

SOLVUS GLOBAL

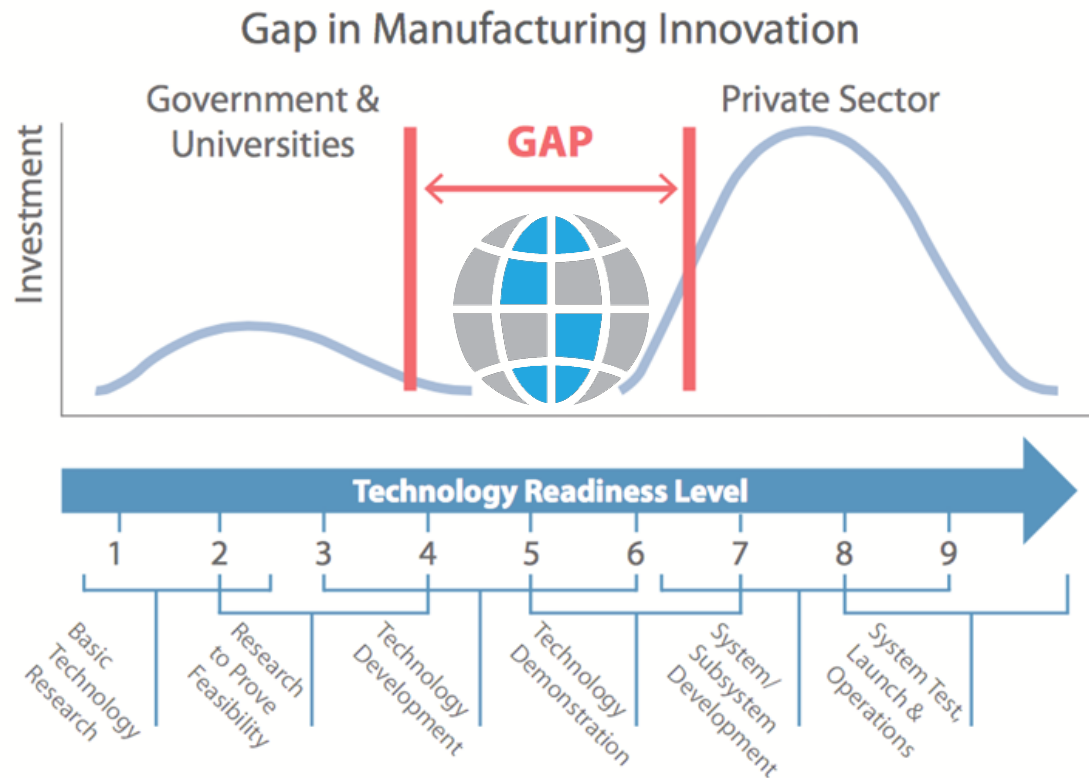
Quality CS Powder & Machine Learning Process Control

Aaron Birt, PhD
Managing Partner
Solvus Global

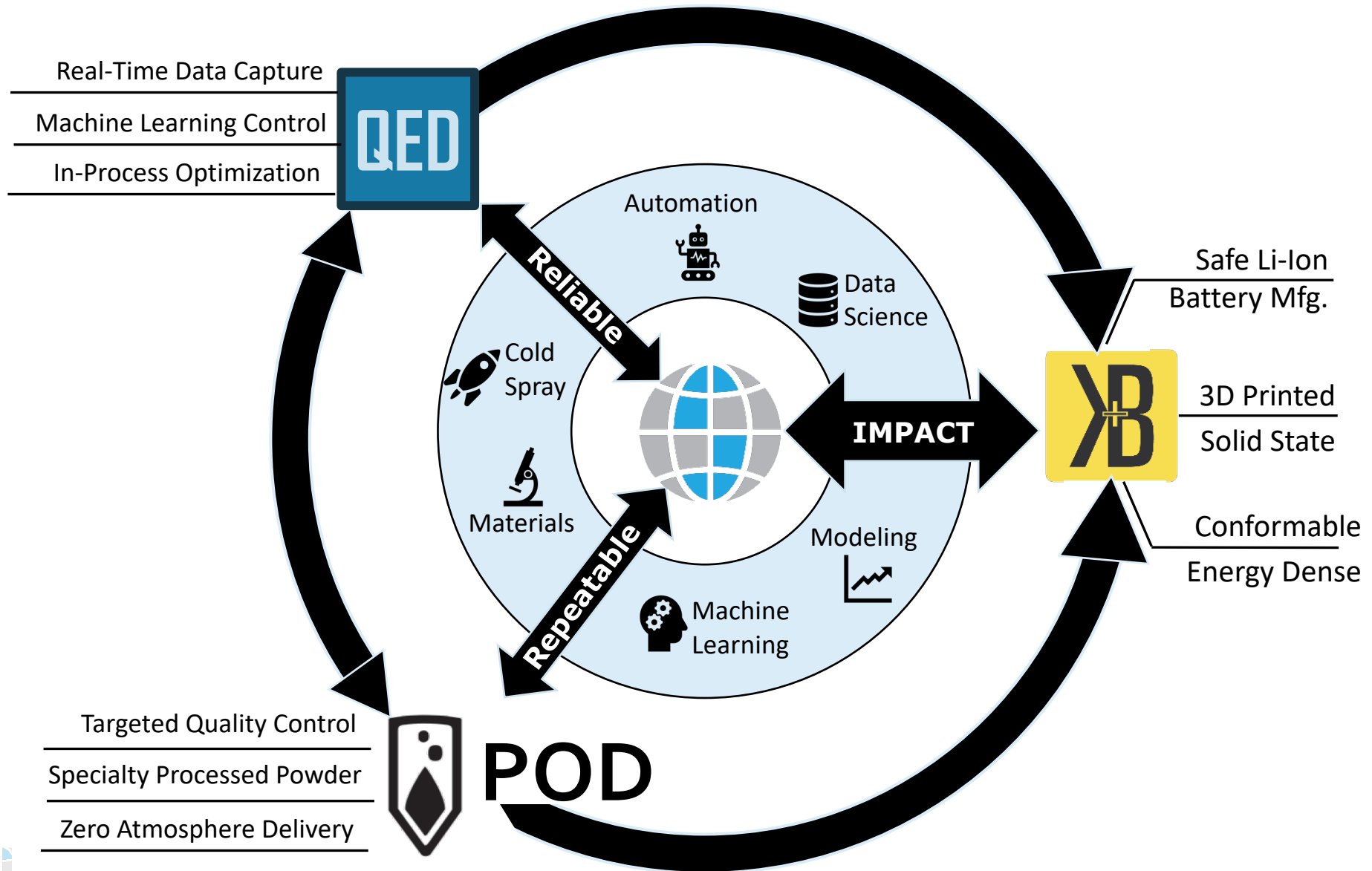


June 26, 2019

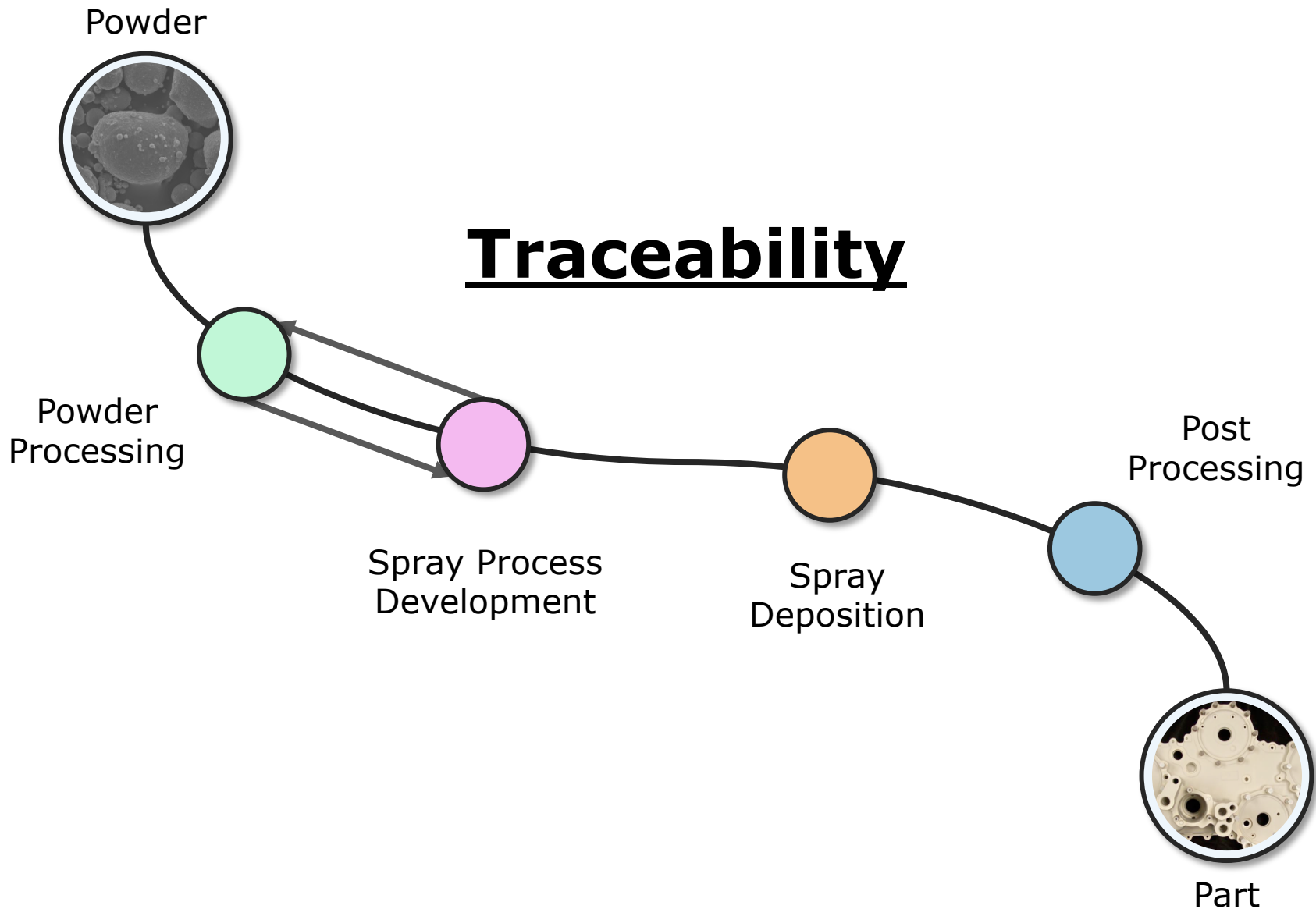
To bridge the Innovation Gap through the identification of critical materials & manufacturing **needs** and the successful **transition** of key university & government research to commercially sustainable **solutions**



Cold Spray: An Ecosystem of Impact

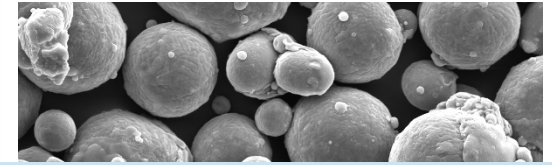
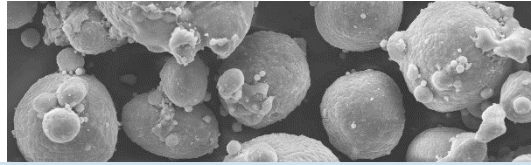
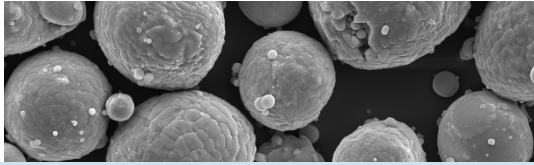


Traceability

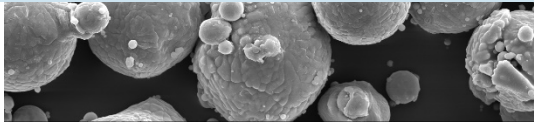


What is Powder?

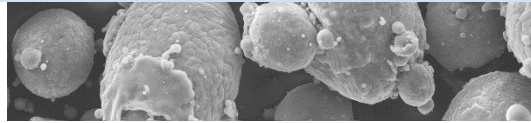
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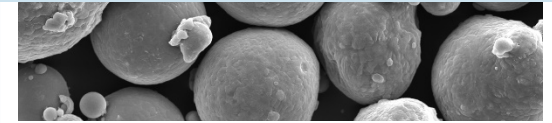
SAAM = Structural Advanced Additive Manufacturing



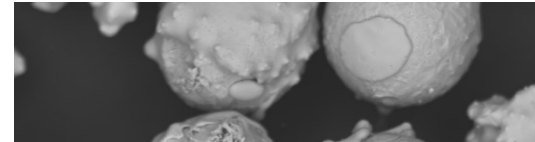
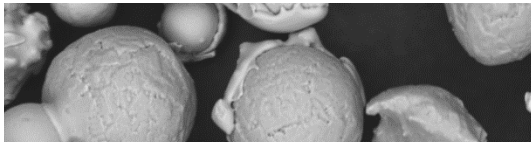
SAAM-AL6061-G1H1



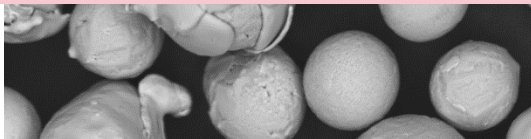
SAAM-AL7075-G1H1



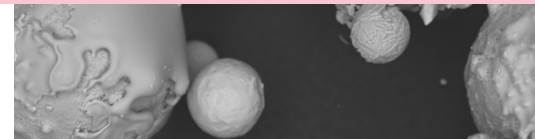
SAAM-AL2024-G1H1



WIP = Wear & Impact Resistance



WIP-C1

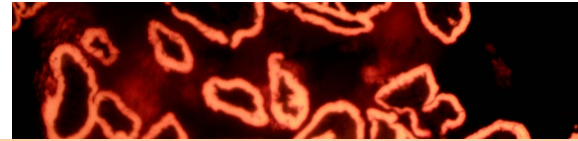
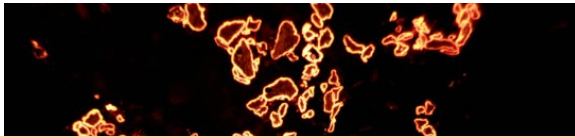


WIP-BC1

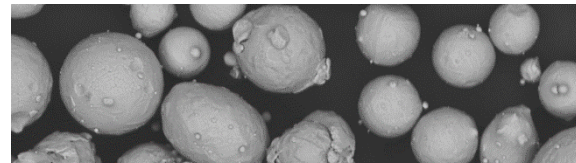
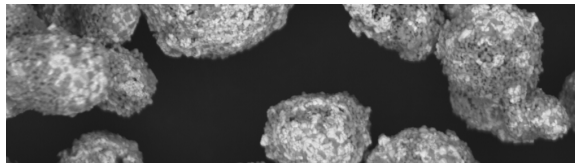
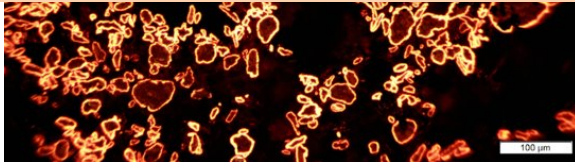
www.powdersondemand.com



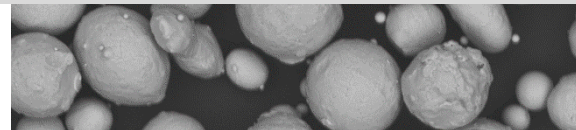
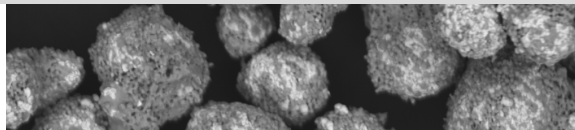
...and many more to come!

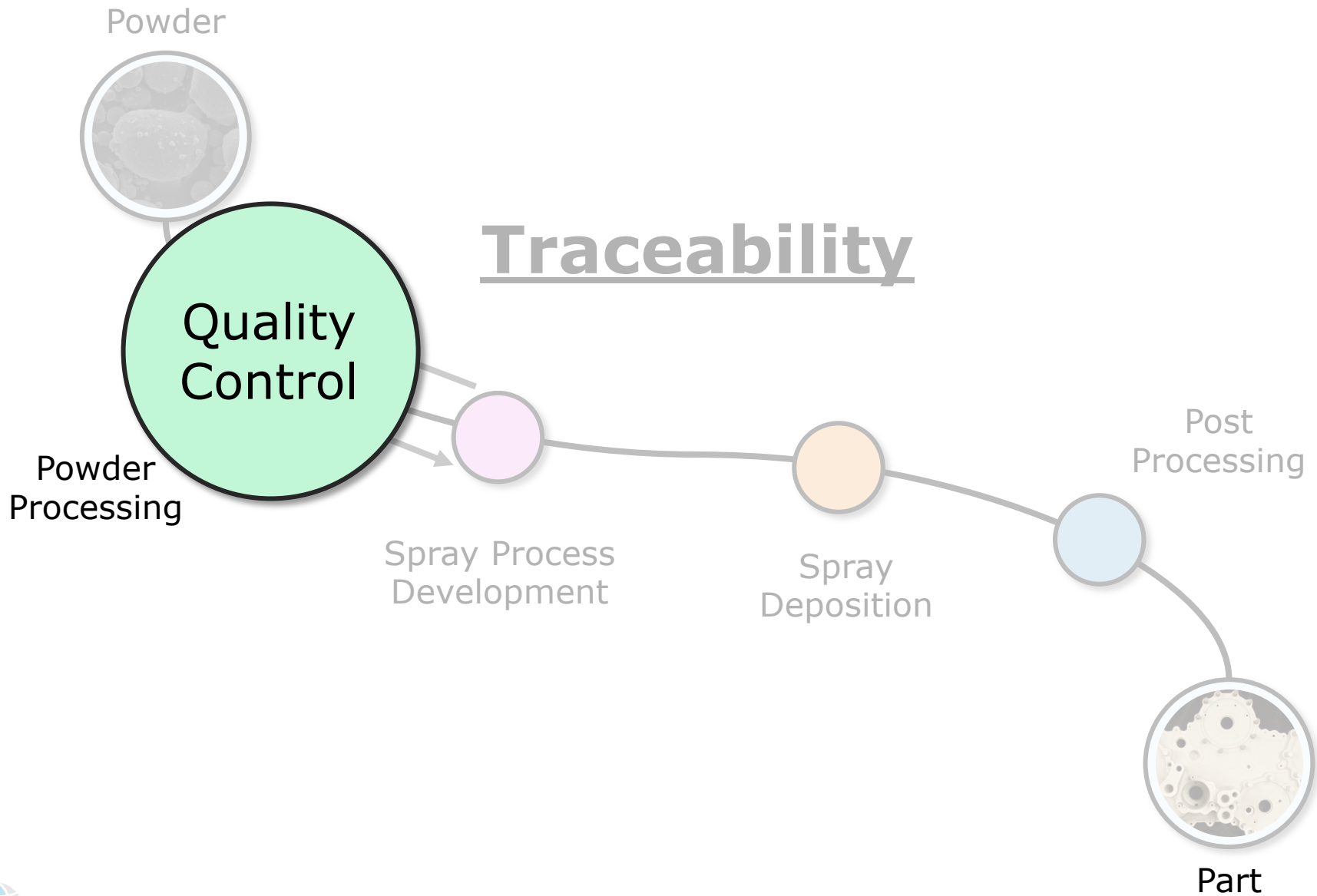


Coated Ceramic & Metal Powders



WC-based & Iron-based Wear Materials

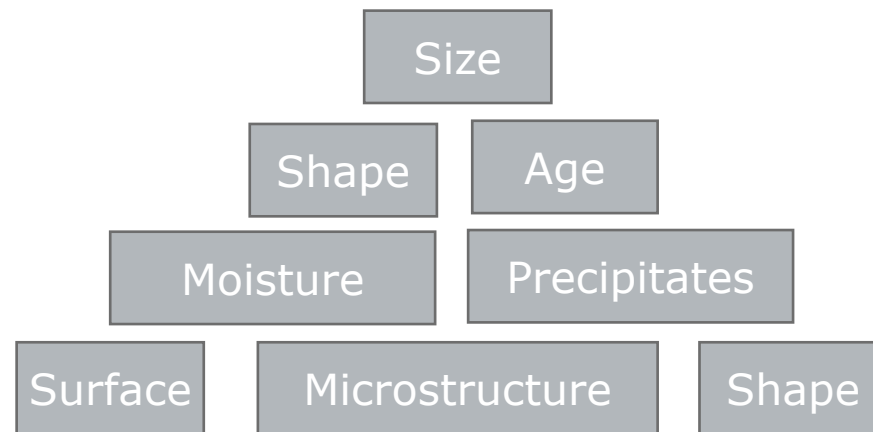




Quality Control in Cold Spray is
UNIQUE
Among Powder Processes



What Matters in Cold Spray?

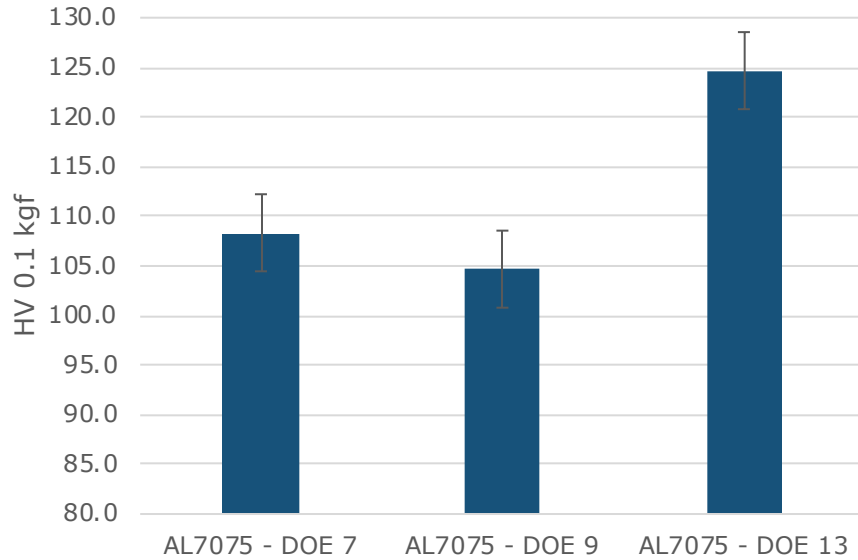


Everything



(1/2a) Maintaining Quality Feedstock

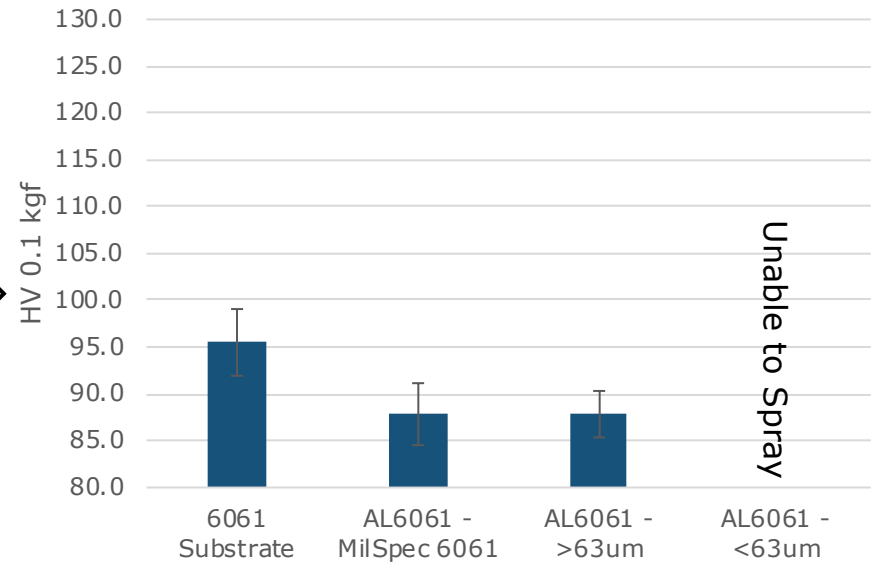
Fluidized DOE vs Hardness



- Phases
- Surface Chemistry
- Grain size

Size Impacts
Sprayability

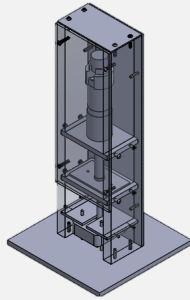
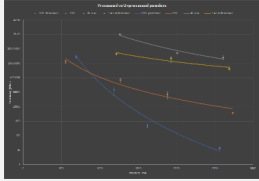
PSD vs Hardness



(2b) Maintaining Quality Feedstock

Compressibility

OUTPUT



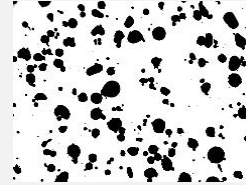
Description: Measures conductance of powders at increasing loads

Automation Status: Final fabrication

Backlighting

OUTPUT

D10:17.5573
D25:23.5677
D50:30.5189
D75:38.6453
D90:45.9596
Below 106 micron:100
Below 90 micron:100
Below 53 micron:97.1229
Below 38 micron:73.5464
Below 20 micron:15.766
Below 10 micron:0.9377



Description: Measures particle size distribution using optical backlighting

Automation Status: data collection fully automated

Sieving

OUTPUT

wt% of powder
<20 μm
20-38 μm
38-53 μm
> 53 μm



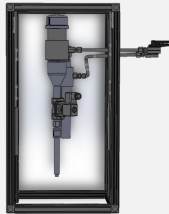
Description: Measures particle size of powder sample using vibrational sieving

Automation Status: Complete

Impact

OUTPUT

Compaction Efficiency



Description: Measures ability of a powder to compact into puck during impact

Automation Status: Initial prototype operational – automated design in process

Flowability

OUTPUT

Carney Flow (g/s) + Hausner Ratio



Description: Measures flowability of powder using **two** methods

Automation Status: TBD – will be automated after impact

Density

OUTPUT

Tapped + Bulk Density

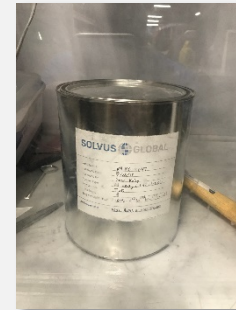


Description: Measures the tapped and bulk density of powder samples

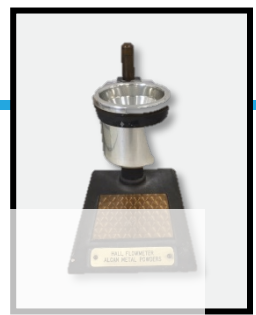
Automation Status: TBD – will be automated after flowability

Maintaining Quality Feedstock

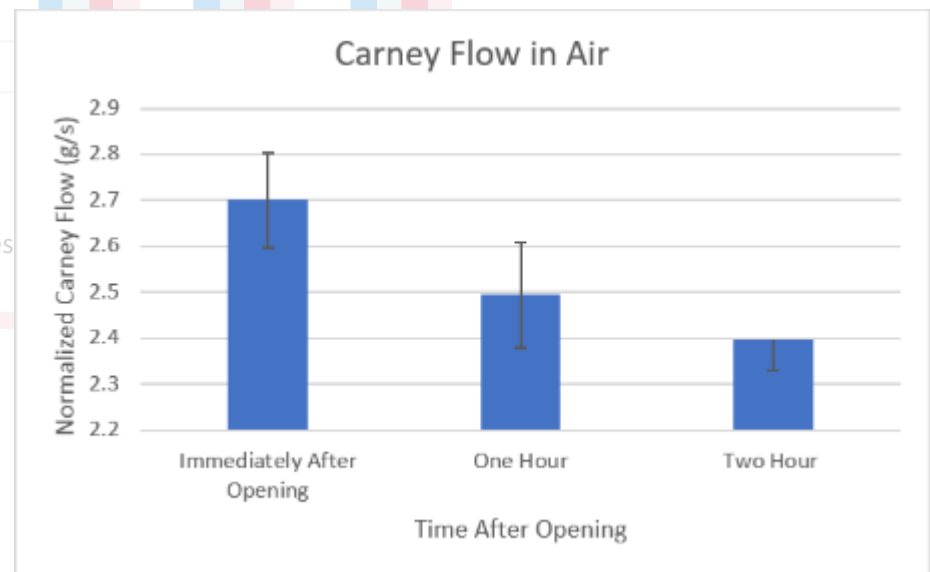
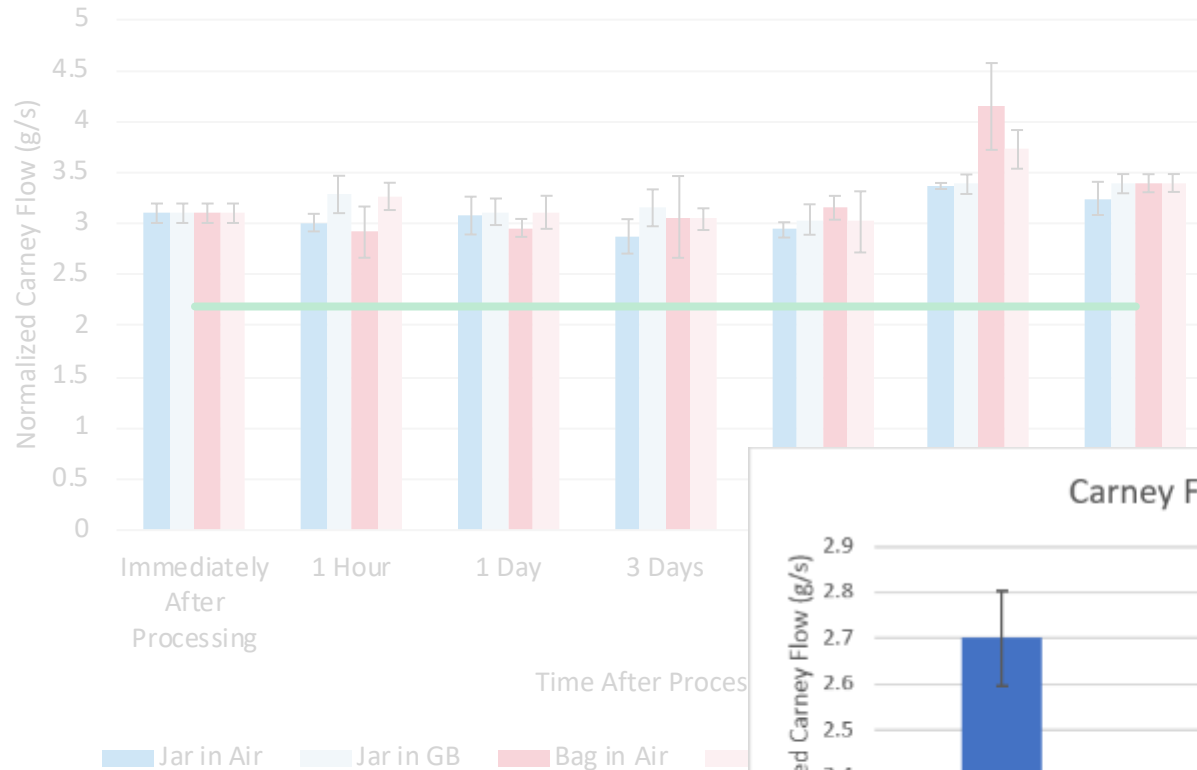
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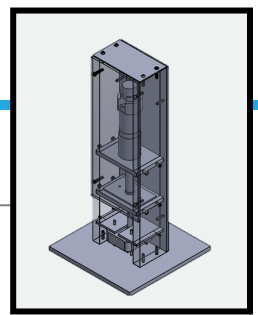
(3a/b) Maintaining Quality Feedstock



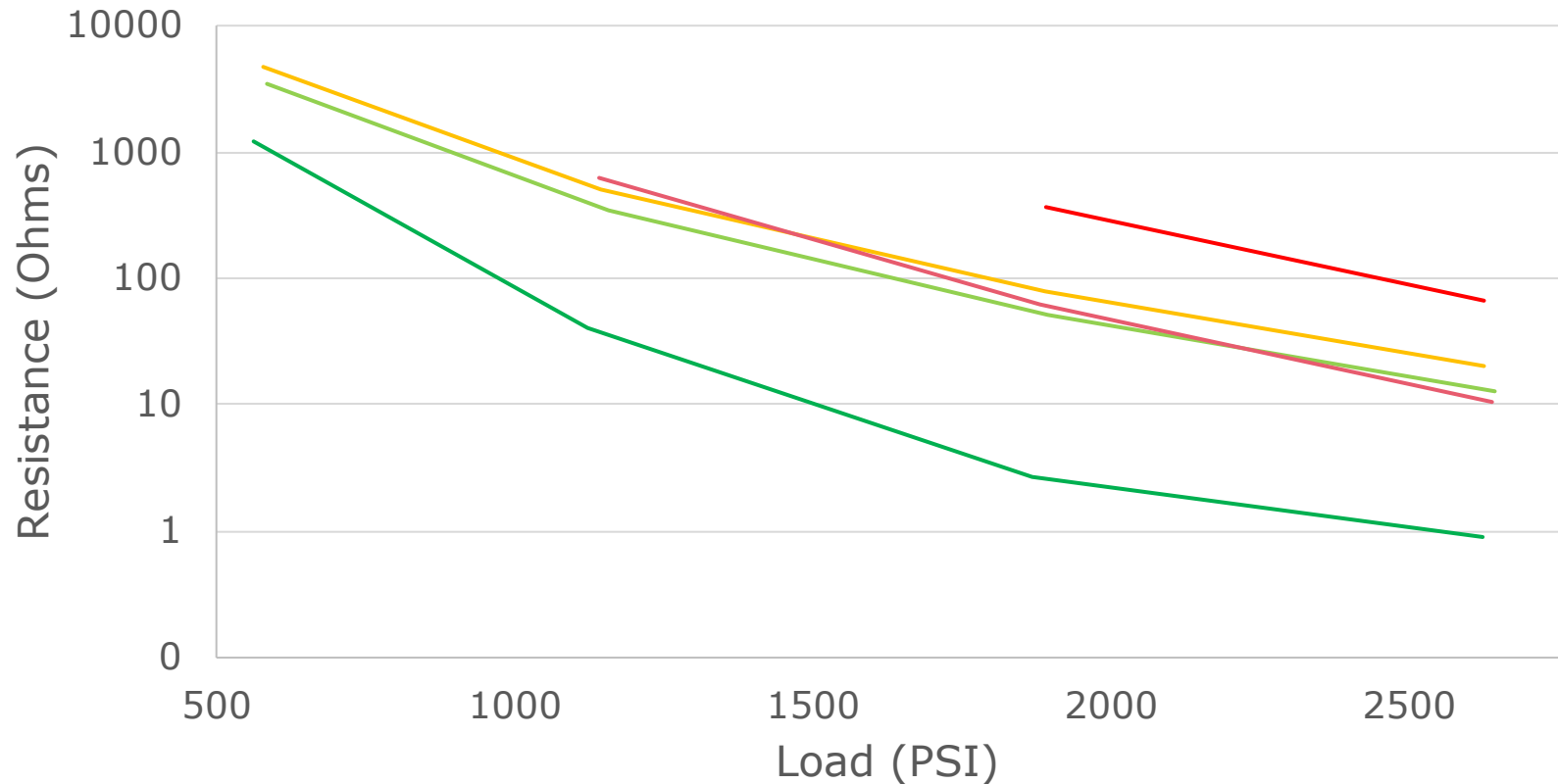
Carney Flow Over Time



(1/2a) Maintaining Quality Feedstock



Al6061 Powder Purity



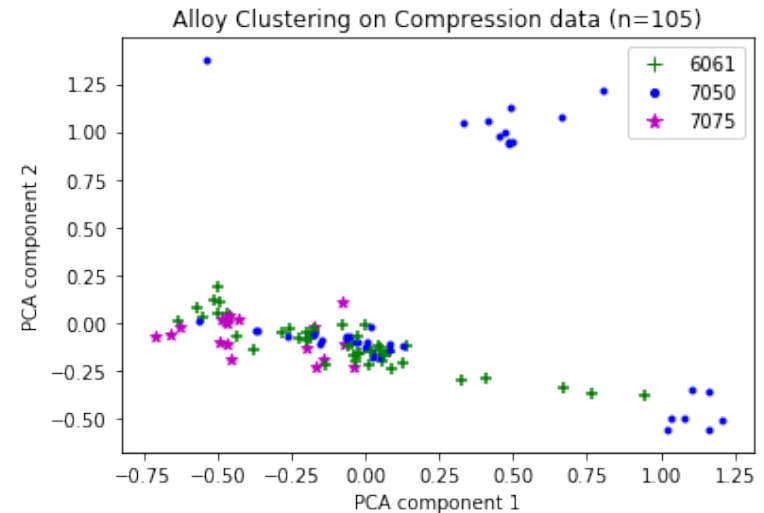
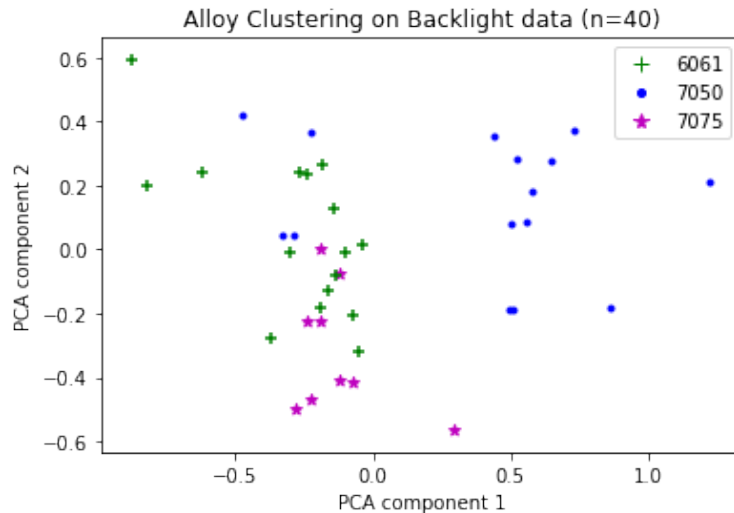
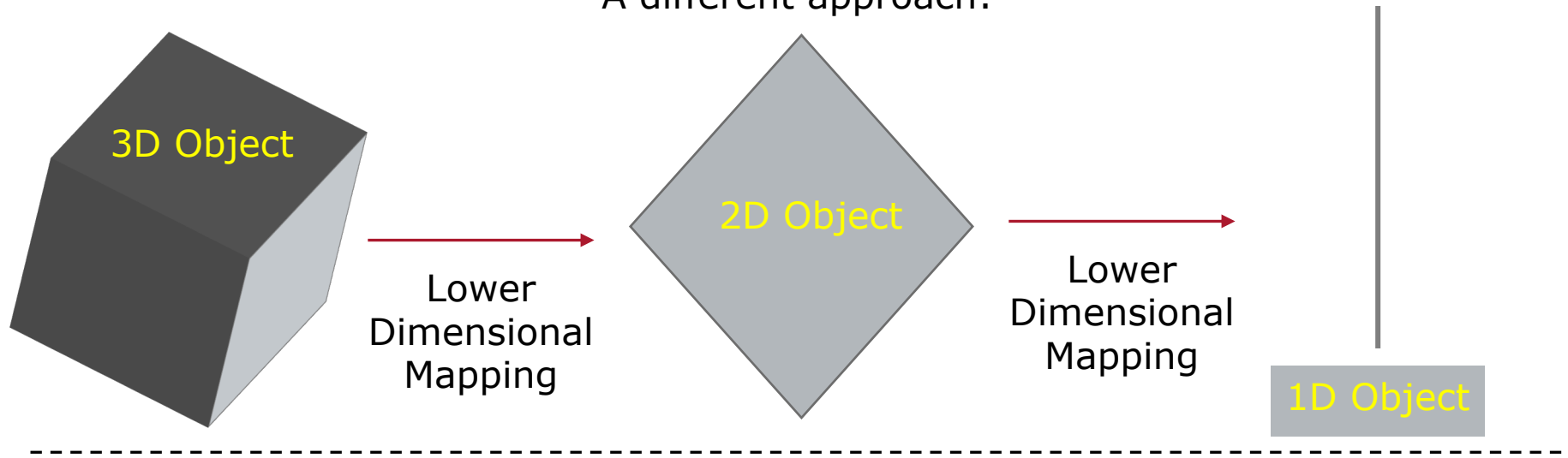
% Purity of Al6061 (5056 contaminant)

100	95	90	85	75
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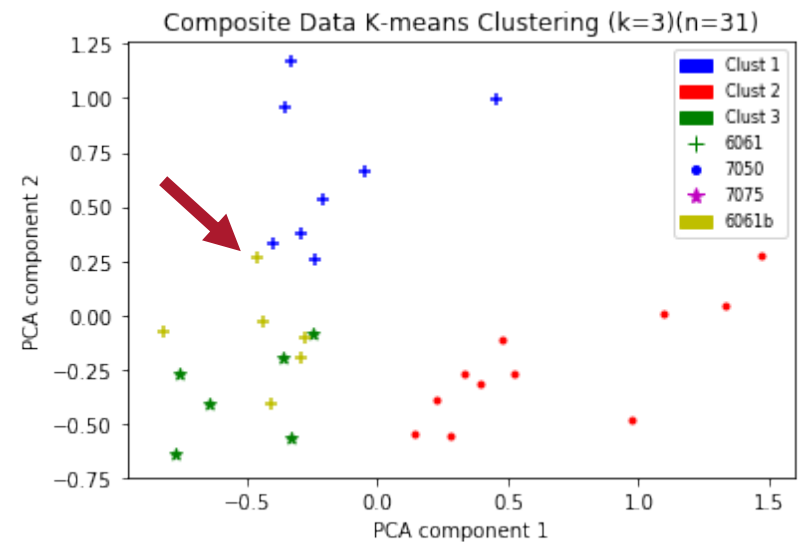
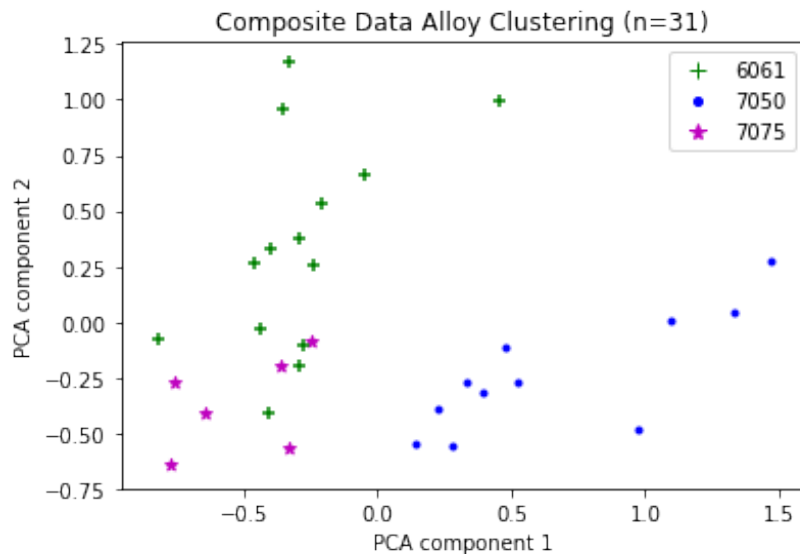
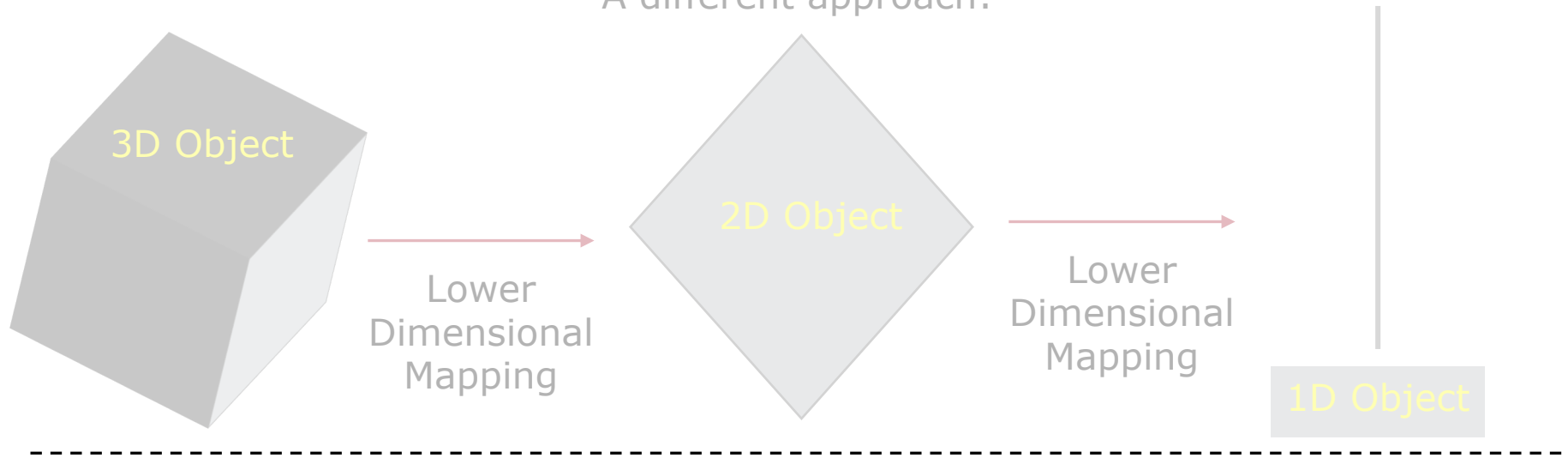
(2c) Maintaining Quality Feedstock

A different approach:



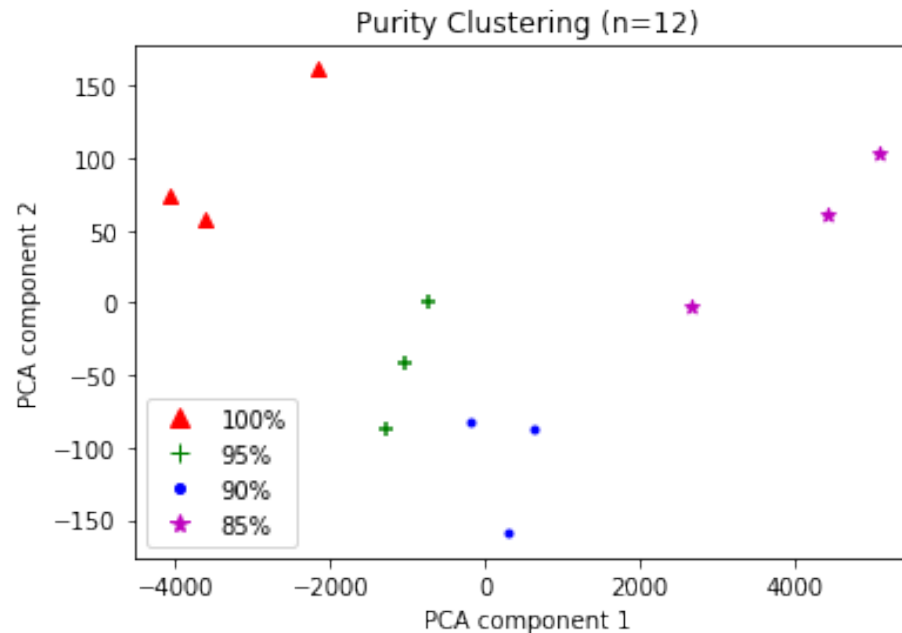
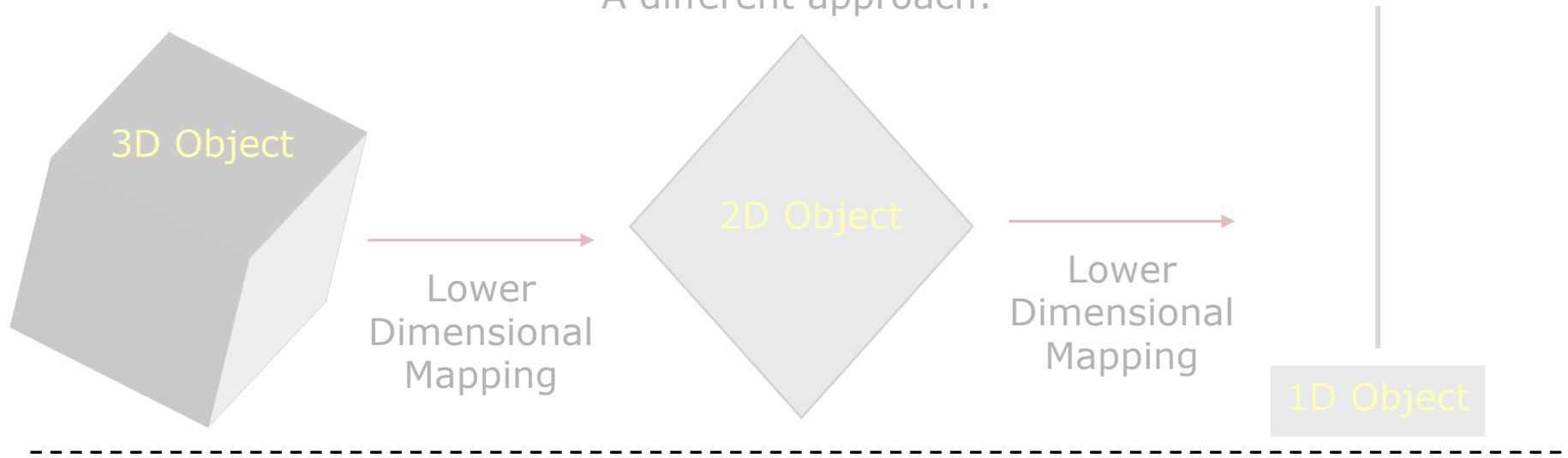
(2c) Maintaining Quality Feedstock

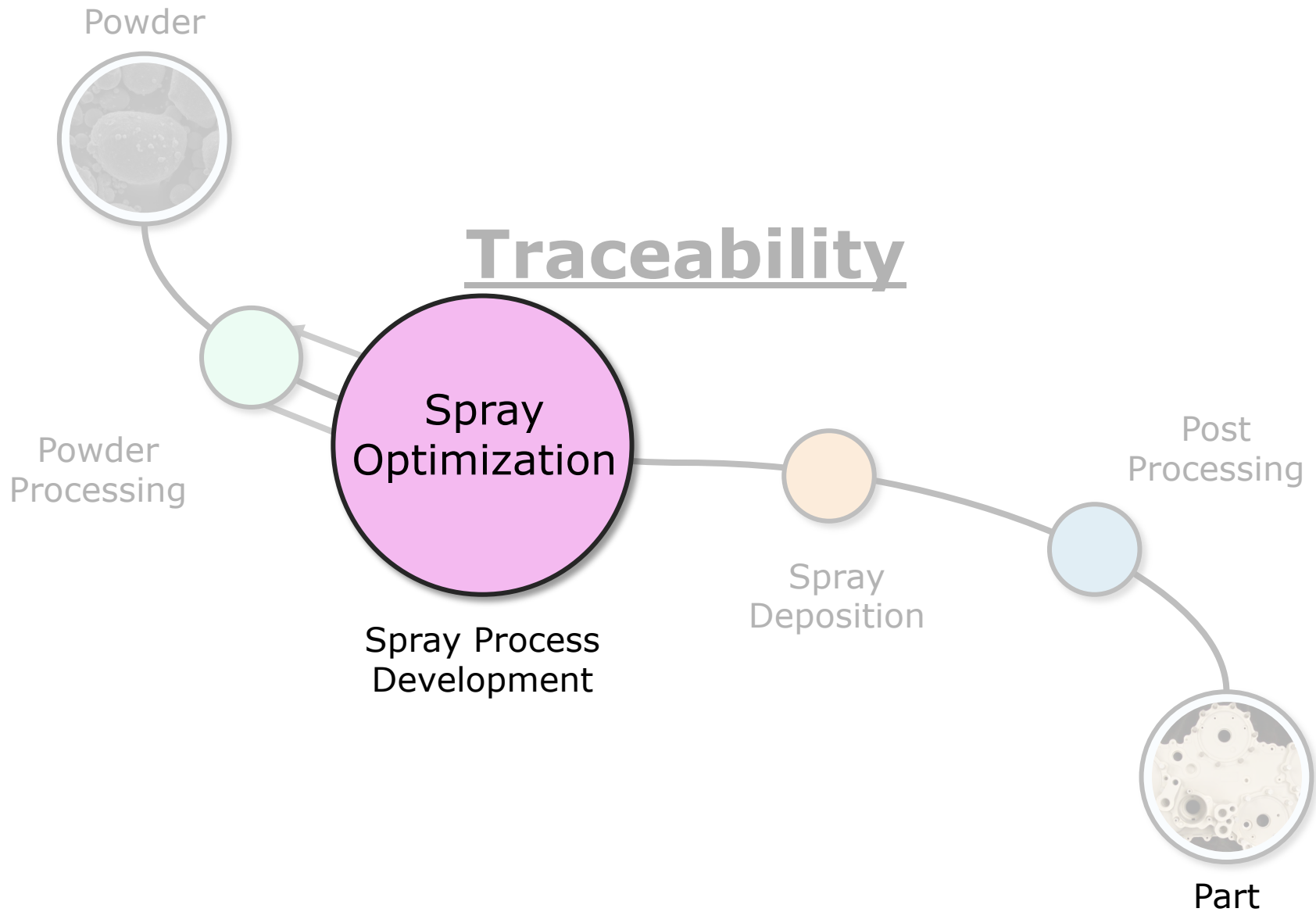
A different approach:



(2c) Maintaining Quality Feedstock

A different approach:





Spray Optimization: Data Management

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The interface shows a three-step process for data management:

- Select a Table:** The user selects 'size' from a dropdown menu.
- Select your Columns:** The user selects the following columns: D10 Size, D25 Size, D50 Size, D75 Size, and D90 Size.
- Fetch Data:** The data is fetched and displayed in a table.

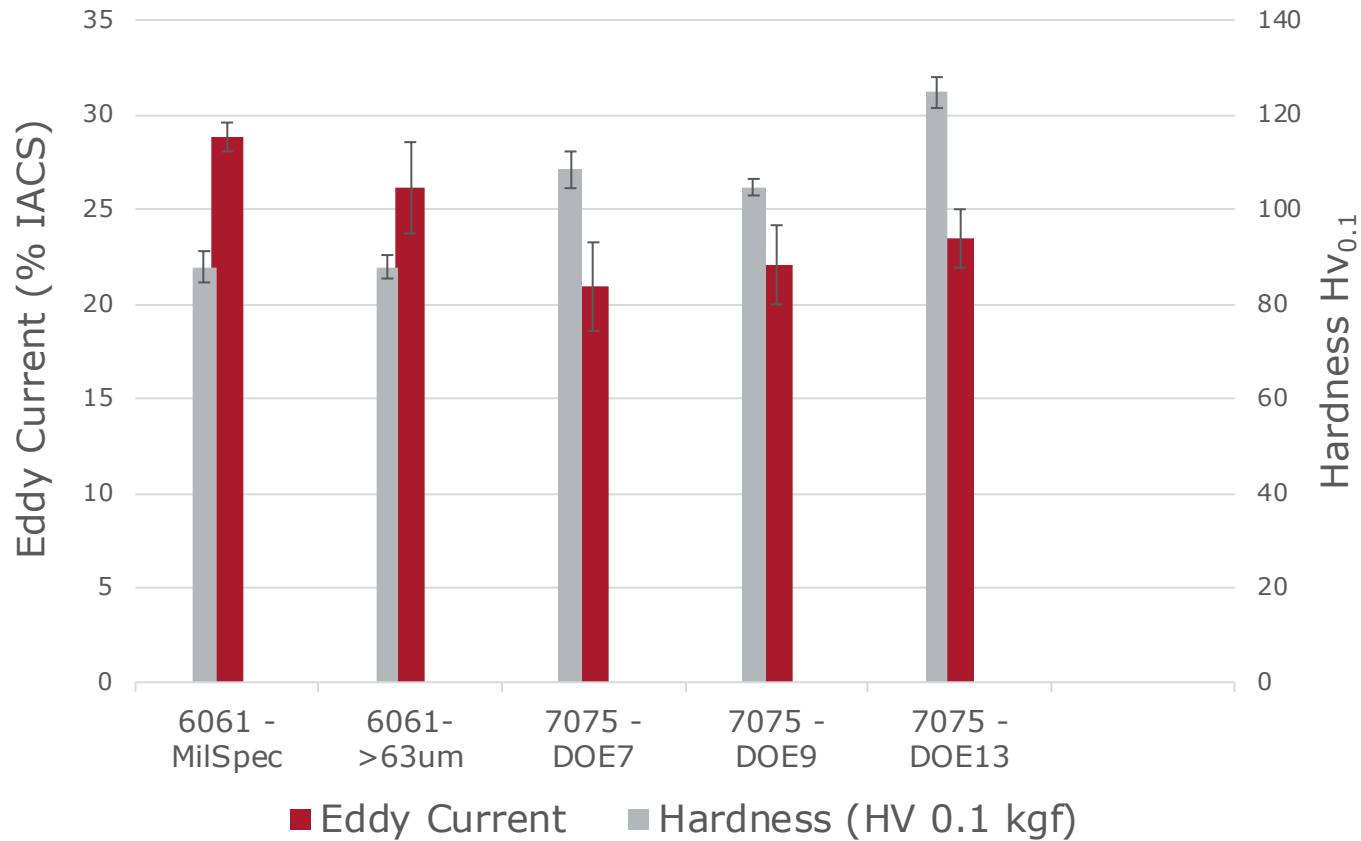
The final data table is titled 'Process Powder Data' and contains the following data:

ID	D10 Size	D25 Size	D50 Size	D75 Size	D90 Size	Flowability Average	Flowability Standard Deviation	Powder Preparation ID	Powder ID
1	49	84	21	21	21	21	21	cadu	2493280771
2	85	2	61	61	61	61	61	zato	2268491430
3	11	46	73	73	73	73	73	jifueco	7715038638
4	49	2	56	56	56	56	56	ob	9335580354
5	43	97	84	84	84	84	84	zakug	9886300393
6	58	82	44	44	44	44	44	nip	8951480140
7	3	58	39	39	39	39	39	ri	9873198596
8	17	36	23	23	23	23	23	biviw	8666083248
9	44	31	56	56	56	56	56	aw	5089505688
10	81	78	36	36	36	36	36	nasohhes	1826878299
11	70	60	61	61	61	61	61	wuare	7296502267
12	99	90	13	13	13	13	13	utu	3129700549
13	79	54	31	31	31	31	31	wuhhoc	3763914912
14	18	71	74	74	74	74	74	notjo	151560688
15	85	33	49	49	49	49	49	luv	7405041933
16	28	36	0	0	0	0	0	punorso	3341355544

Data Import (Automated) → User sorts by table → User selects desired attribute = **Access to ALL characterized powder data**

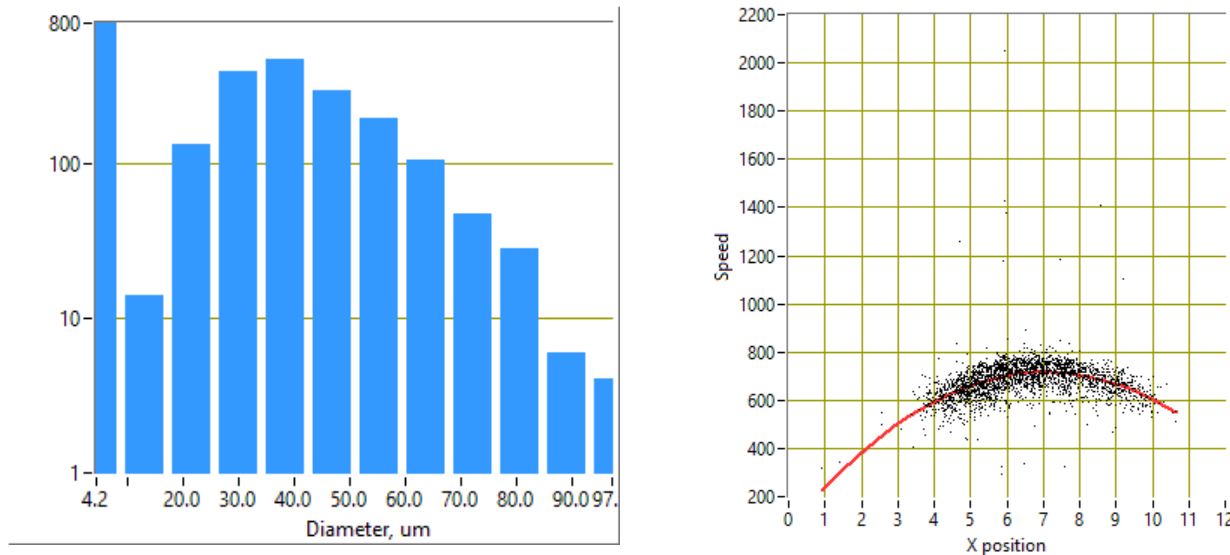


Eddy Current vs Hardness Values for CS Consolidated



Spray Optimization: AI-Powered Spray Engine

The Need: A way to reduce the complexity of parameter selection & optimization without undue experimentation.



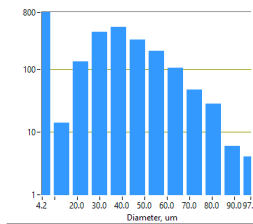
Oseir HiWatch HR Velocimetry System

The Question: Can we reduce optimization time for entire particle distributions by using machine learning coupled with physical models?



Spray Optimization: AI-Powered Spray Engine

Particle Size Distribution



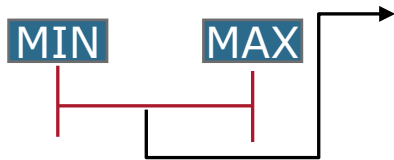
Diameter

Alloy

Geometric Properties

Material Properties

Process Set Conditions



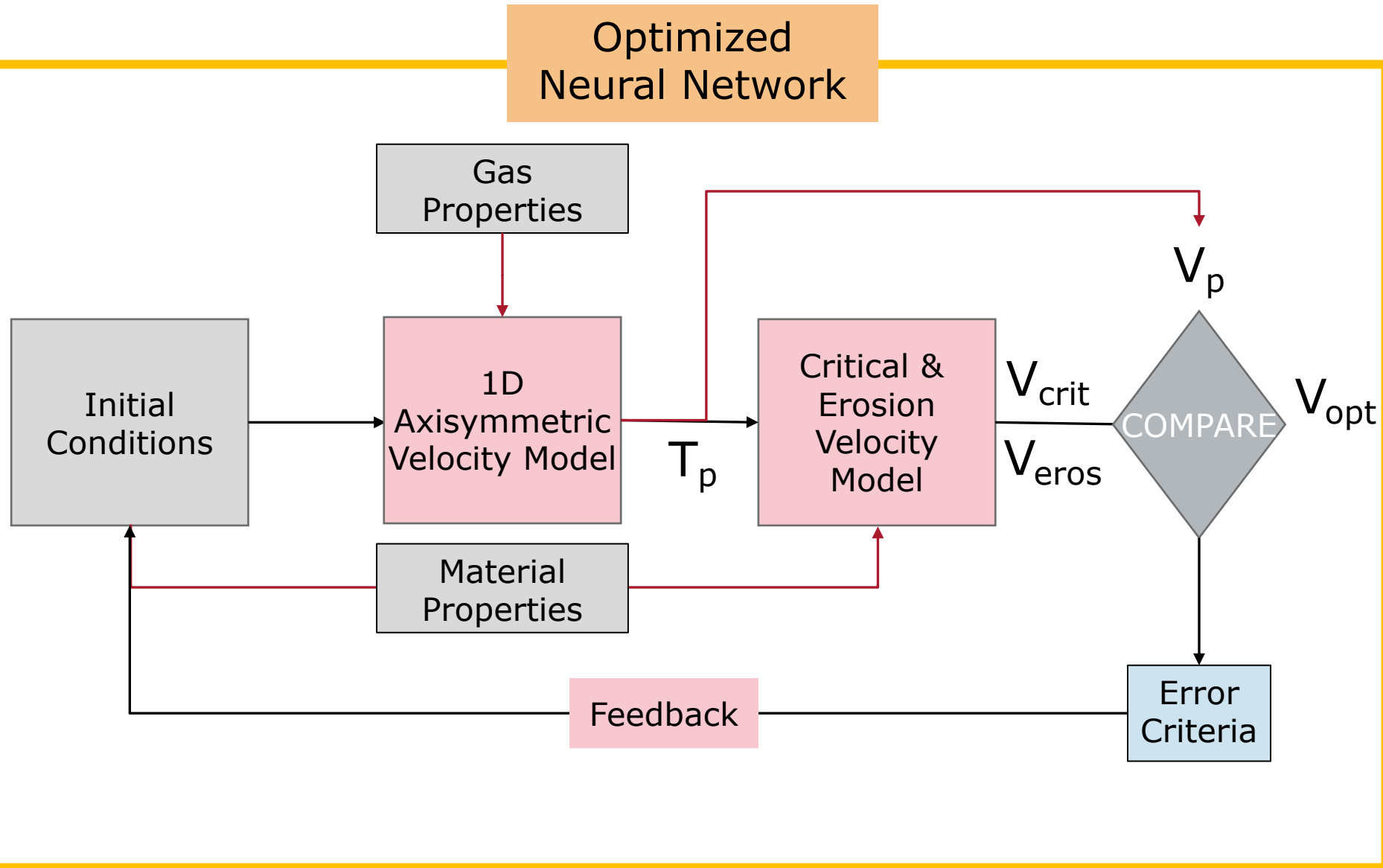
Gas T,P

Standoff

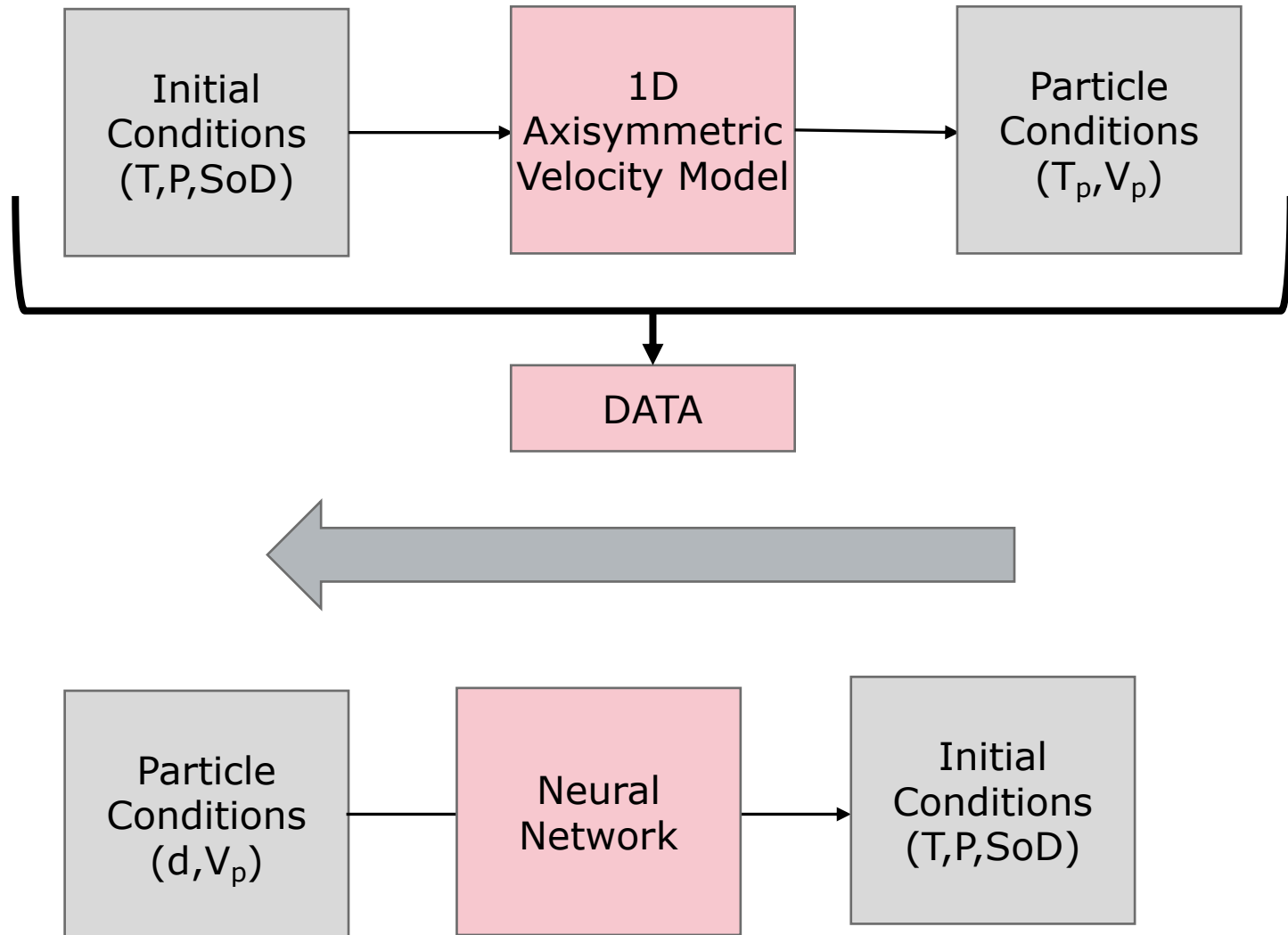
Spray Conditions

Initial Conditions

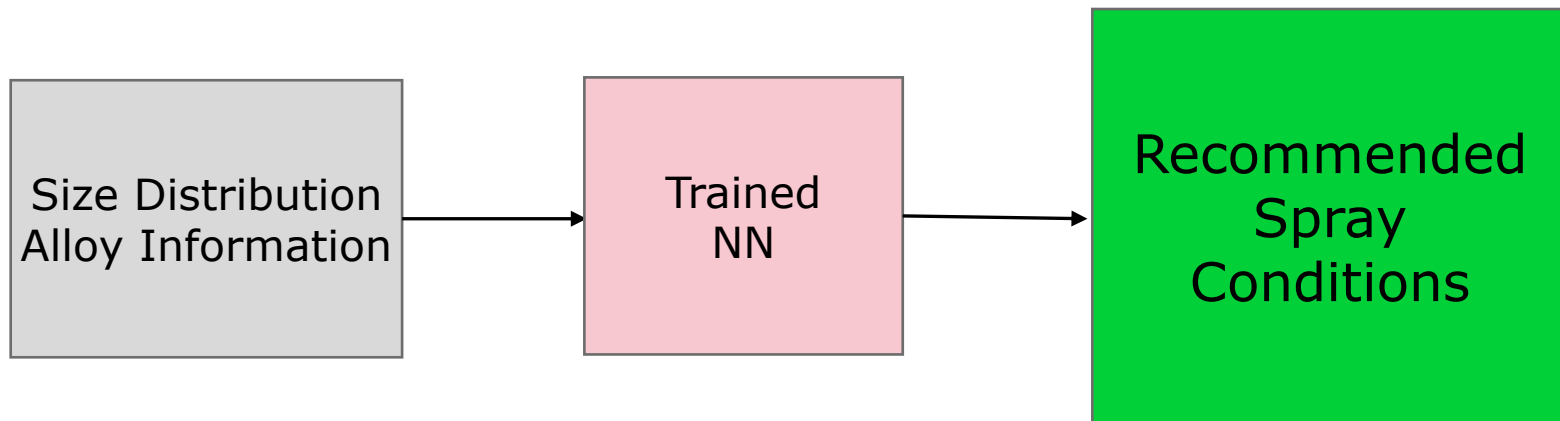
Spray Optimization: AI-Powered Spray Engine



Spray Optimization: AI-Powered Spray Engine



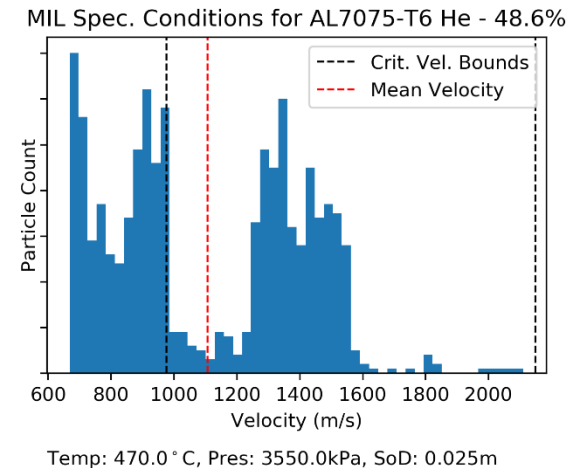
Spray Optimization: AI-Powered Spray Engine



Spray Optimization: An Example

Problem: We want to further improve cost efficiency of Al7075 Deposition.

Question: Can we reduce costs by switching to nitrogen?



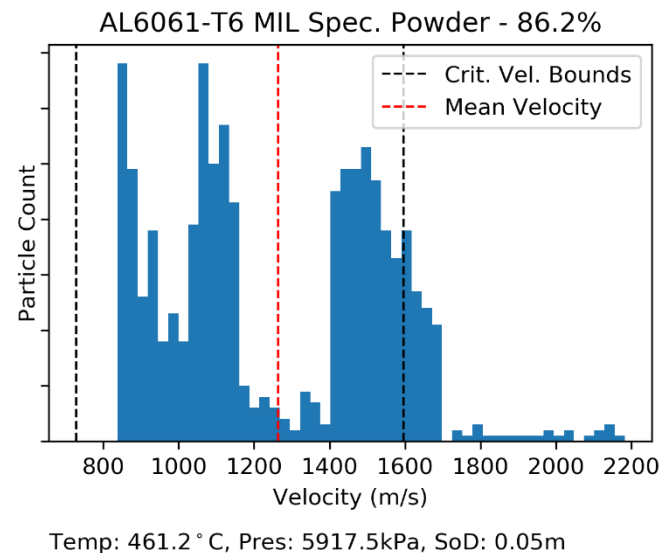
Solution: Further optimize around Temperature, Pressure, Standoff Distance to achieve greater deposition efficiency.



Spray Optimization: An Example

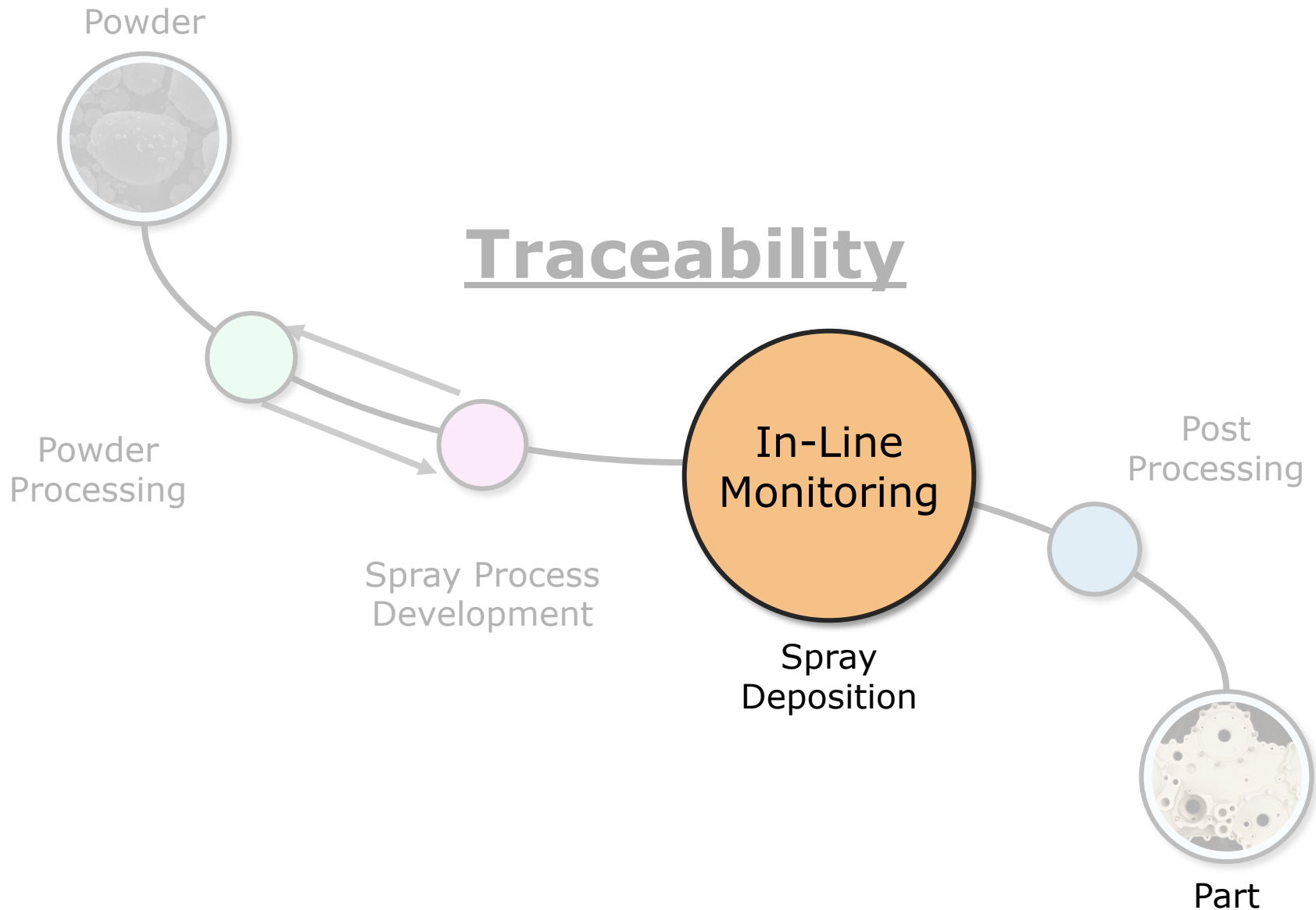
Problem: Too much Aluminum 6061 Powder is lost during spray

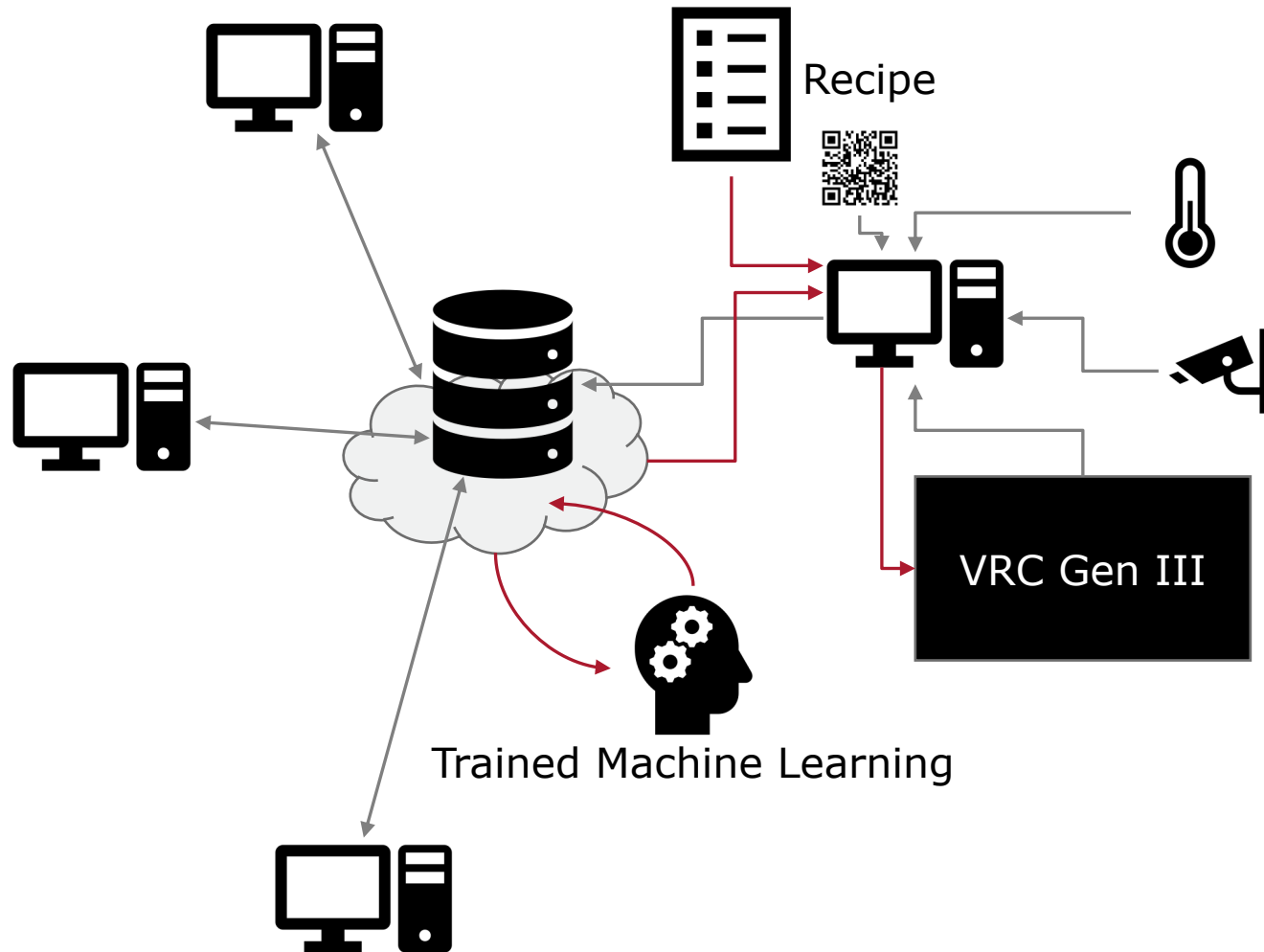
Question: Can we increase deposition efficiency without altering cold spray processing conditions?

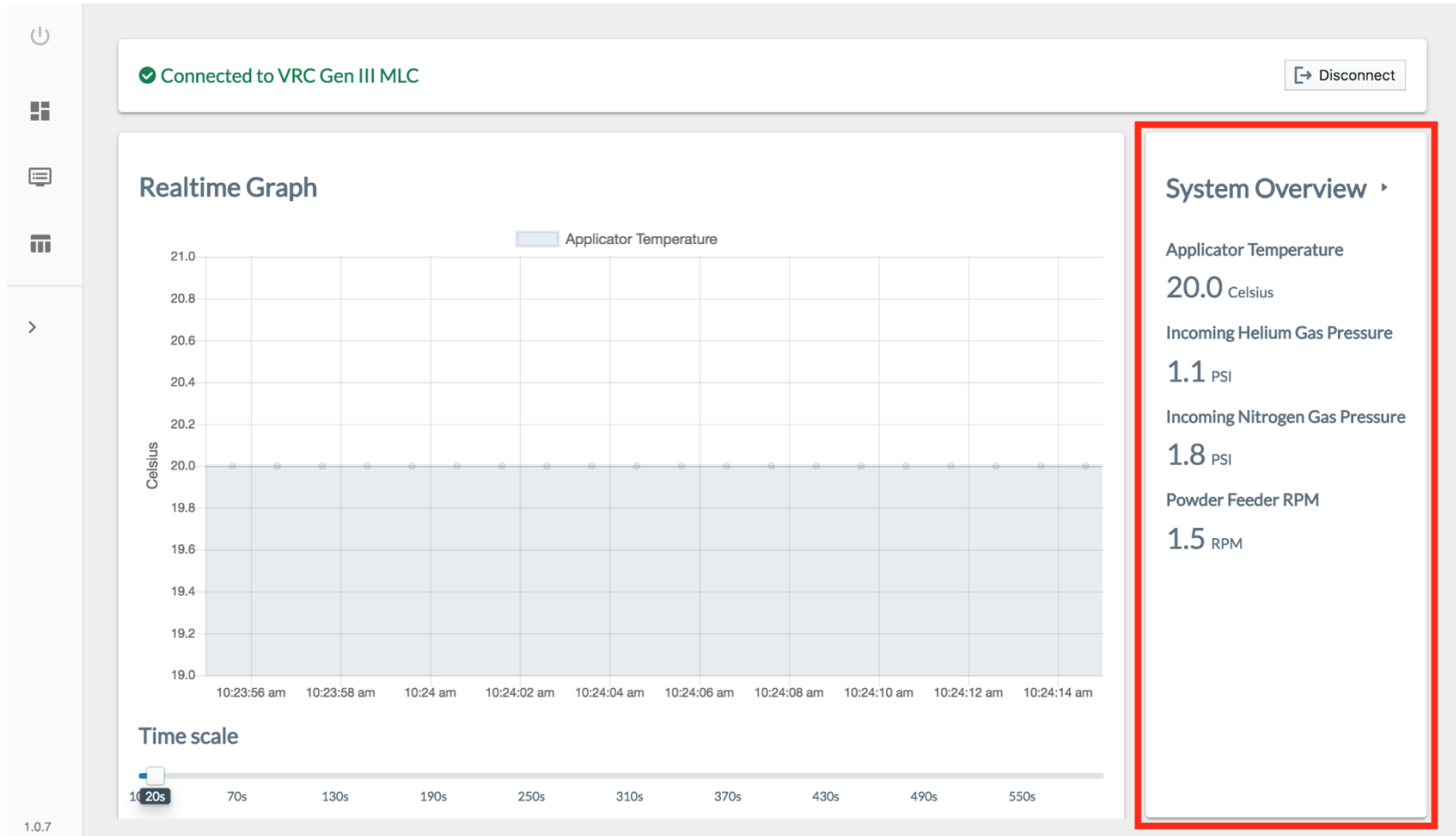


Solution: Optimize around a tightened size distribution to maximize particles in critical velocity range.

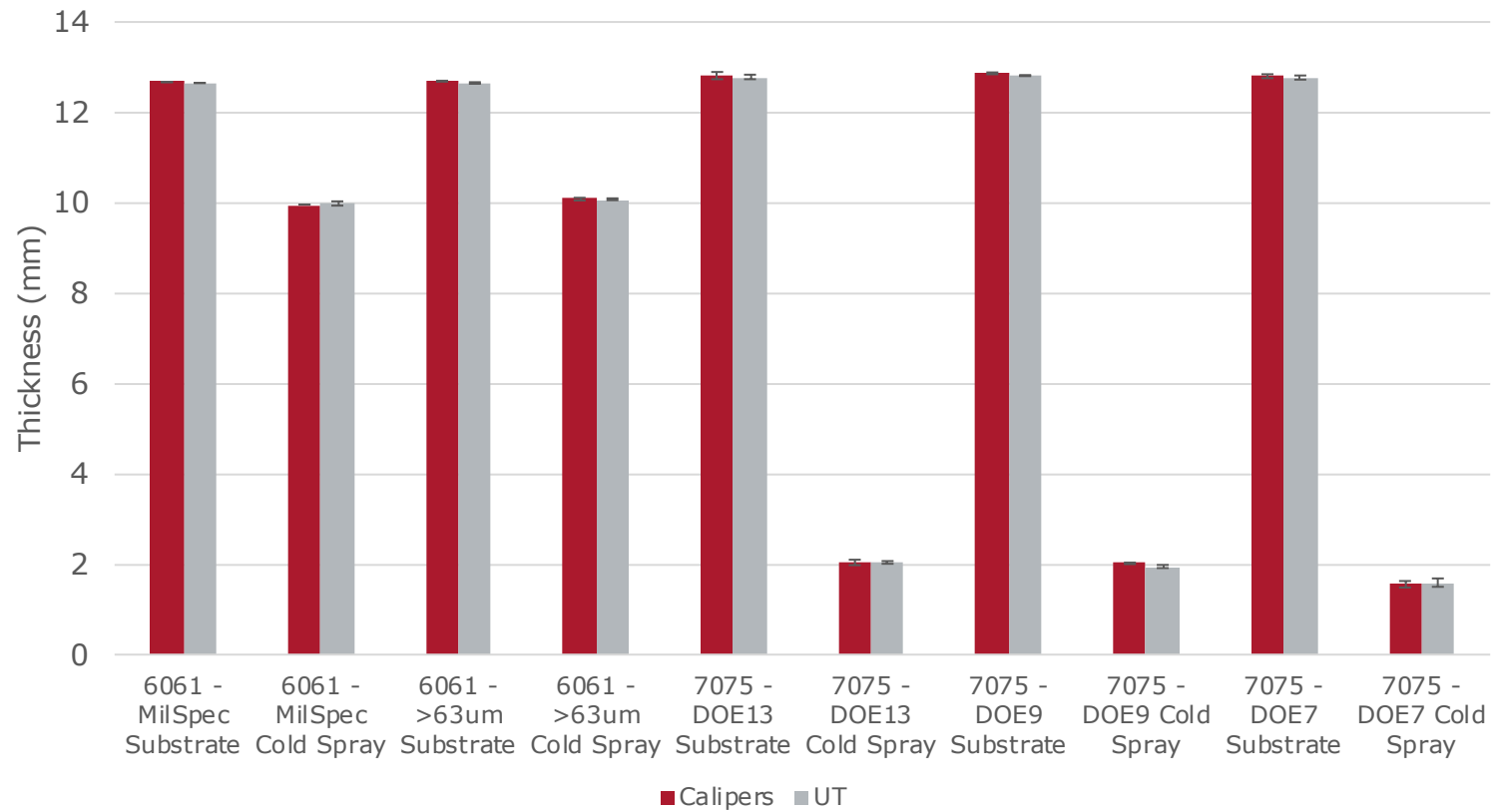


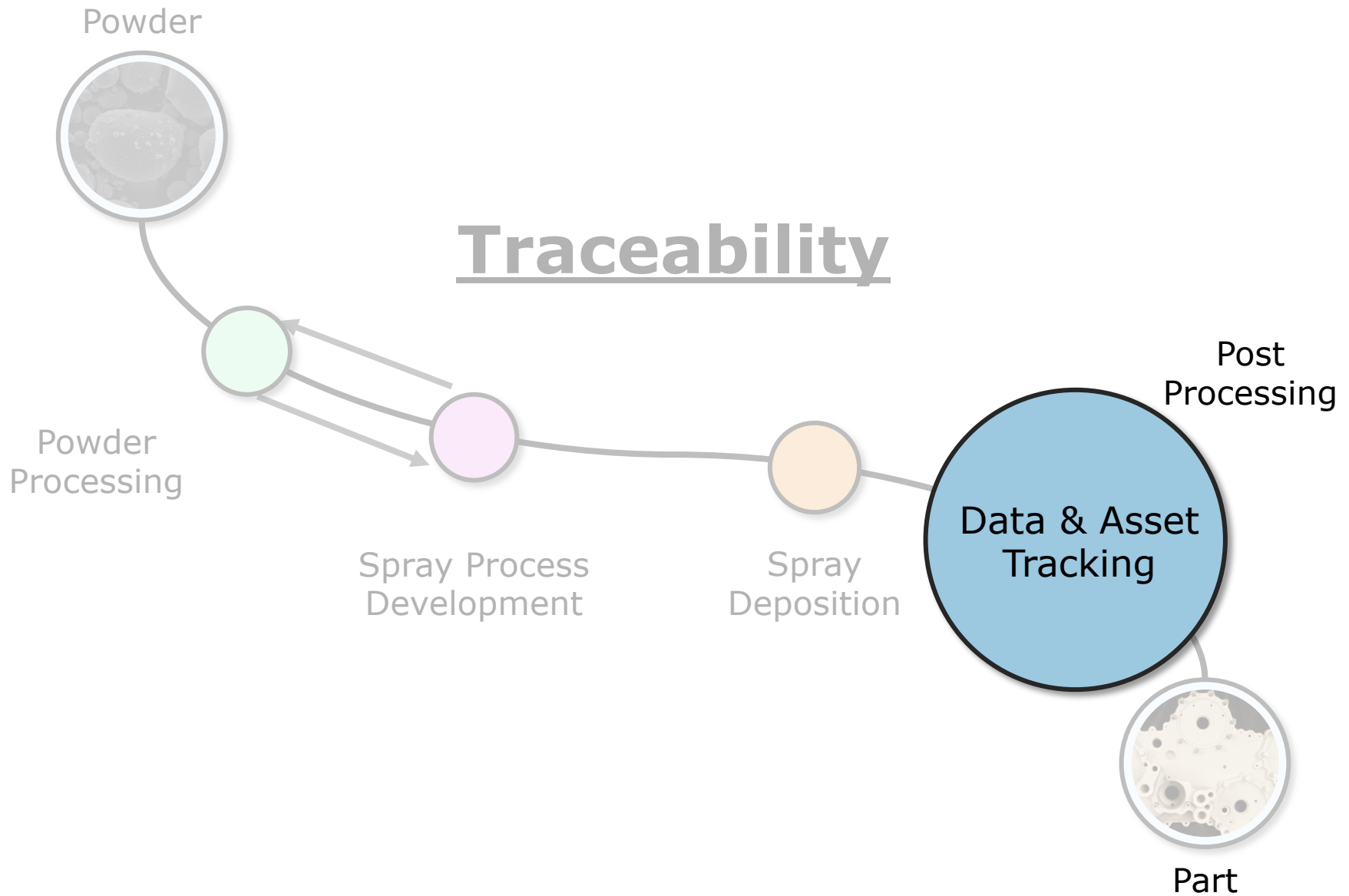


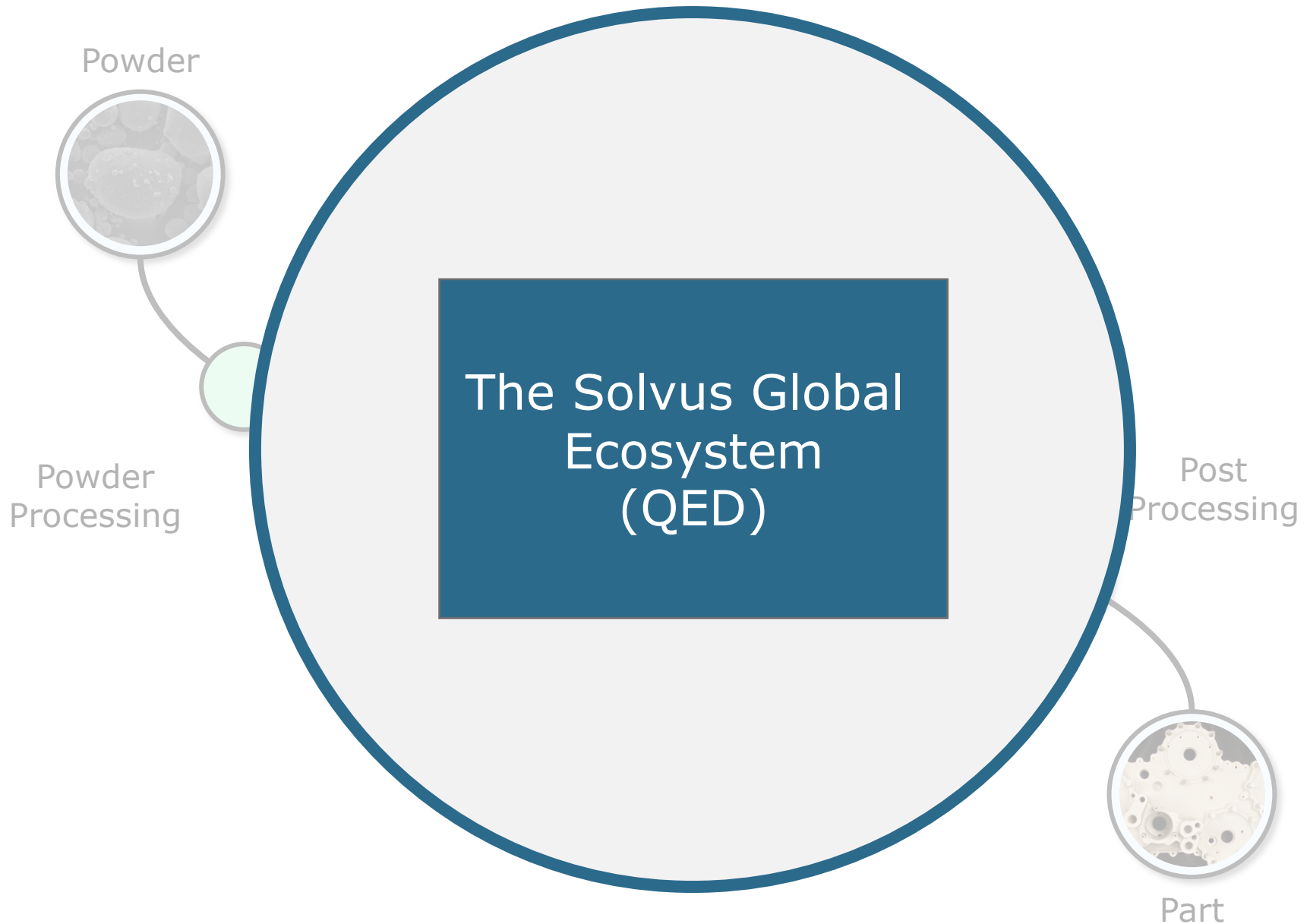


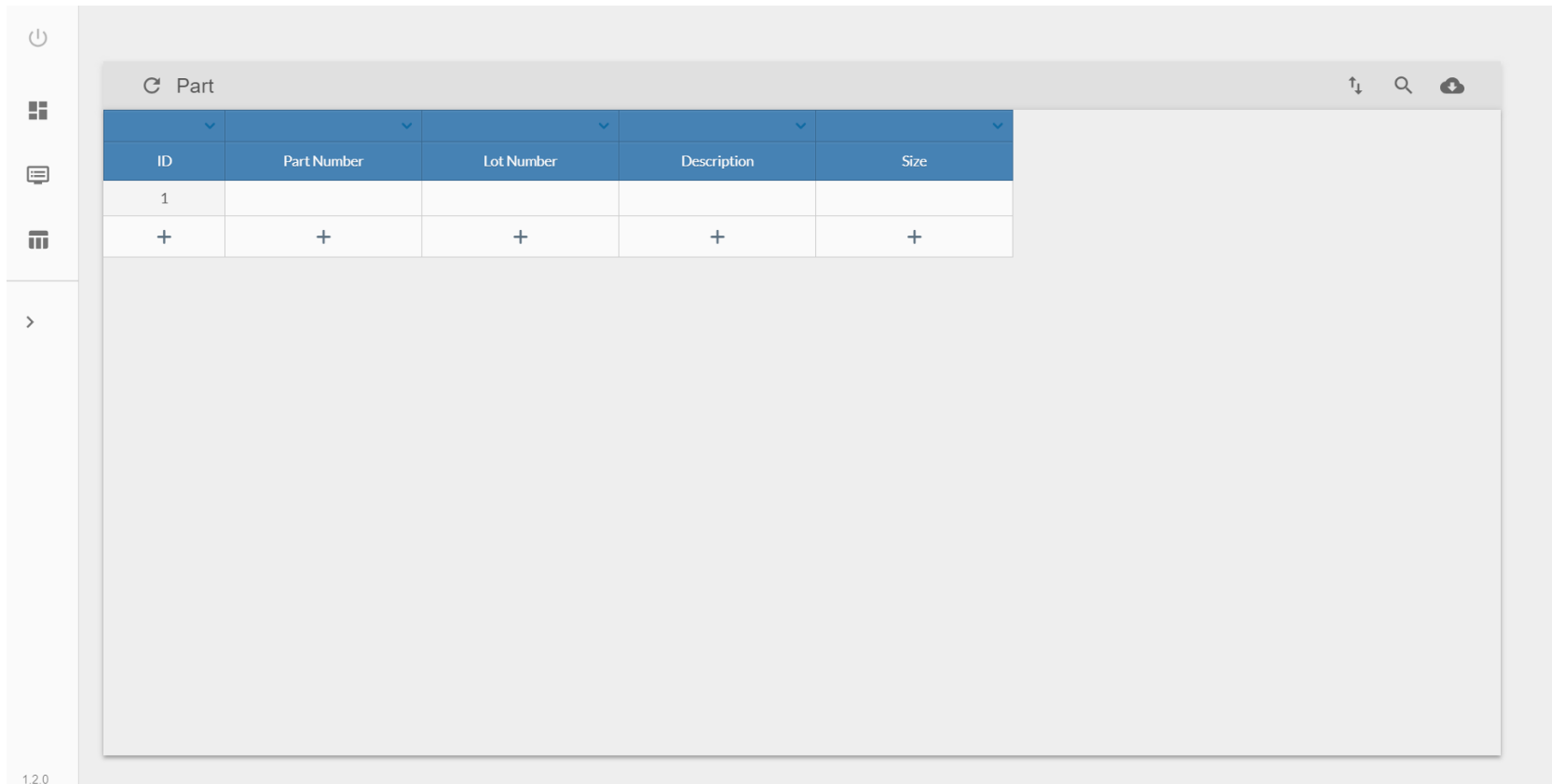


Comparison of UT vs Physical Measurements





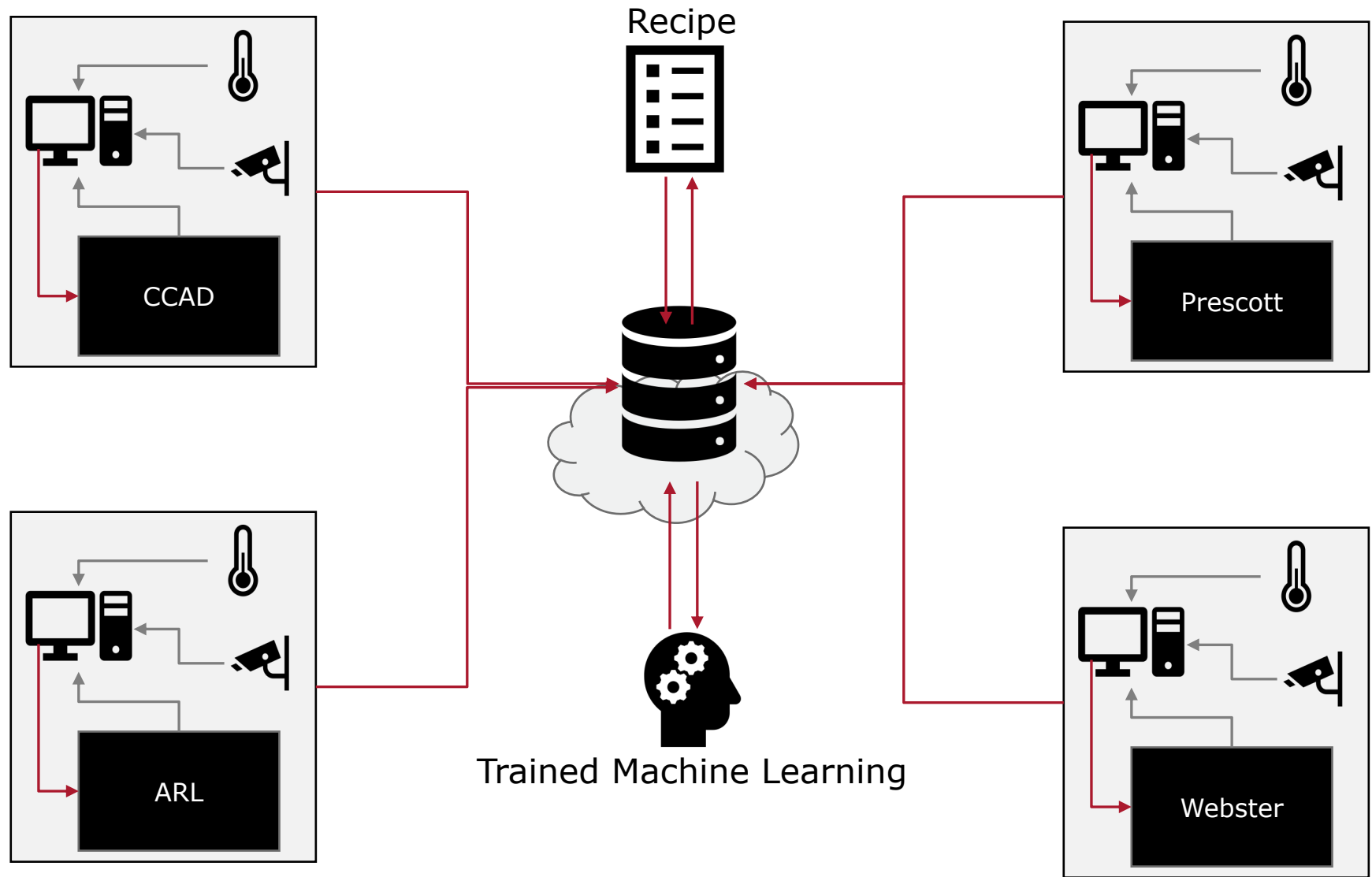


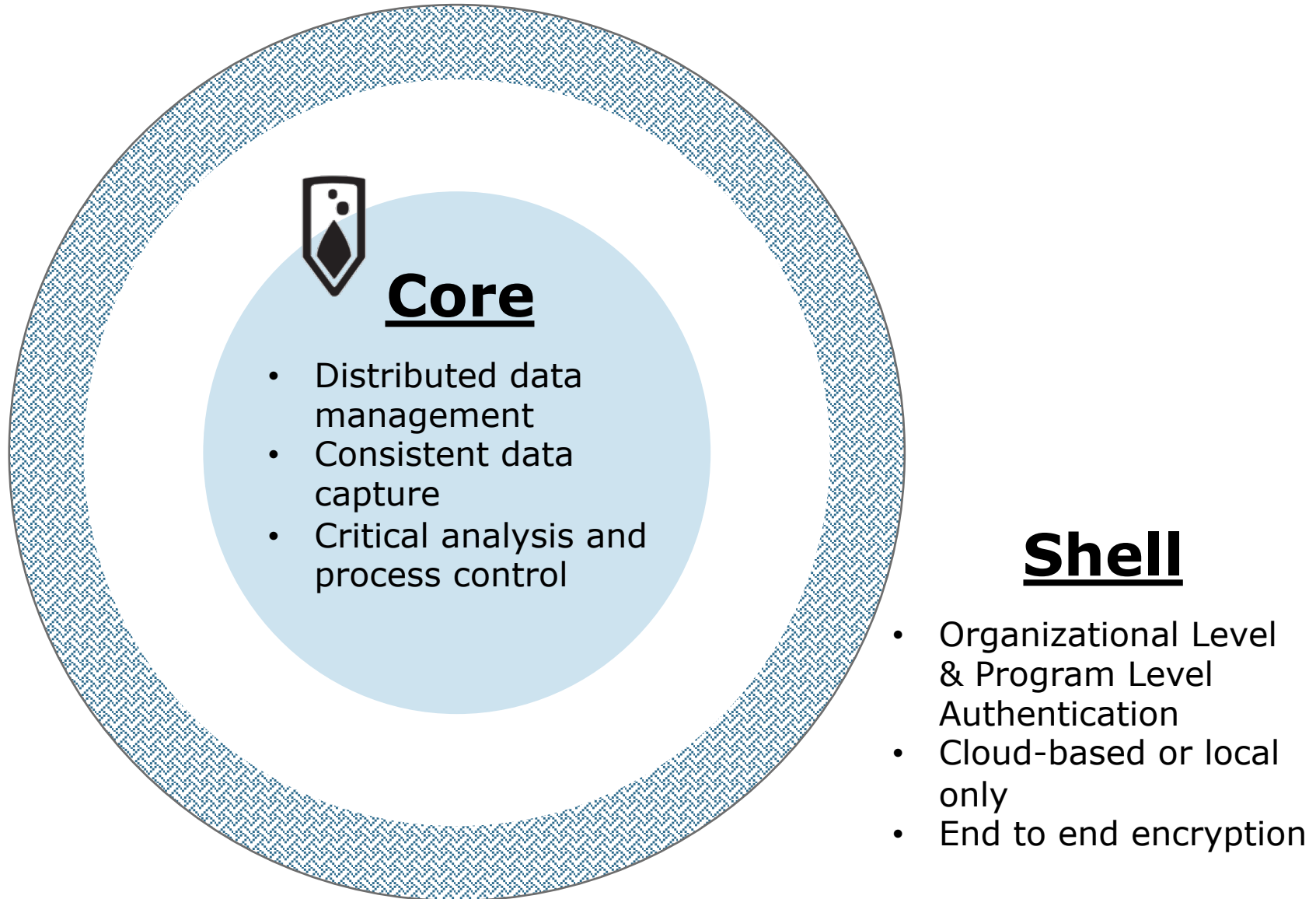


Part

ID	Part Number	Lot Number	Description	Size
1				
+	+	+	+	+

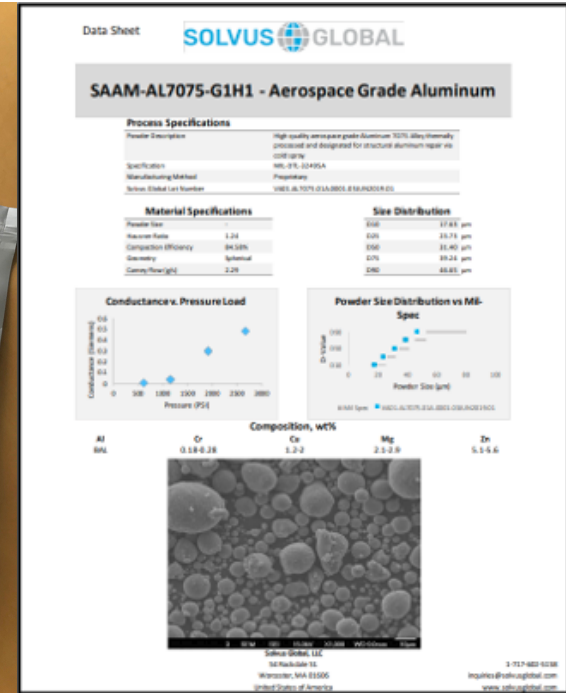
1.2.0



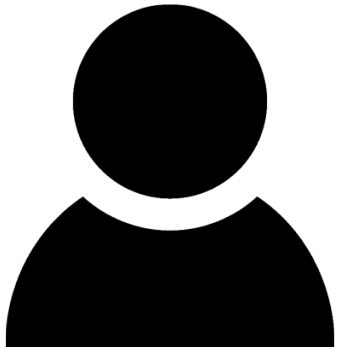


(3c) Knowing Your Feedstock

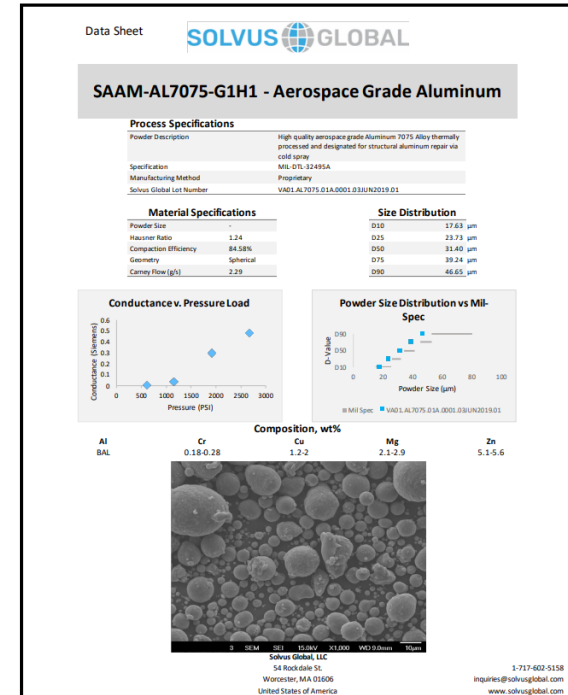
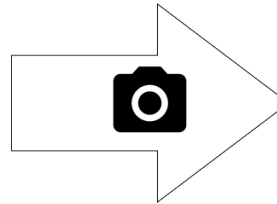
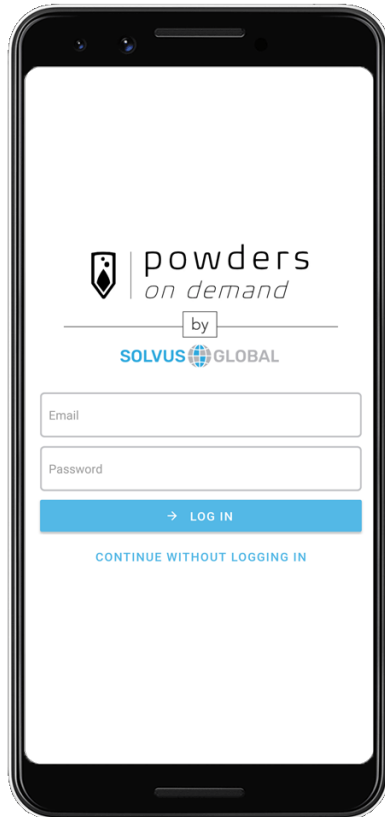
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(3c) Knowing Your Feedstock



powder





Thank You

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aaron.birt@solvusglobal.com
www.sovlusglobal.com

**Visit 104 Prescott
Street for Tour &
Drink Tickets @ 5:15
PM Tonight**