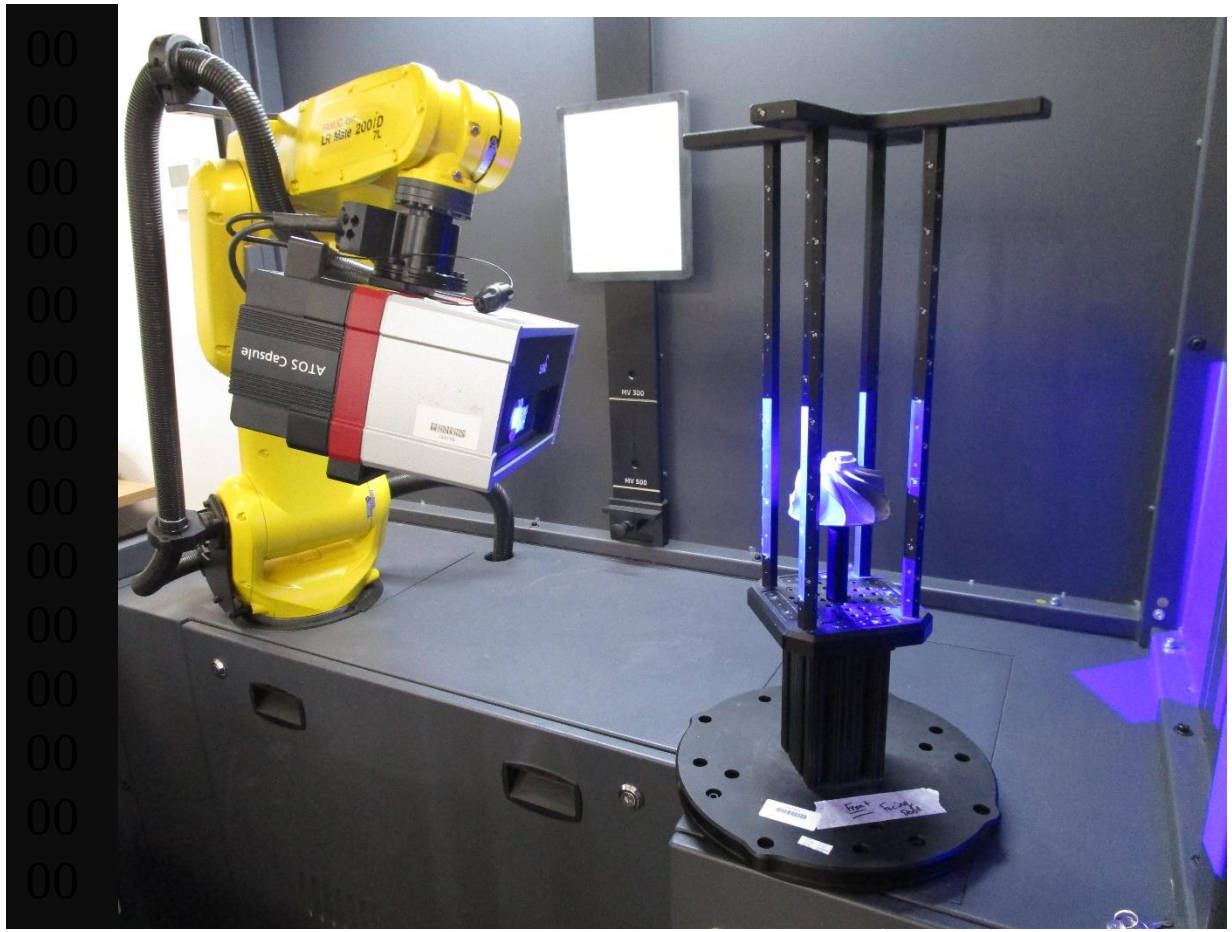
BL – Manual To Semi-Auto

- Definitive Reduction in Cycle Time
  - Manual WL to Manual BL = 29%
    - Increased Capacity
  - Manual WL to BL Semi-Auto = 59%
    - Maintain Same Accuracy
- Demand still increasing
  - Increased R&D volume
  - Increased FAIR and Deltas
  - Increased CPK studies
  - Increased tooling inspection



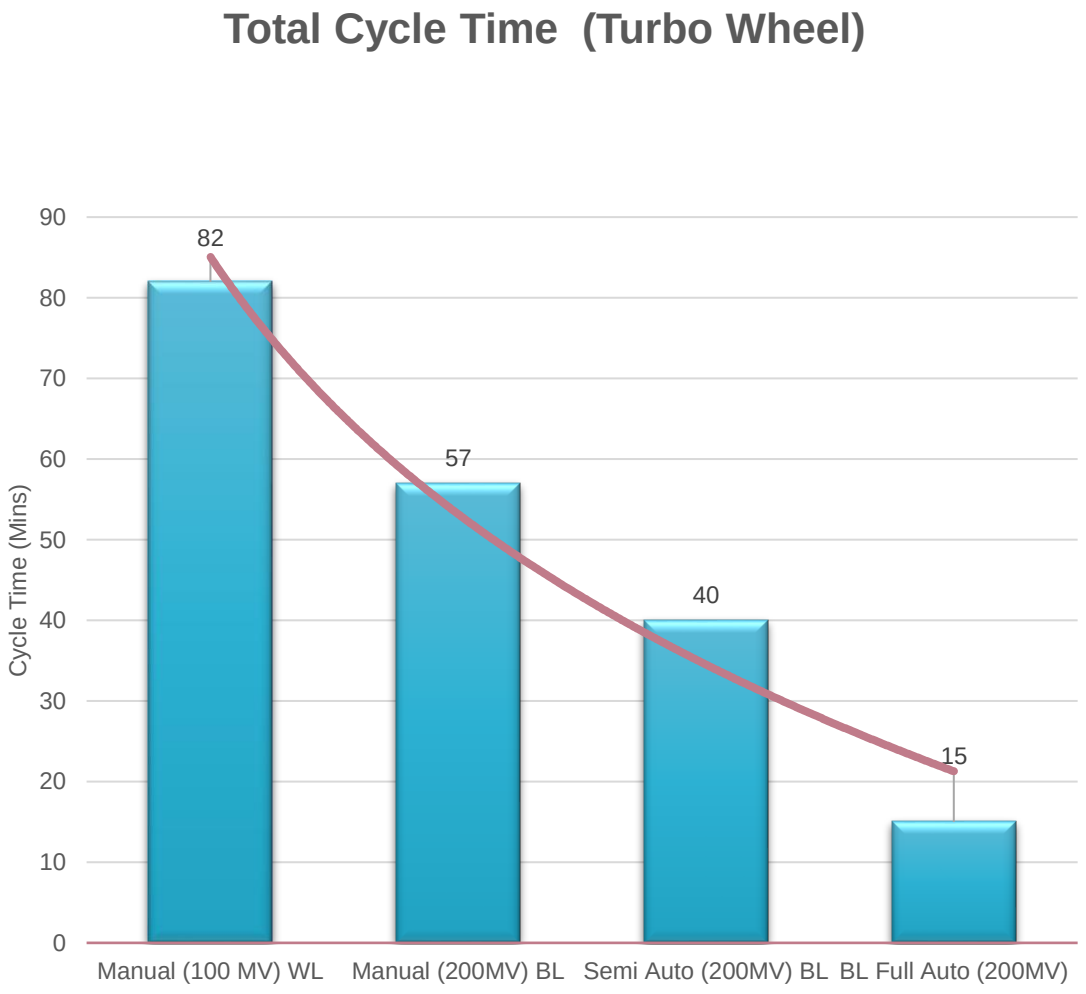
BL – Semi-Auto to Full Automation

- Metrology acquired fully–automated unit to meet demand
  - ATOS ScanBox from Capture 3D
  - DCC Fanuc Robot Arm with attached Capsule
- Programmable scanning routine
  - Program shooting positions
  - Software calculates path for speed and collision avoidance.
  - Increased repeatability with increased speed.

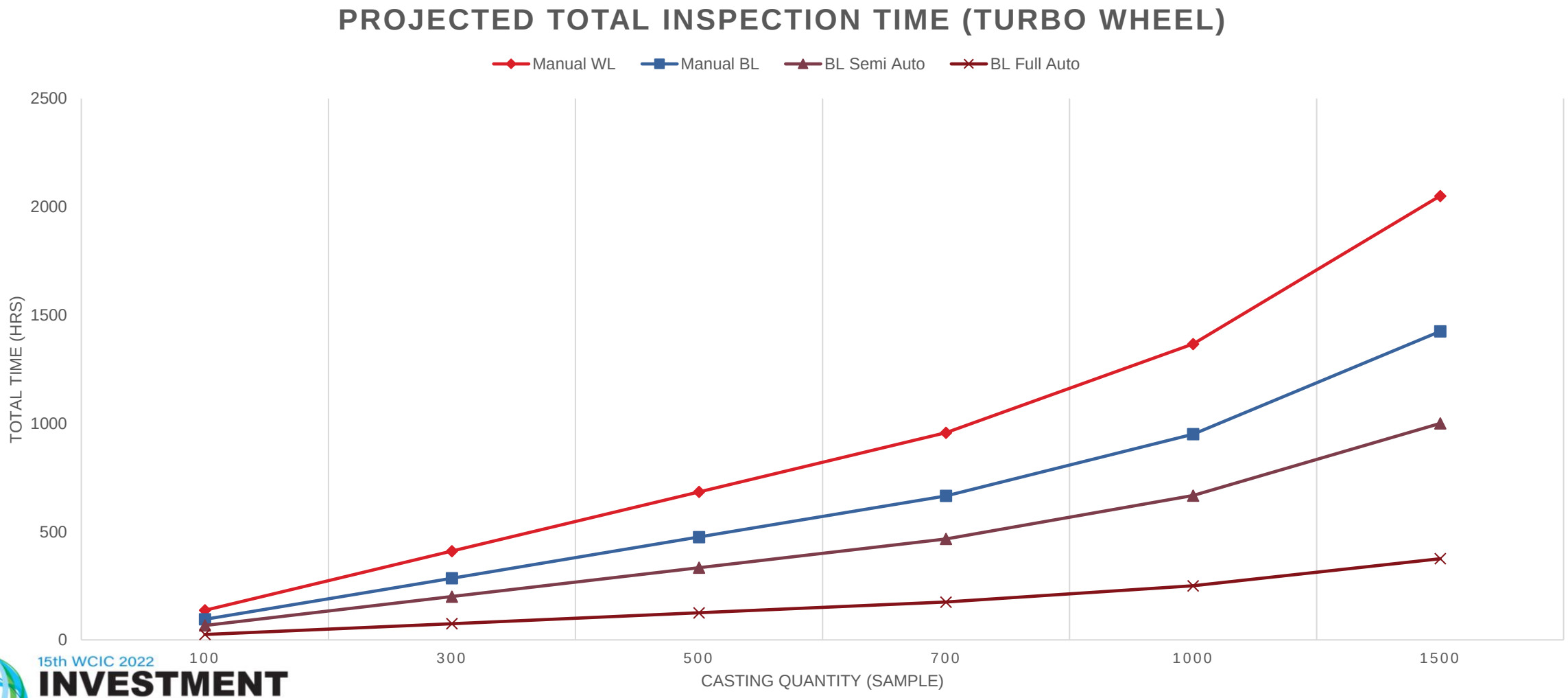


Structured Light Life Cycle

- Dramatic decrease in cycle time
  - Manual WL to Full Auto = 81%
  - Manual BL to Full-Auto = 73%
  - Semi-Auto to Full-Auto = 63%



Projected Total Inspection Time

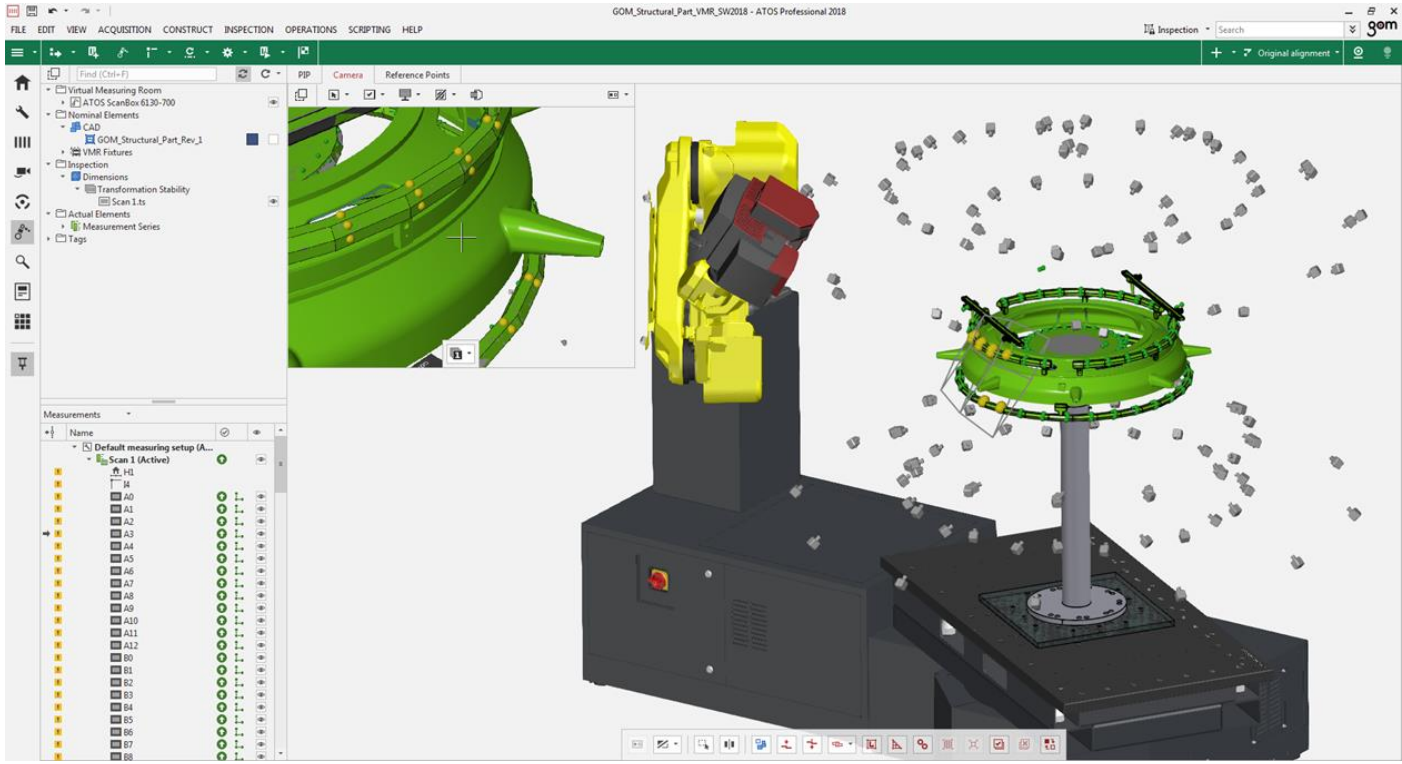


Business Challenges with Hitchiner

- Profitability – Pinpoint challenges in QMS and Manufacturing Processes
- Efficiency – Real Time Data Feedback Loop
- Visibility – Information that is vital to clear transparency
- Process Improvements – By understanding QMS and Manufacturing Processes with Individual Machine Performance.
- Understand Bottlenecks and Improve Cycle-Time. Reduce Non-Conforming Parts.

Collaboration with Hitchiner

- Virtual measurement process
  - Measuring setup
  - Simulated reference points
  - ATOS measurement series
  - Ensure mesh completeness
  - Transformation stability check
  - Estimate the cycle time

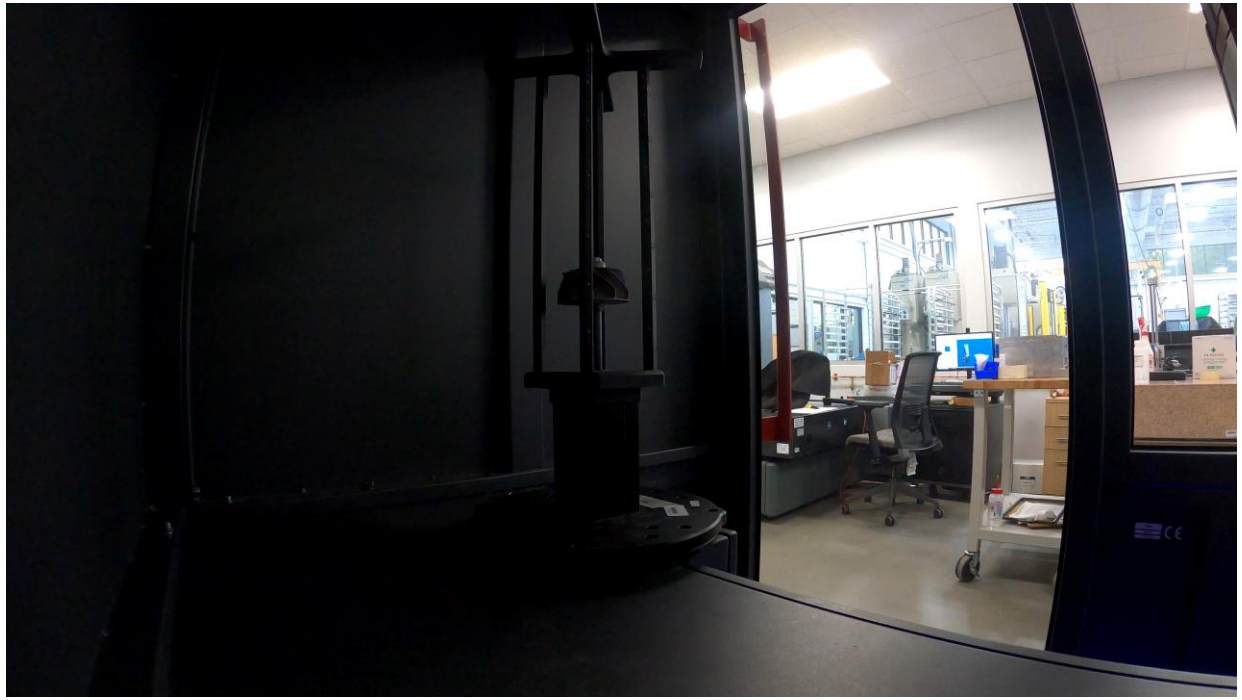


Capture 3D – Customer Support

- Reviewing processes with Hitchiner
  - Understanding customer needs
- Generating financially sound business case
  - Economically aided Hitchiner
- Creating a winning team
  - Consistent support for Structured Light team
  - Collaboration focus on success
- Make long term improvements
  - Mutually beneficial relationship with Hitchiner

Summary

- Advancement in Structured Light and CMM capabilities have allowed Hitchiner to grow within multiple markets
- Improvements within Metrology methods have sustained meeting customer print requirements
- Improved casting historical traceability
- Able to fully meet production demands
- Improvements within new product introduction process



Questions?