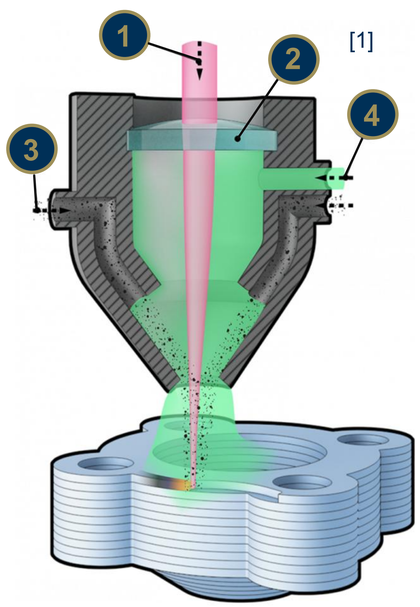
Schlieren: Gas Flow Visualization

Georgia Institute of Technology
Sadhana Kumar, **Ivan Chen**, *Cooper Delgandio, Aarush Gupta,*
Dr. Zachary Brunson, Dr. Aaron Stebner

Artificial Intelligence in Manufacturing Pilot Facility

Directed Energy Deposition (DED)



[1]

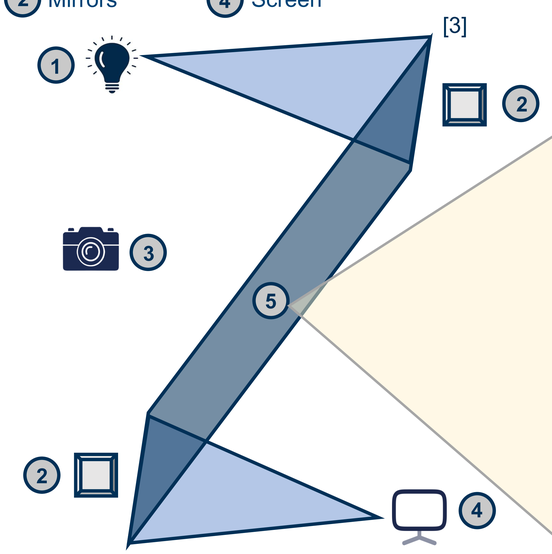
- Powder blown, laser DED method
- Product built layer-by-layer

1. Laser heats up a local region
2. Carrier gas deposits metal powder

1. Laser Beam
2. Focusing Lens
3. Metal Powder
4. Inert Gas (Ar)

Schlieren: A Way to See the Unseen

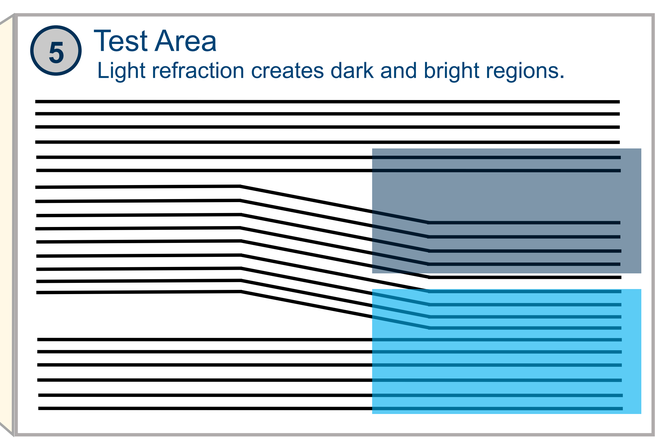
1. Light Source
2. Mirrors
3. Camera
4. Screen



[3]

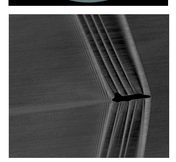
What does it do? [4]

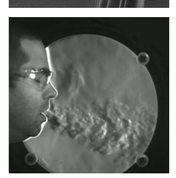
- Visualizes fluctuations in index of refraction
  - Changes in pressure
  - Changes in temperature
  - Changes in density

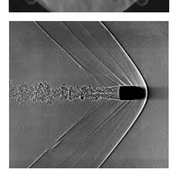


Common Visualization Applications:


[5] Heat dissipation from a system

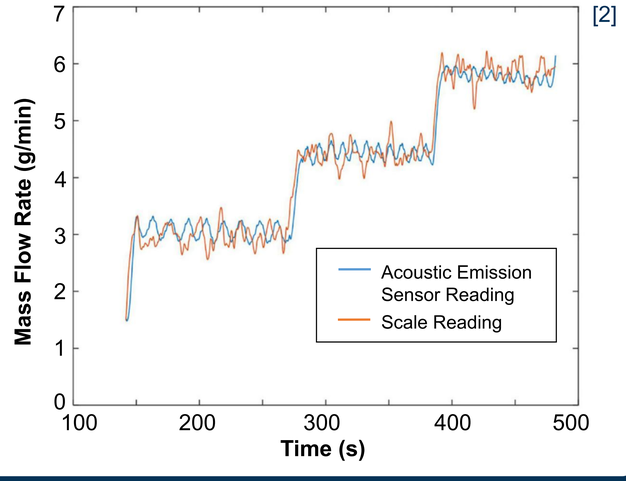

[6] Shock waves from a jet plane


[5] Exhalation and inhalation in humans


[7] Flow streamlines caused by a fast-moving object

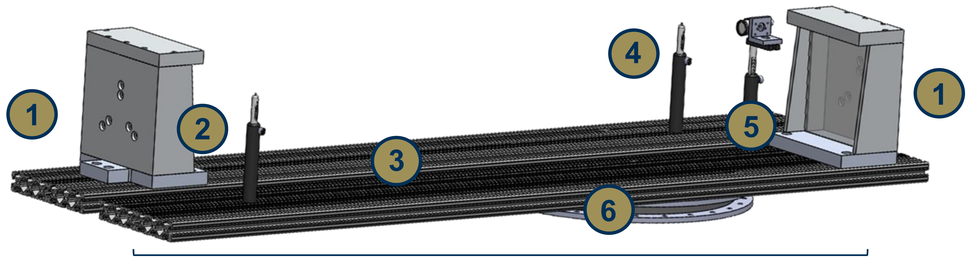
Dealing With Bad Vibrations

- High variability and periodicity in mass flow among nominal DED printers
- Unknown, system agnostic mass flow pattern and source
  - Nozzle, bed, or material instability



[2]

How Do We Fit it in a Metal Printer?

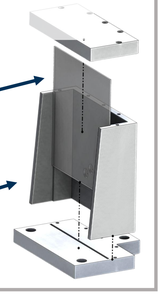


60" focal length

1 Adjustable Mirror Mount

Low refractive index window (~1)
(0.12" museum acrylic)

Powder-safe enclosure



2 Light Source

3 64" Railing

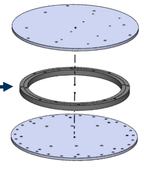
4 Knife Edge

5 Camera

6 Swivel Base

Rotary positioning system

17" swivel bearing



Future Work

- Fabrication
- Setup and testing on Optomec
- Setup and testing on Mazak
  - 3 different nozzles
- Setup and testing on RPMI

RPMI

Optomec

Mazak

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OLD VERSIONS

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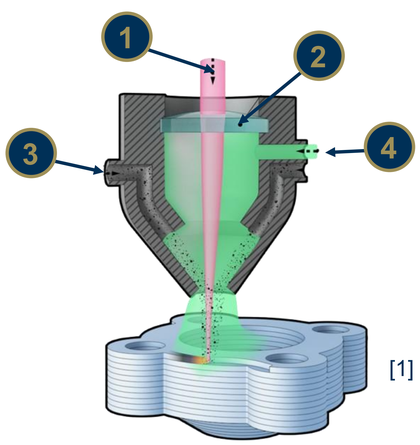
Directed Energy Deposition (DED)

- Layered additive manufacturing method via laser-welded metal powder/wire



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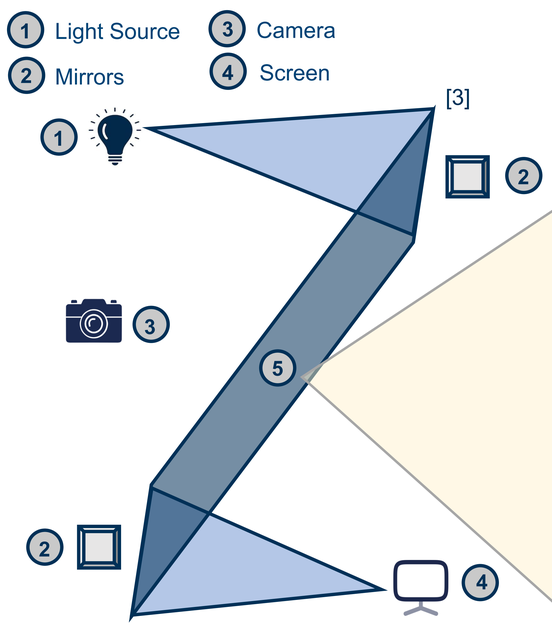
1. **Laser Beam**
2. **Focusing Lens**
3. **Metal Powder**
4. **Inert Gas**

Schlieren: A Way to See the Unseen



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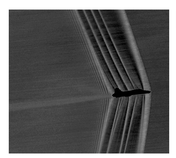
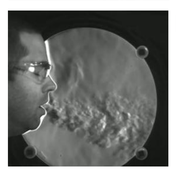


[6] Visualizing shock waves from a jet plane



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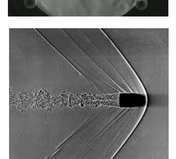

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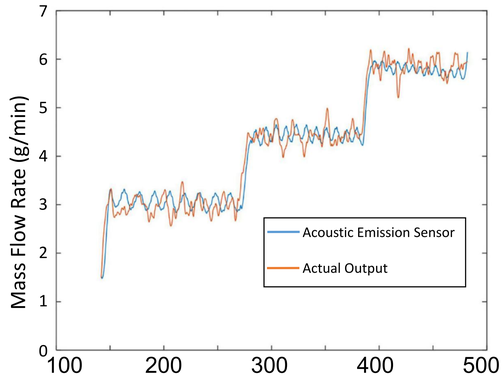

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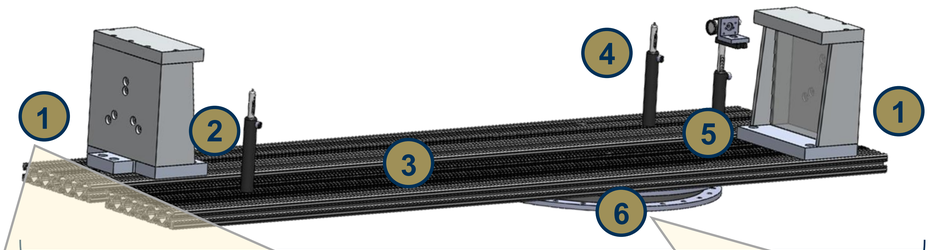

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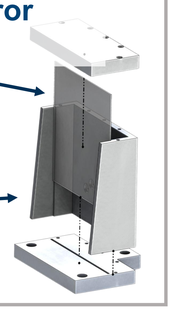

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5. **Camera**
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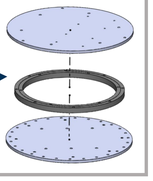
   Rotary positioning system
   17" swivel bearing



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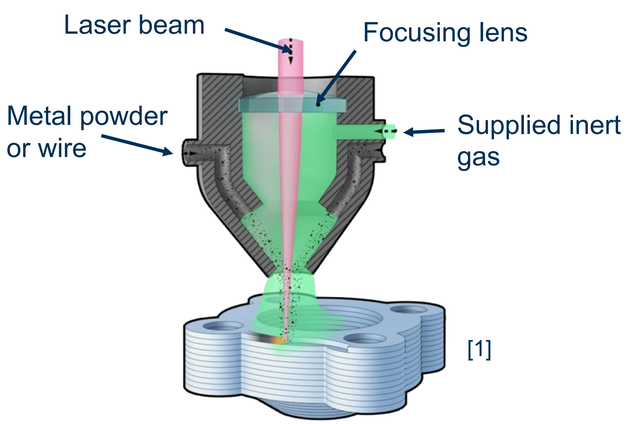

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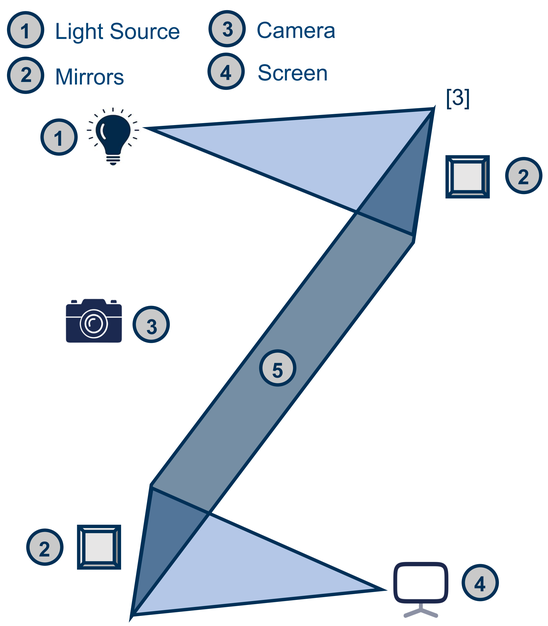
Schlieren: A Way to See the Unseen



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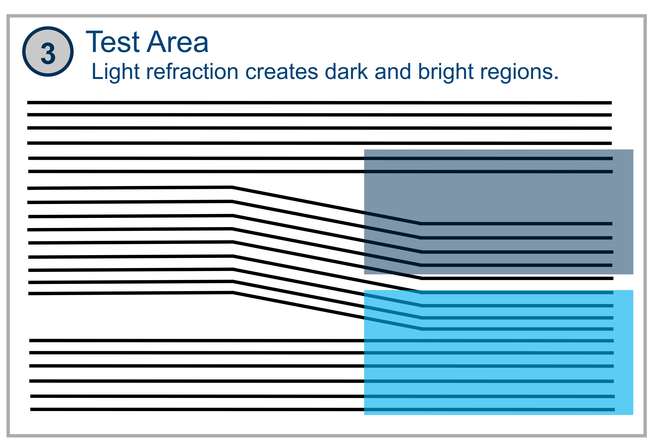

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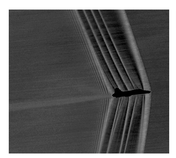
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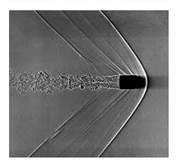
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Bad Vibrations

Our problem:

- Issues with mass flow in the Optomec, Mazak, and RPMI printers
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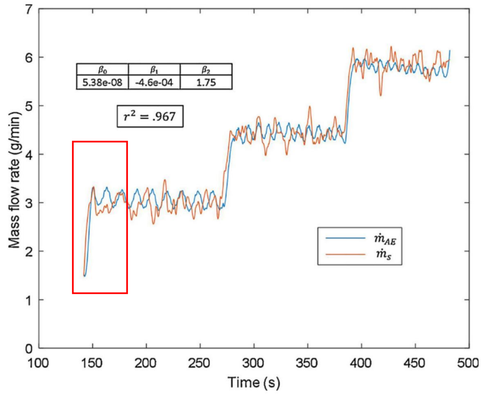
- Unknown flow dynamics
- How gas disperses in the system



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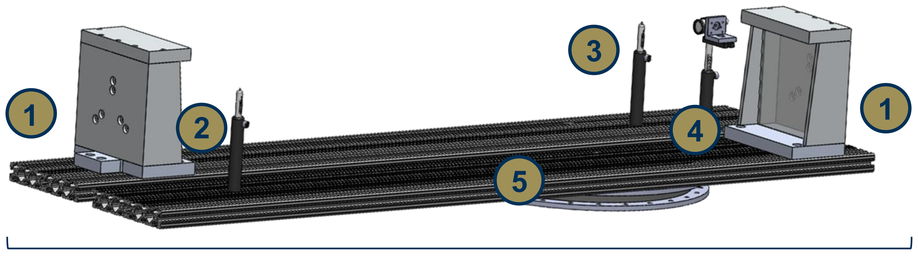

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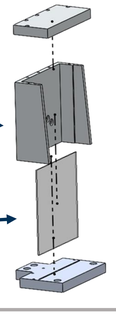

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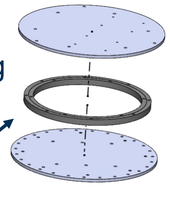

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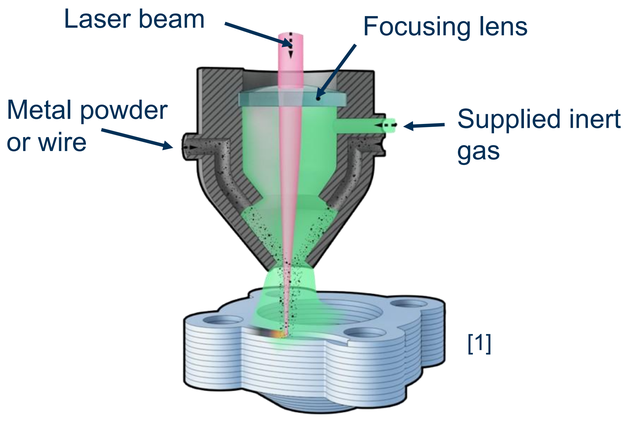

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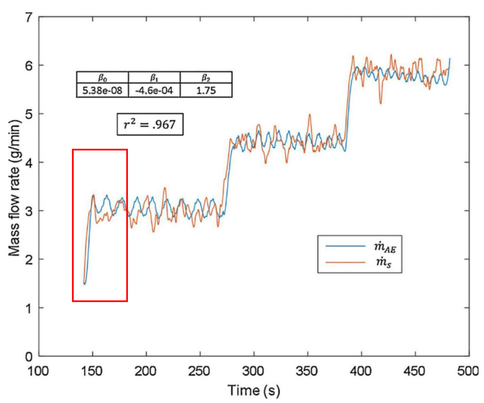


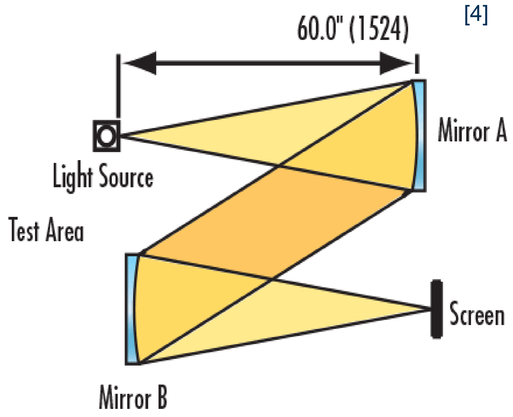
[2]

Schlieren: A Way to See the Unseen

Purpose: [3]

- Visualizes fluctuations in optical density
- Used in fluid dynamics studies

[4]



Components:

- 2 mirrors
- Light source
- Screen
- Blade edge
- Camera

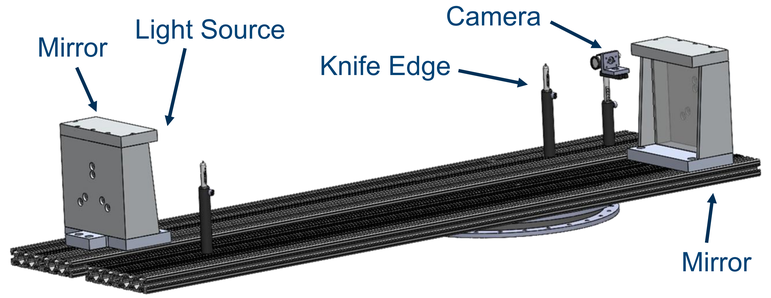
[3]

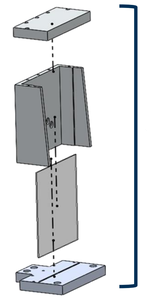
Common Applications: [3]

- Inhalation in humans and animals
- Shock waves from aircraft
- Heat dissipation from a system

[5]

How do we fit it in a metal printer?





Current Schlieren system:

- 60” focal length
- 6” mirrors
- Low refractive index acrylic covering
- Adjustable mirror mounts
- Integration within DED systems

Future Work

- Setup and testing on 3 systems: Optomec, Mazak, RPMI
- Analyze results to determine potential causes of mass flow inconsistencies & periodicity

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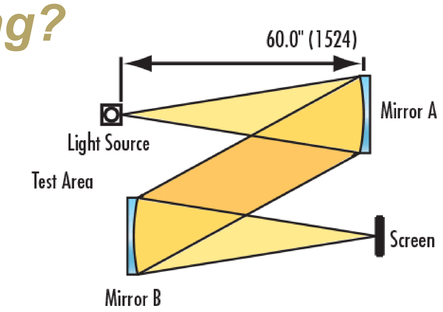
What Is Schlieren Imaging?

- Introduction to Schlieren process
- How it works, steps, etc

- Benefits of using Schlieren?



Information about Camera??

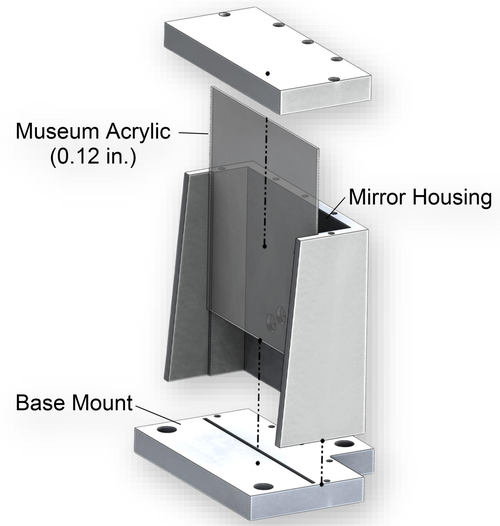
Pyrometry??

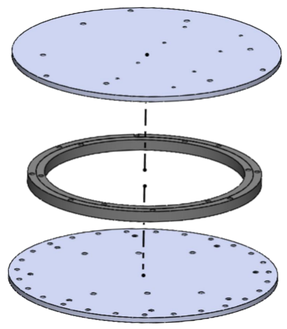
Equipment Assembly

Mirror Housing

- Mirrors and Camera Lenses prone to dangers

- Museum Acrylic infraction index of 1,
- Aluminum 6061 resistance to heat





Angular Modularity

- 17'' Swivel ball bearing
- 27 distinct angles

Imaging Integration in Metal-Additive 3D-Printing

- Modifying (Optimec, Mazak, the other one I forgot)
- Installing Schlieren systems to …

- Purpose of heat visualization in printing

(Image of full system once Files are retrieved)

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Title – Try to keep it ~ 100pt font

Georgia Institute of Technology
You
Others

Collaborators?
them

Artificial Intelligence in Manufacturing Pilot Facility

Try to Keep subtitle fonts around 60

This version will be easier to resize and move boxes.

Also this font is navy 40 pt Arial. All text boxes are loose so you can arrange photos as you like.

For photos, recommended 3pt gold border.
Gold for any flowcharts/shapes to balance color usage.

GT Blue: 0,48,87 RGB
GT Gold: 179,163,105 RGB

30pt for image titles

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