Increase AM Yield: Final Report

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Data Science Career Track - Capstone Project #1
GitHub Project Link
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Springboard

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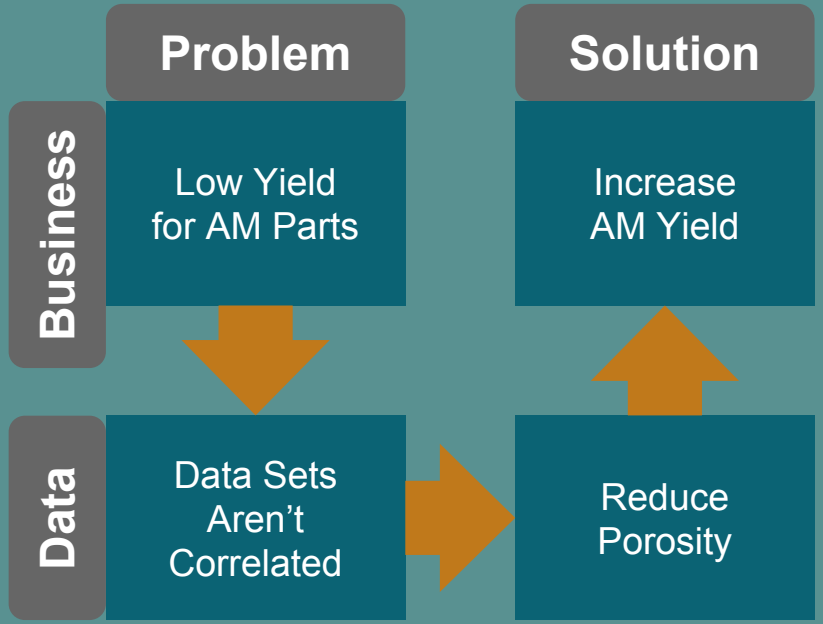
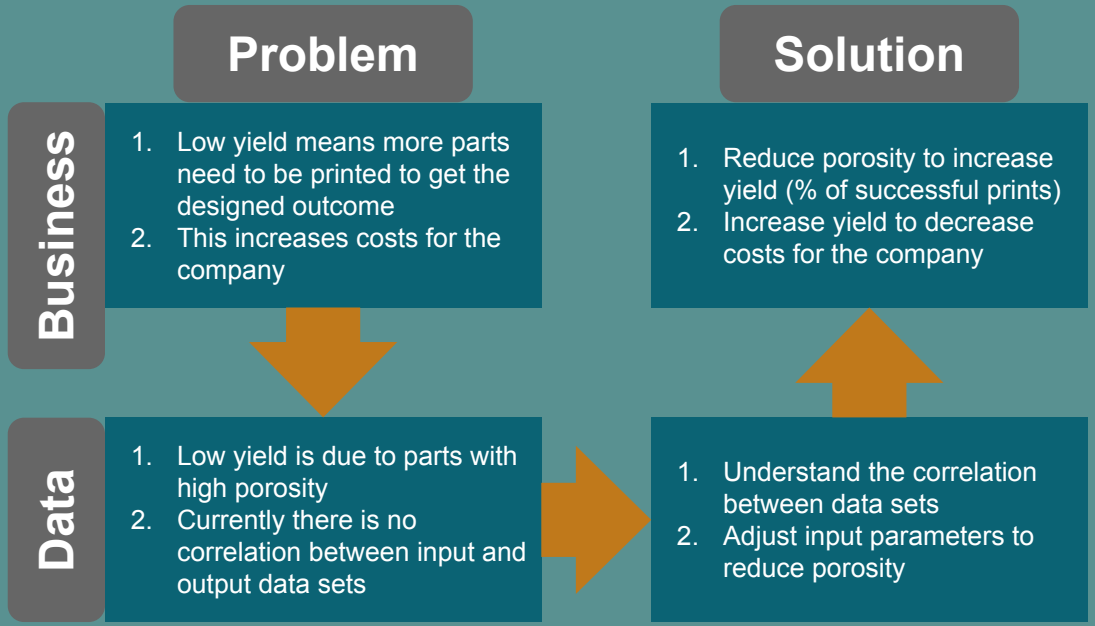
Project Flow

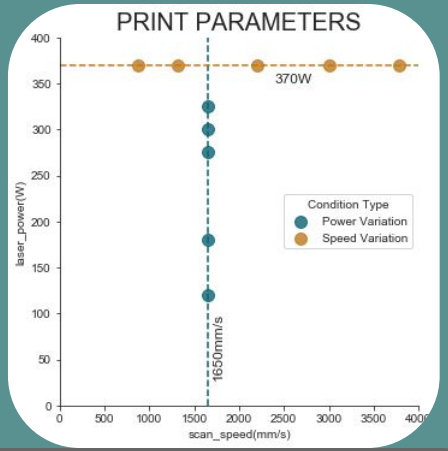


Project Flow - Details



Section 2:
Data Collection

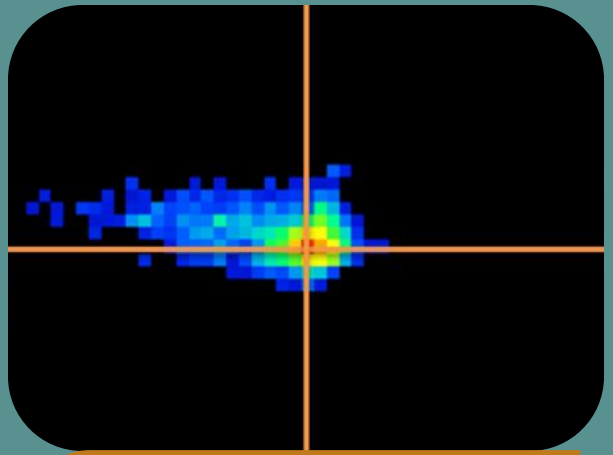
3D Printer



Print Parameters

These are inputs in the printer prior to the build process. Each is kept constant throughout the entire build. A collection of parameters is called a “condition”. 10 conditions were selected for this project.

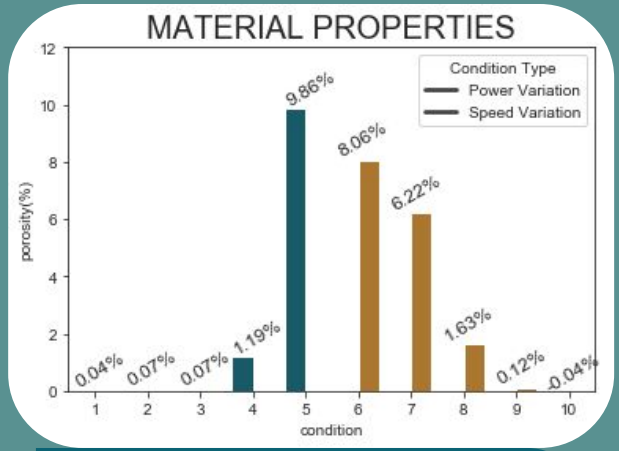
Sensor



Melt Pool Metrics

A thermal imaging sensor collects data on the melt pool during the build process. Due to the volatile nature of the physics involved, this data can be very noisy. Metrics are extracted from each image.

Testing



Material Properties

After the build is complete, a porosity test is conducted for each of the 10 samples, ranging from 0-10%. An ideal build has a porosity of 0%, also known as a fully dense part.

3D Printer

Print Parameters

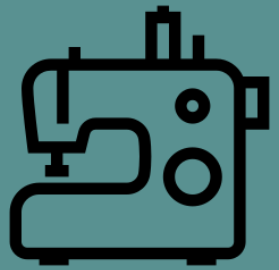
- Laser Power
- Scan Speed
- Layer Height

Sensor

Melt Pool Metrics

- Temperature
- Length / Width / Area
- Spatter

Testing

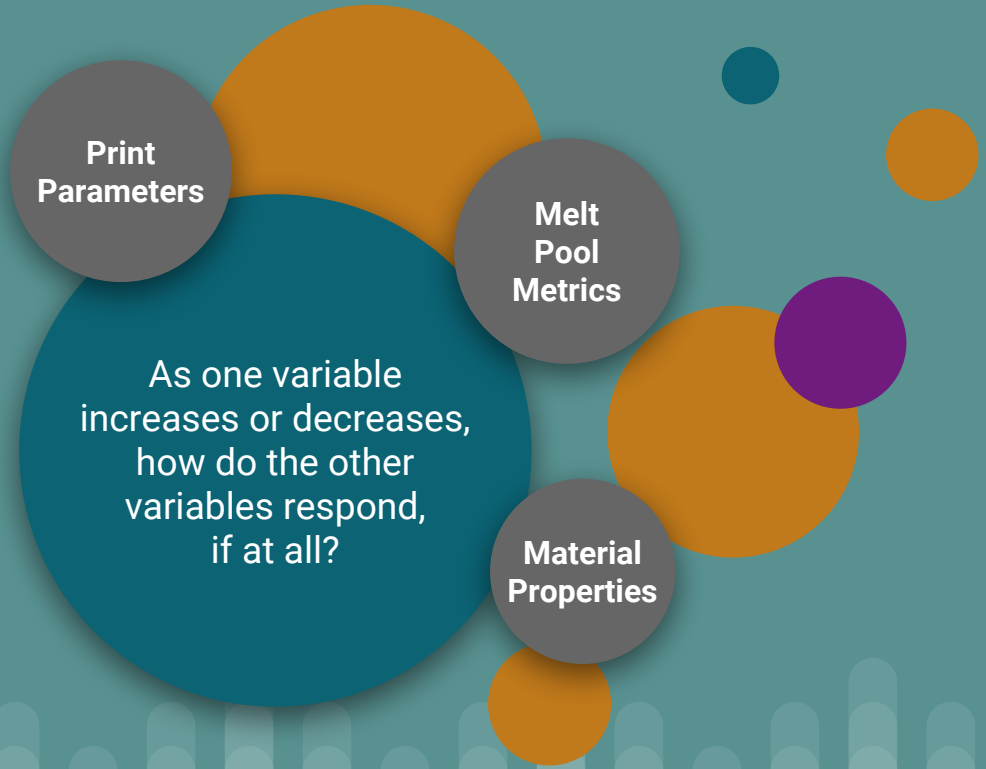


Material Properties

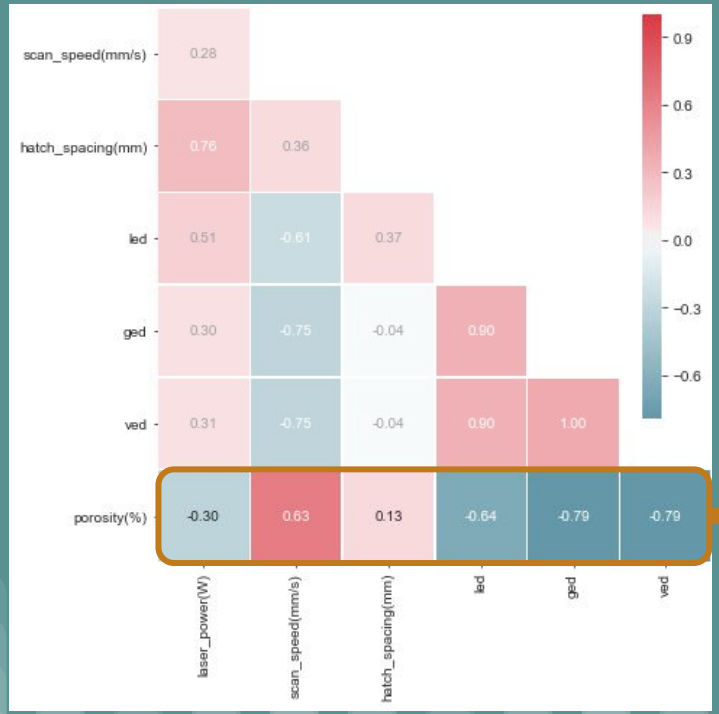
- Porosity

Section 3: Exploratory Data Analysis

Correlation

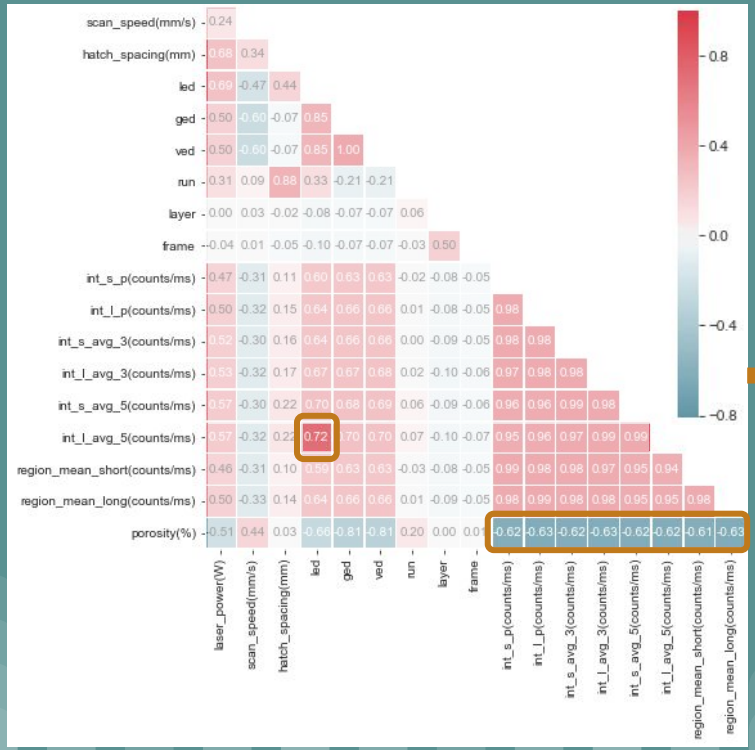


Print Parameters vs. Porosity



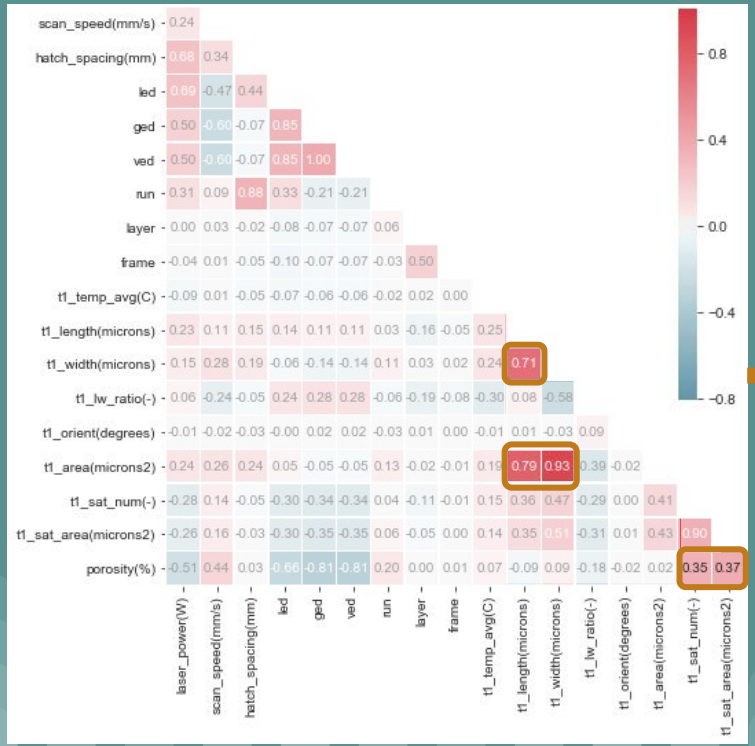
Porosity Correlations	
Laser Power	-0.30
Scan Speed	-0.63
Hatch Spacing	0.13
LED	-0.64
GED	-0.79
VED	-0.79

Print Parameters vs. Melt Pool Metrics vs. Porosity



Correlations		
Long Intensity (5)	LED	0.72
Intensity Values	Porosity	-0.61 to -0.63

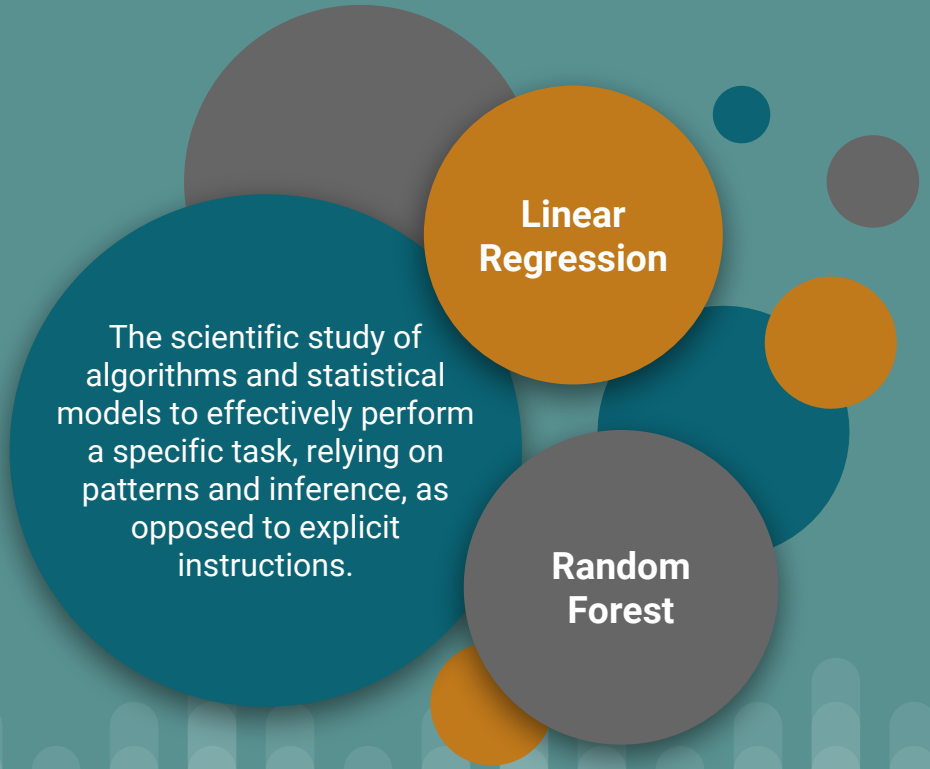
Melt Pool Metrics vs. Porosity



Correlations		
Length	Width	0.71
Length	Area	0.79
Width		0.93
Number of Satellites	Porosity	0.35
Area of Satellites		0.37

Section 4:
Machine Learning

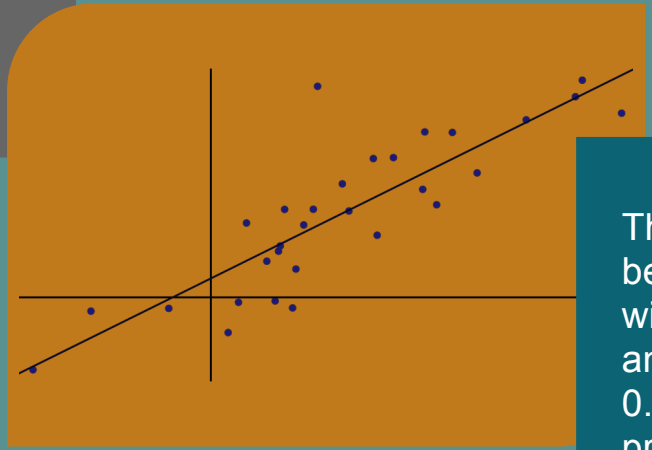
Machine Learning



Linear Regression

The act of fitting a line to two or more variables to show a linear relationship between them.

Variable	Coeff
GED	1400
Hatch Spacing	2.3
Scan Speed	0.0
Laser Power	-0.1
VED	-41
LED	-304

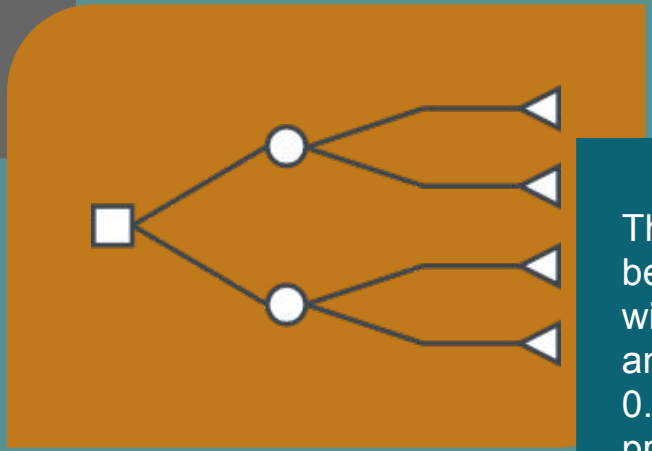


The Print Parameters were the best in predicting the Porosity, with an RMSE value of 0.638 and an R-Squared value of 0.952. The best individual predictor was GED with coefficient of 1400.

Random Forest

Many decision trees are used to separate the data into groups to determine their outcomes.

Variable	Import.
VED	0.50
Scan Speed	0.32
LED	0.17
GED	0.01
Laser Power	0.00



The Print Parameters were the best in predicting the Porosity, with an RMSE value of 0.124 and an R-Squared value of 0.998. The best individual predictor was VED with an importance level of 0.50.

Machine Learning Results

Variables		Linear Regression		Random Forest		
Name	# of Vars.	RMSE	R^2	# of Trees	RMSE	R^2
All Features	44	0.641	0.952	2	0.85	0.914
VIF	2	1.486	0.741	5	0.295	0.990
Print Parameters	7	0.638	0.952	6	0.124	0.998
Melt Pool Metrics	37	0.638	0.952	3	0.181	0.996

NOTE:

- The lower the # of variables, the better
- The lower the RMSE value, the better
- The higher the R^2 value, the better

Section 5: Conclusion

Conclusion

Print Parameters

Inputs set prior to the printing process

Melt Pool Metrics

Sensor Data captured during the printing process

Material Properties

Porosity calculated after the printing process

Machine Learning

Random Forest model used to predict porosity

Results

The best way to increase yield is to reduce porosity in the printed parts. The user's most direct method of achieving this is by controlling the VED, or Volumetric Laser Energy Density, which is a combination of Print Parameters.

Looking Forward

	Increase Number Of Conditions	Image Analysis	Higher Resolution Of Porosity
Current	10 conditions were selected. 5 with the same Laser Power, 5 with the same Scan Speed.	Melt Pool Metrics were extracted from the images to create numerical datasets for further analysis.	Porosity was measured over the entire volume of each condition. This lead to averaging the Melt Pool Metrics over the entire build.
Future	It may be beneficial to select other pairs of Print Parameters to further understand the printing process.	It may be beneficial to use image analysis on the melt pool images directly to find patterns that may not be understood through the metrics.	It may be beneficial to increase the resolution of the porosity value for each condition. This may increase the correlation between the two data sets.