EML4551-2

Team 510: Climatic Camera

Design Review VI

Nash Bonaventura
Diego Gonzalez
Bryce Shumaker

Team Introductions

Diego Gonzalez
Design Engineer

Nash Bonaventura
Simulation Engineer

Bryce Shumaker
Project Manager

Stakeholders

__Engineering Mentor__
Kourosh Shoele, Ph.D.
Assistant Professor
FAMU-FSU College of Engineering

__Sponsor__
Vinayak Hegde,
Reliability Engineering Manager
Danfoss Turbocor Compressors, Inc.

Diego Gonzalez

Project Objective

The objective of the project is to design a product that will maintain operation of a recording device at extreme temperatures (-40 to 160 °C) (-40 to 320 °F)

Diego Gonzalez

Background

- Air compressor manufacturer
- Components tested by reliability engineering department
- Components are tested using cyclic temperature tests
- Test Temperature range (-40 to 160 °C)
- Cameras operates between 0 and 45 °C

Diego Gonzalez

Current Problems

- Physical presence is necessary to monitor
- Window gets foggy and obstructs view
- Reflection from window
- Outside Visuals
  - Fixed viewing distance
  - Low reachability

Diego Gonzalez

Customer Needs

- The device provides live continuous monitoring
- The device is isolated from the testing environment
- The device can be adjusted to different orientations
- The device has computer connection capabilities
- The device has failure detection capabilities

Diego Gonzalez

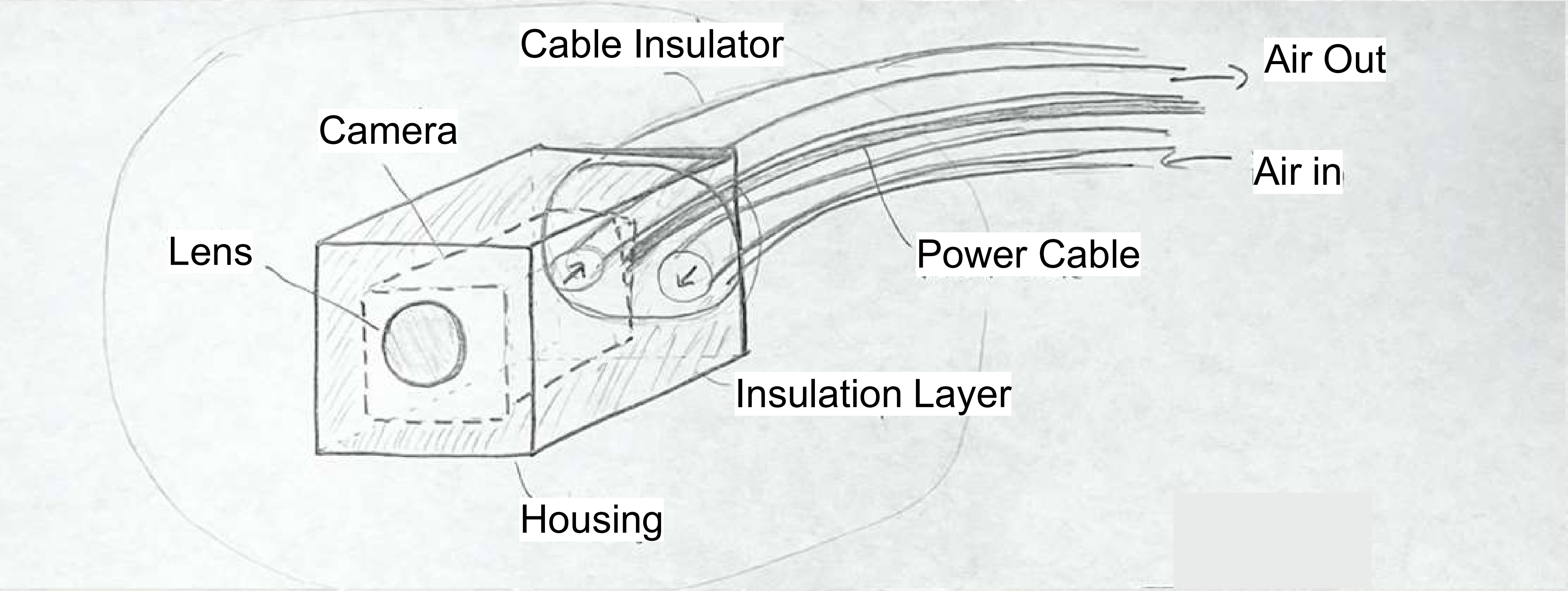
Available Resources

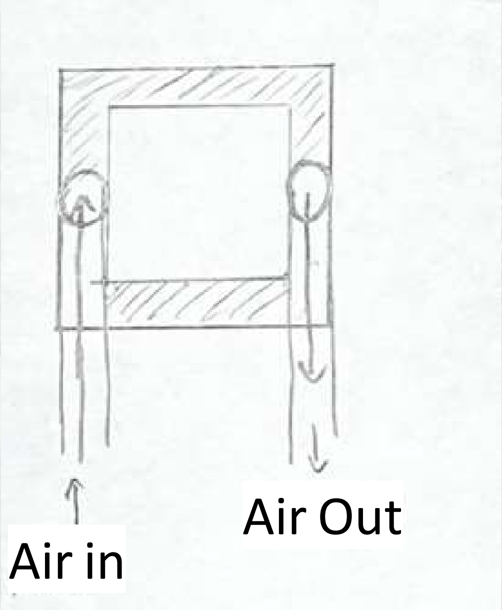
- Compressed Air – temperature regulation
- Laptop – power supply, software interface, data storage
- Chamber Port – connection with auxiliary systems
- Racks – mounting
- Machine Shop

Diego Gonzalez

Selected Concept

Compressed air, USB Borescope Camera





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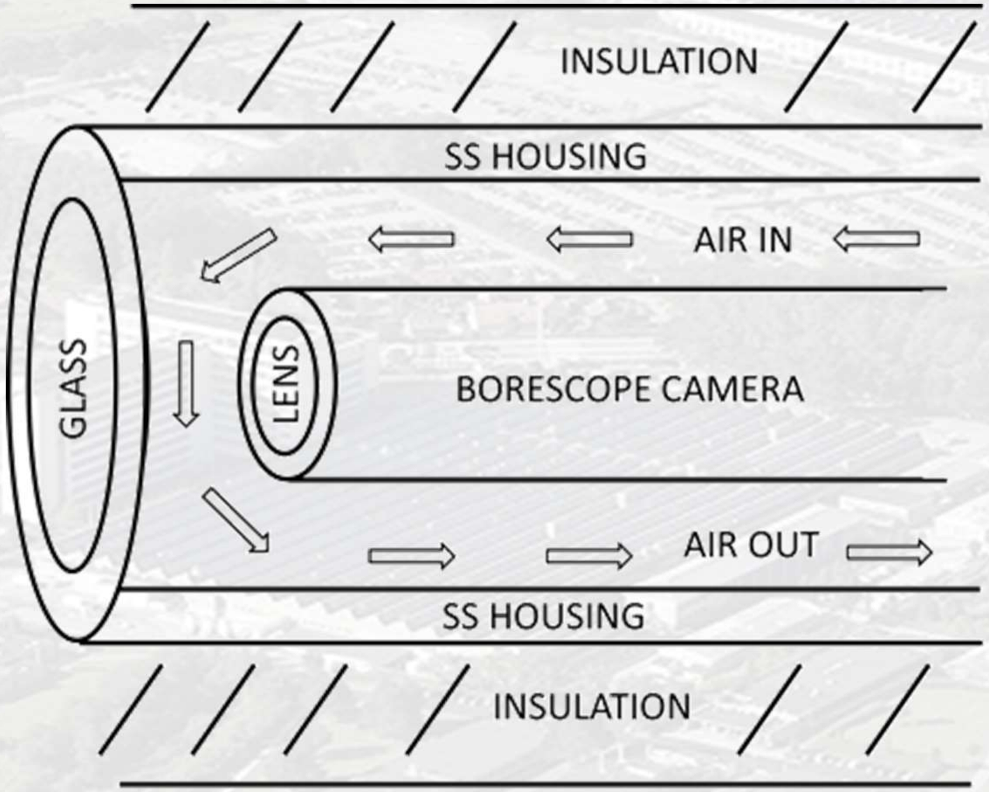
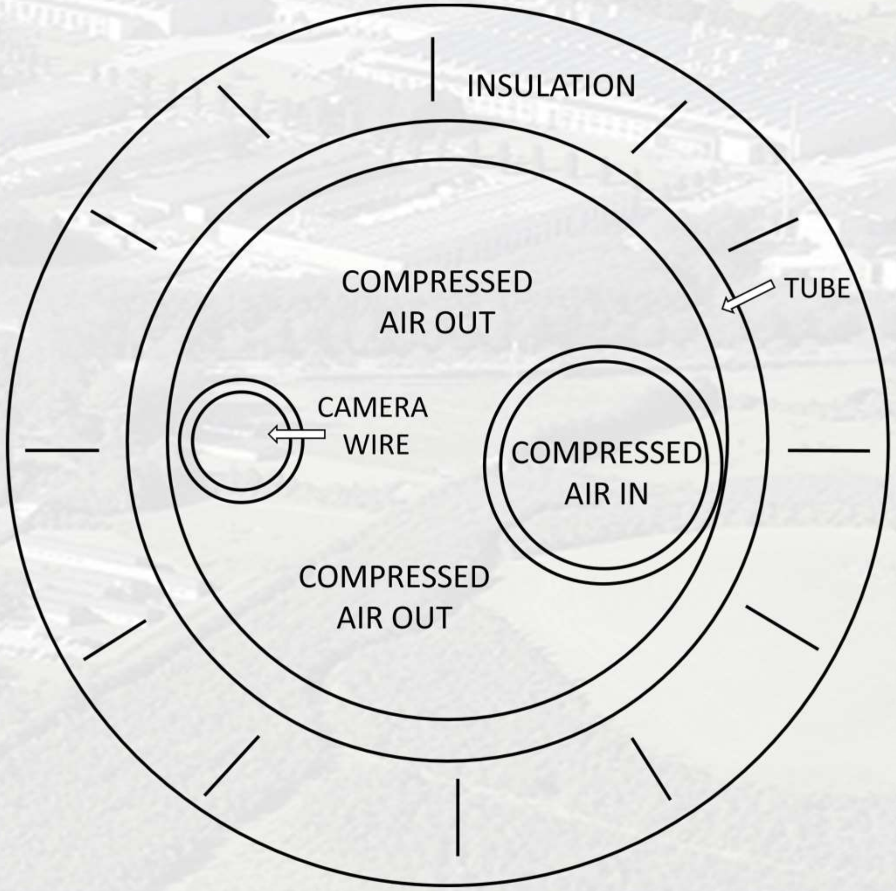
Selected Design





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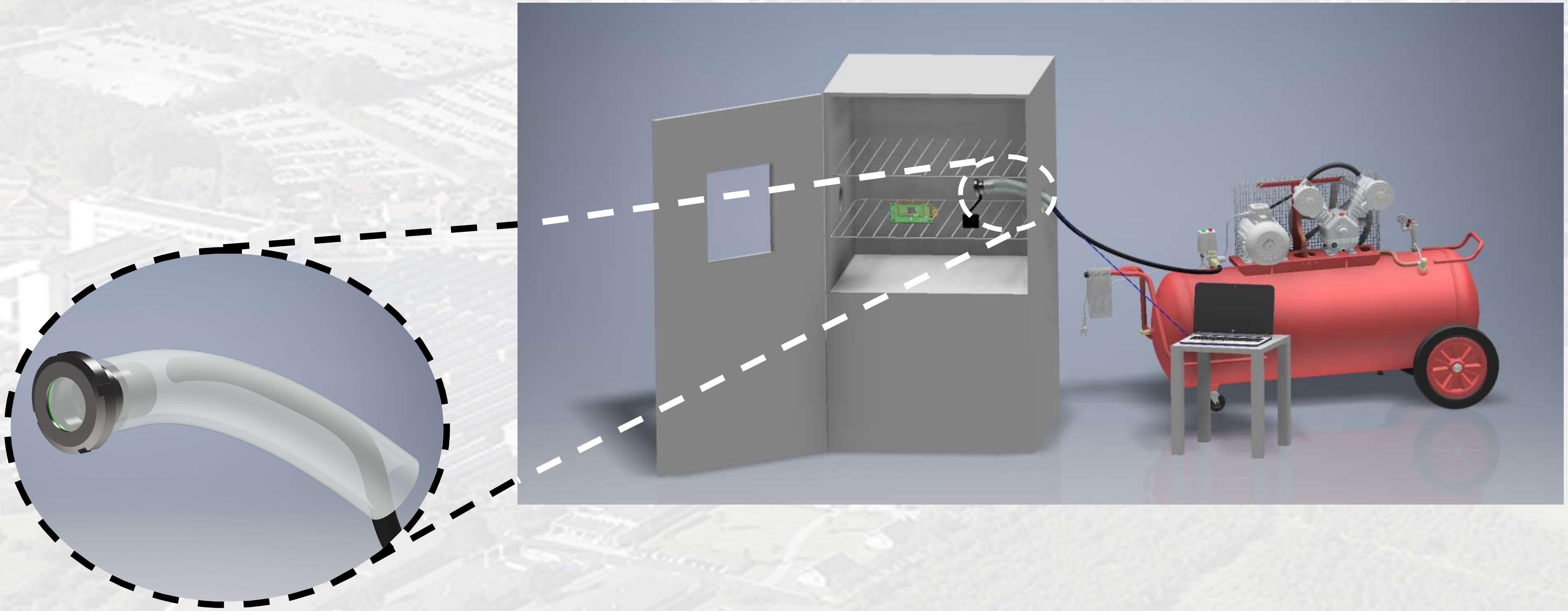
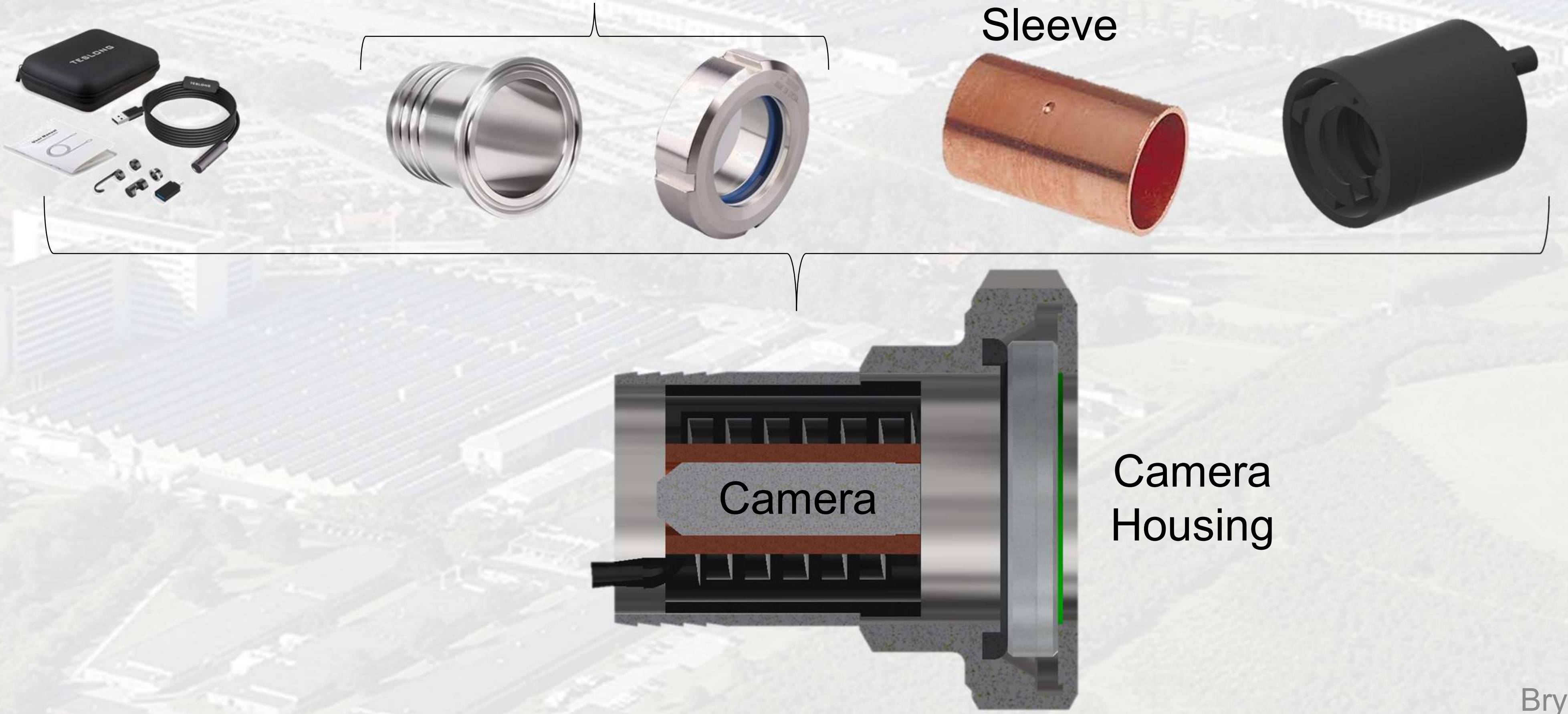
Overall System



Bryce Shumaker

Design Functions: Monitor



Borescope Camera

Housing

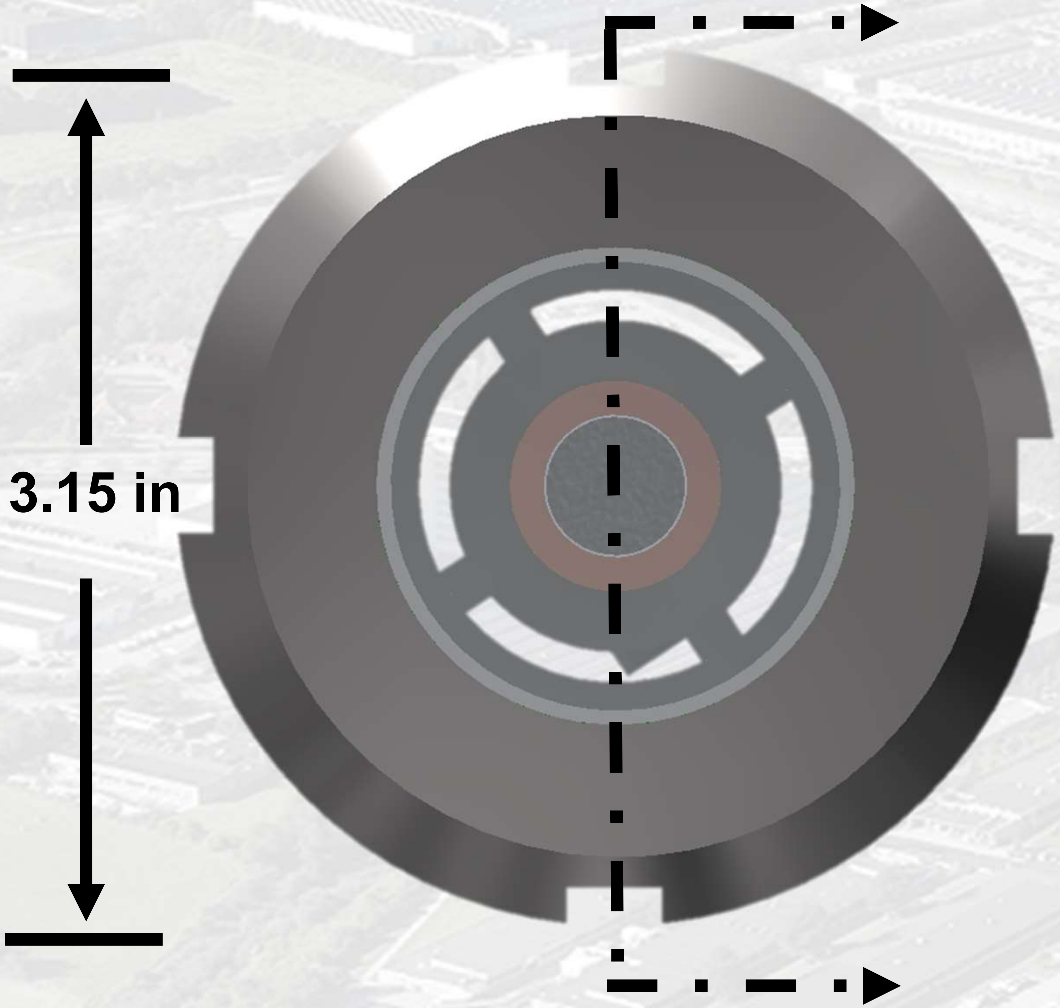
Copper
Sleeve

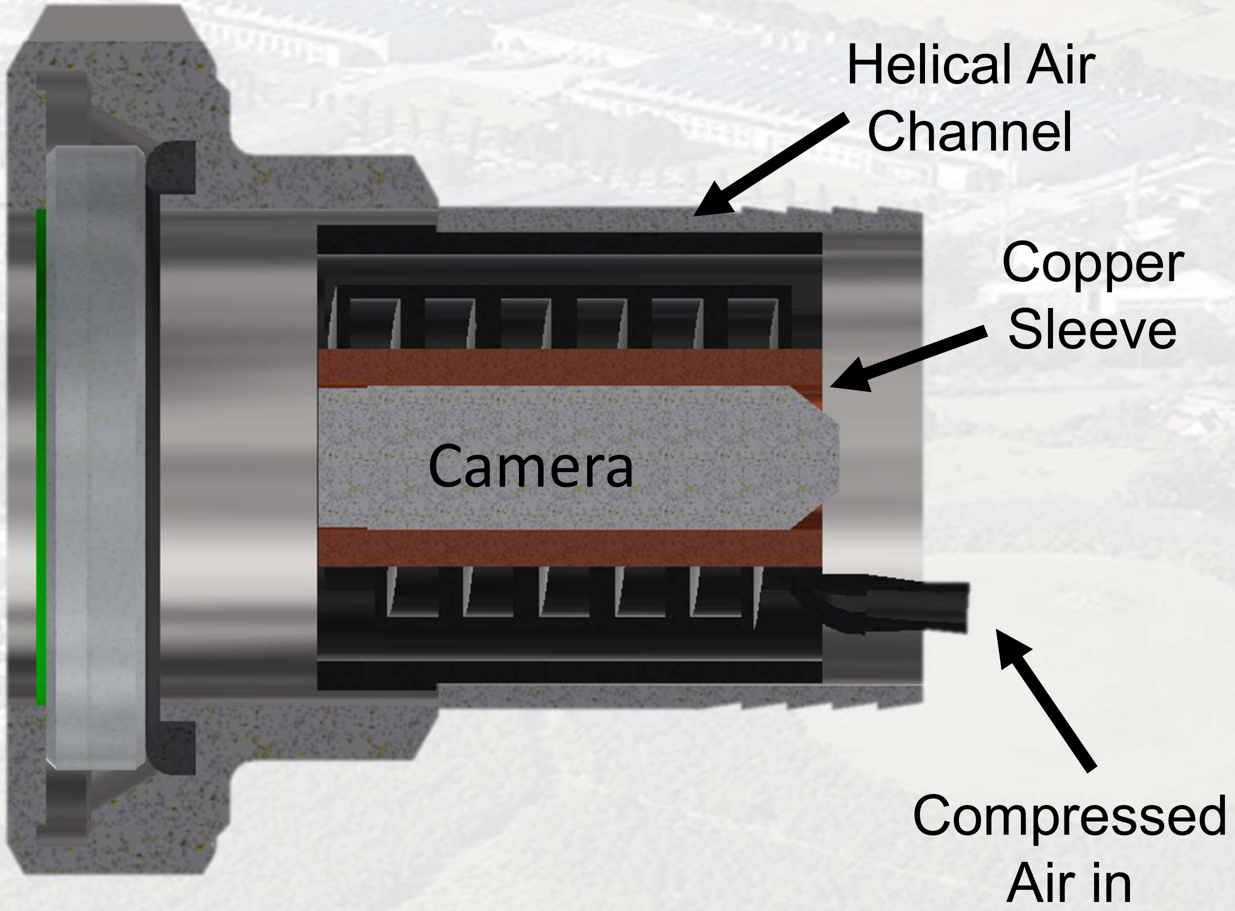
Air Channel

Camera
Housing

Bryce Shumaker

Detailed Design





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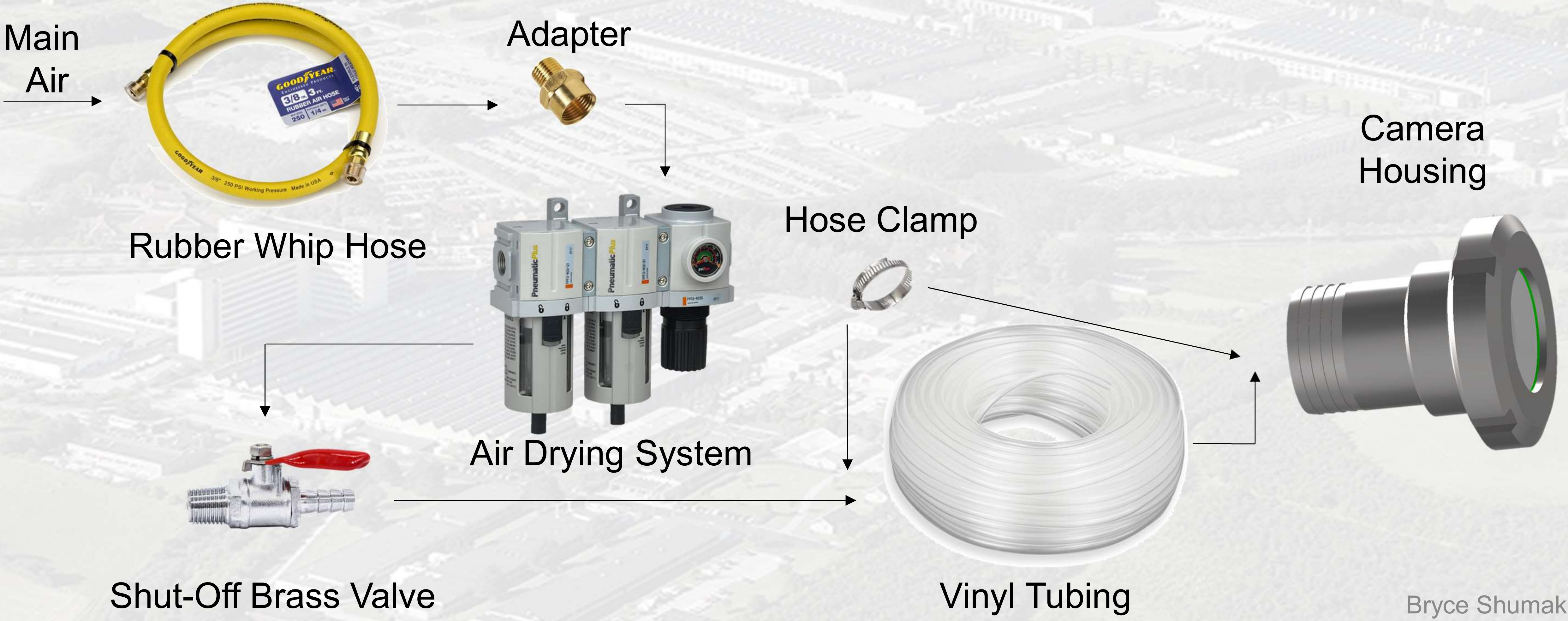
Design Functions: Isolate



Main Air

Rubber Whip Hose

Adapter

Air Drying System

Shut-Off Brass Valve

Hose Clamp

Vinyl Tubing

Camera Housing

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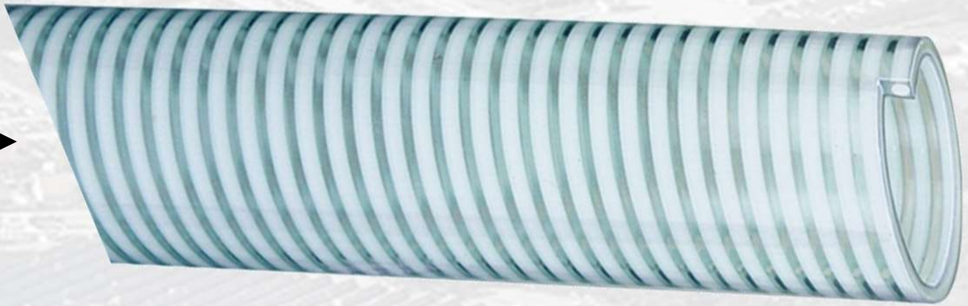
Design Functions: Isolate

Melamine Foam Pipe Insulation

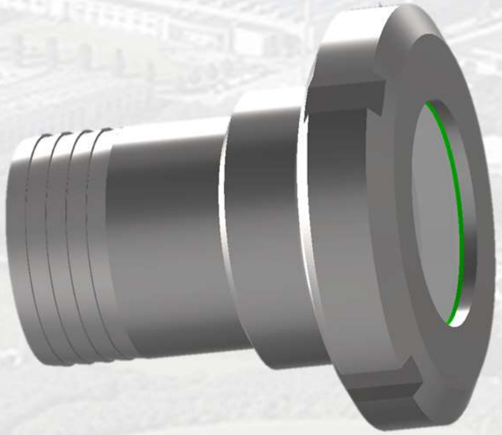
-40 to 176 °C

External Hose Clamps



Suction and Discharge Hose

Hose Clamps



Camera Housing

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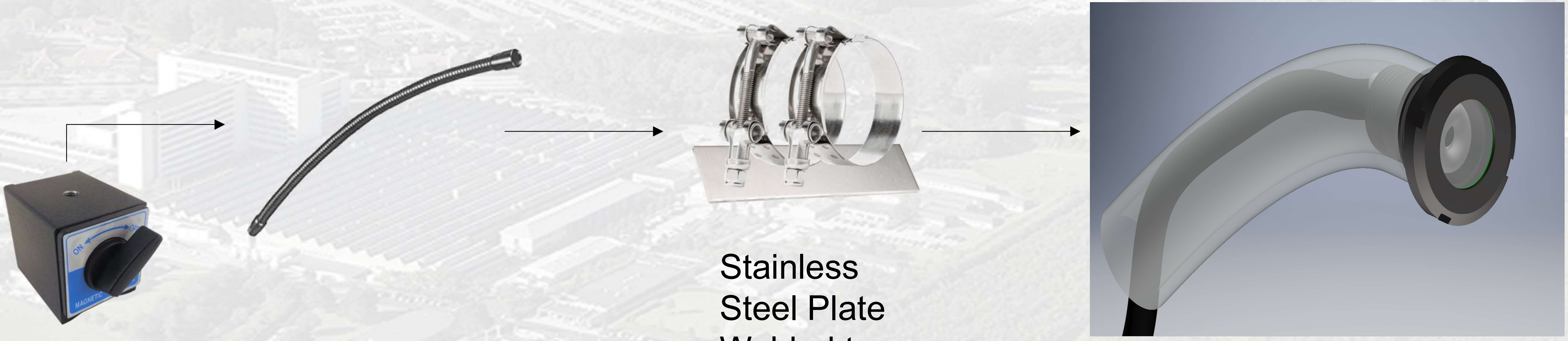
Design Functions: Support



Device

Magnetic
Base

Gooseneck

Stainless
Steel Plate
Welded to
Hose Clamps

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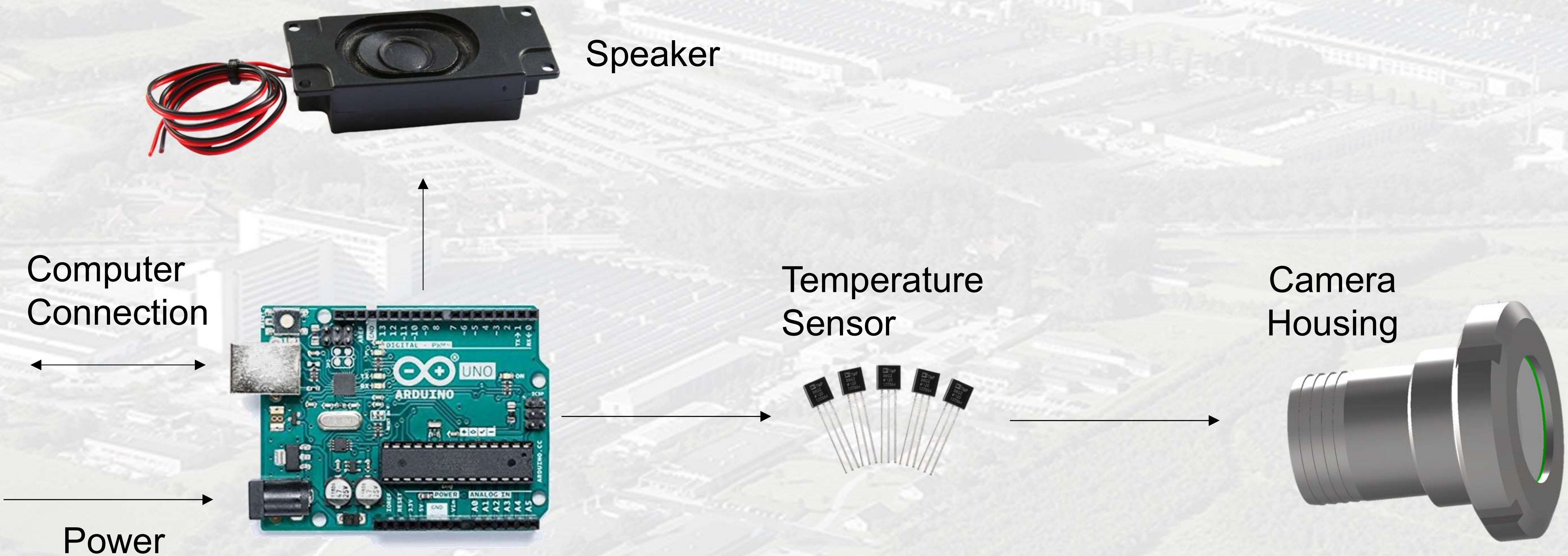
Design Functions: Alarm System



Speaker

Computer
Connection

Temperature
Sensor

Camera
Housing

Power
Cable

Arduino

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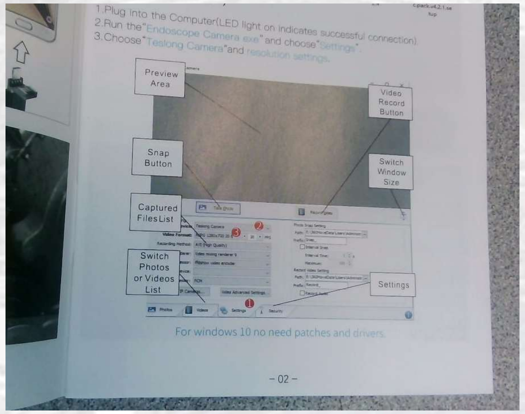
Current Design Problems

- Borescope camera LED light reflection in Glass



1.Plug into the Computer(LED light on indicates successful connection).
2.Run the"Endoscope Camera.exe"and choose"Settings".
3.Choose"Teslong Camera"and resolution settings.

For windows 10 no need patches and drivers.

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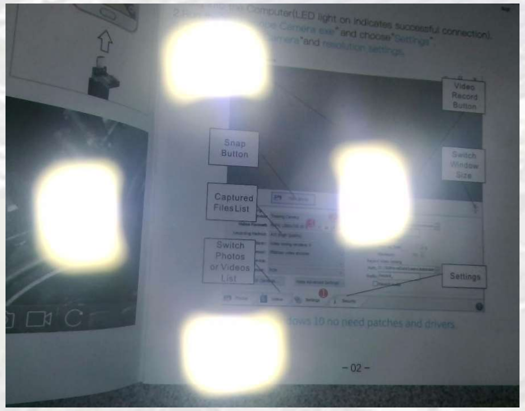
LED's Off



LED's On

- 1. Anti-reflective glass
  - 99% Transmission of Light
  - Less than 0.5% of Reflection
- 2. Outside Lighting

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Budgeting

🟩 Items Received
🟨 Items Requested

$ 531.66

Item #	Item Description	Quanti	Price
1	Borescope Camera	1	49.99
2	Glass Housing	1	22.52
3	Housing Body	1	12.22
4	Clamp for Housing	1	$11.39
5	Clamp set	1	$11.90
6	Goose neck	1	$9.95
7	Magnet base	1	$16.99
8	Desicant Air Dryer	1	$129.99
9	Shut-Off Brass Valve	1	$8.98
10	Brass Reducer	1	$3.79
11	Vynil Tubing	1	$9.97
12	Copper rod	1	$25.49
13	Smaller Hose Clamps	1	$2.99
14	ABS Filament	1	$21.99
15	Rubber Whip Hose	1	$8.62
16	Arduino	1	$19.99
17	Temperature sensor	1	$9.99
18	Speaker	1	$11.99
19	Teflon Tape	1	$4.99
20	Pipe Insulation	1	$47.92
21	Inside pipe (Tigerflex)	60	$30.00
22	Anti-reflective glass	1	$60.00
			$531.66

Bryce Shumaker

Simulation

COMSOL Problem Setup

- L-VEL turbulence model
- Heat transfer simulated in steady-state
- Natural convection on exterior surfaces
- Pressure at the air inlet of the model tested at <u>0.1 psi</u> and <u>1.0 psi</u>
- Air enters the device at ambient temperature
- Heat generation of the camera is negligible

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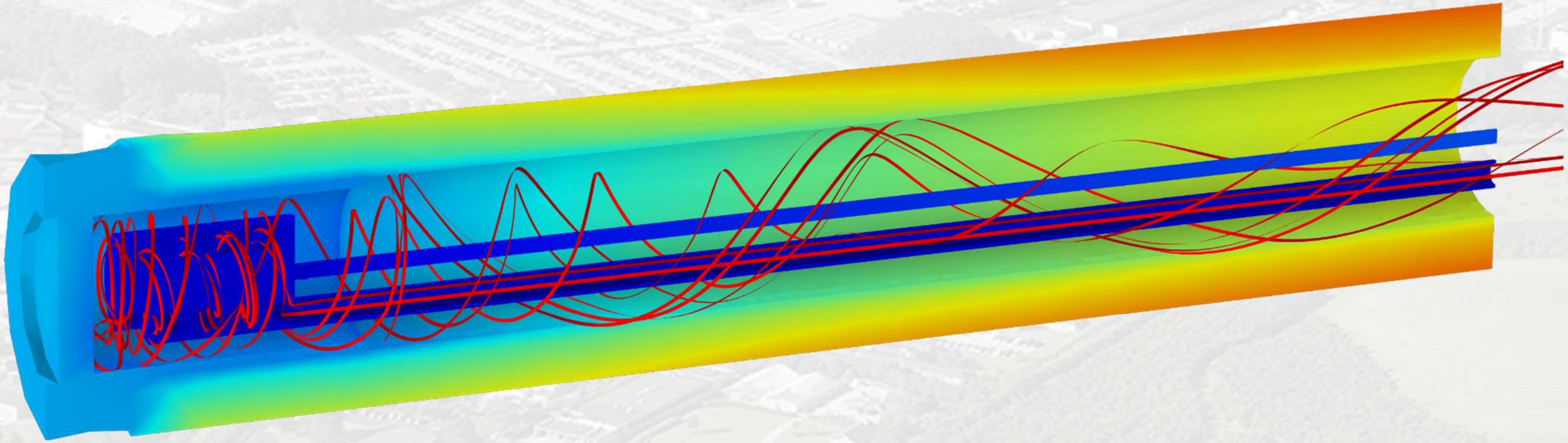
Simulation

Streamlines of the Velocity Field



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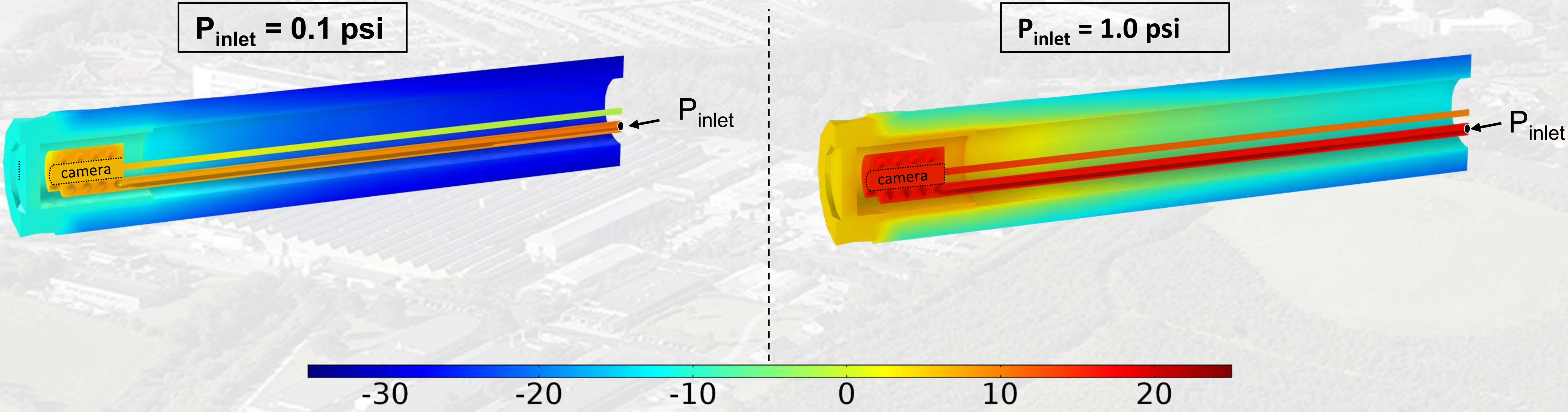
Simulation

Temperature Distribution of the Device

Cold Extreme: $T_{chamber}$ = - 40°C



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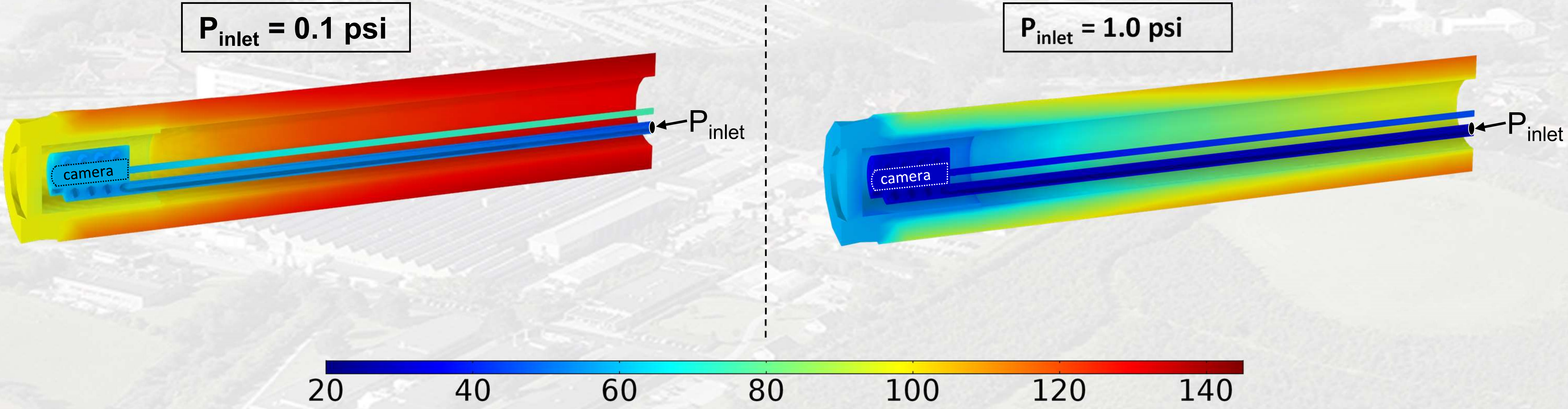
Simulation

Temperature Distribution of the Device

Hot Extreme: $T_{chamber}$ = 160°C



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Simulation

Surface Temperature of the Camera

Chamber at the **cold extreme**

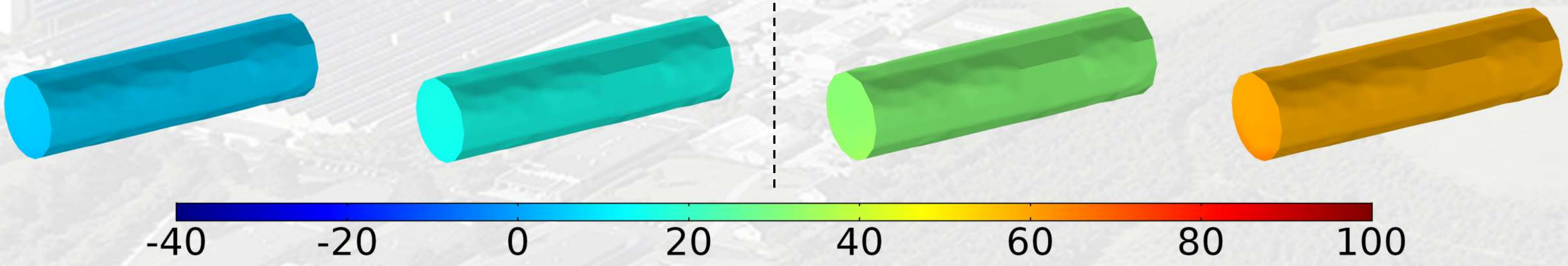
P_{inlet}= 0.1 psi
T_{min}= 6.18°C

P_{inlet}= 1.0 psi
T_{min}= 15.5°C

Chamber at the **hot extreme**

P_{inlet}= 1.0 psi
T_{max}= 34.8°C

P_{inlet}= 0.1 psi
T_{max}= 65.7°C



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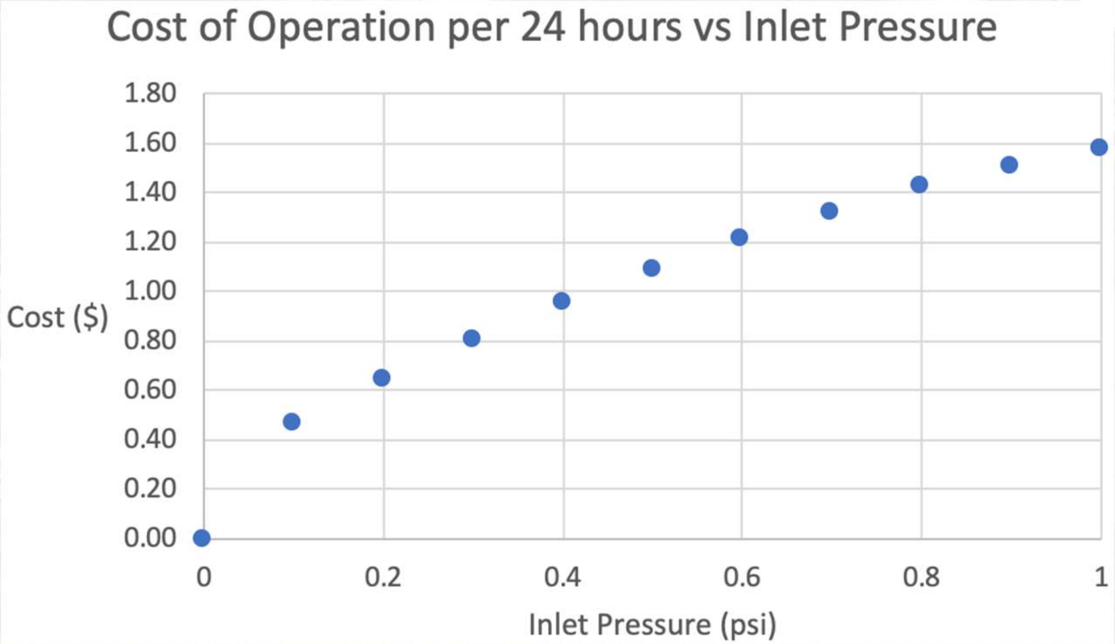
Cost of Operation

<u>General assumptions for estimating the cost of operation</u>:

- The price of electricity is \$0.10/kWh
- The set point of the compressor is 100 psi
- The compressor consumes 20 kW per 100 cfm of compressed air at 100 psi

$$\frac{20\ \cancel{kW}}{100\ \cancel{cfm}}\ \frac{\$0.10}{1\ \cancel{kW}\cancel{h}}\ \frac{100\ \cancel{cfm}}{4.72\times 10^{-2}\ m^3/\cancel{s}}\ \frac{1\ \cancel{h}}{3600\ \cancel{s}} = \underline{\$0.012\ \text{per}\ m^3}$$

Note: Solutions from the COMSOL simulation for the volumetric flow rate were used together with the cost per cubic meter of compressed air found from internet sources to get an estimate for the cost of operating the device.



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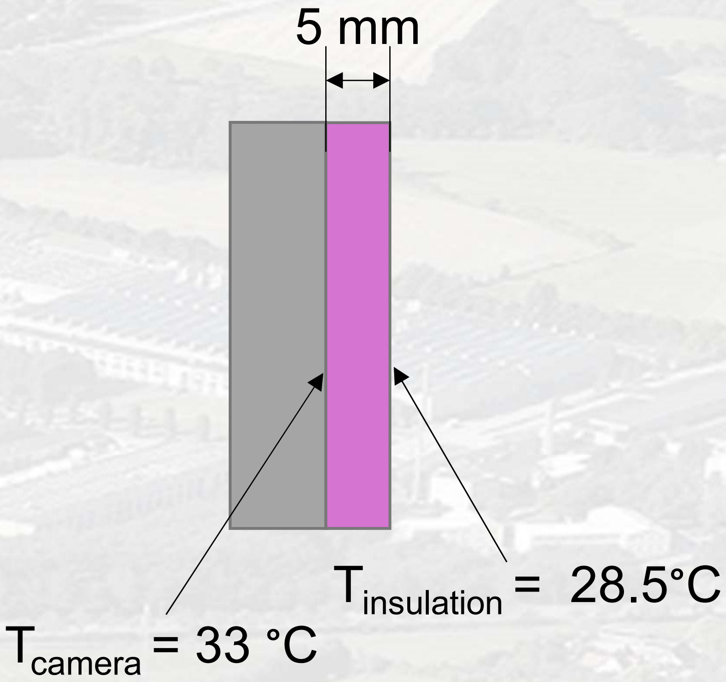
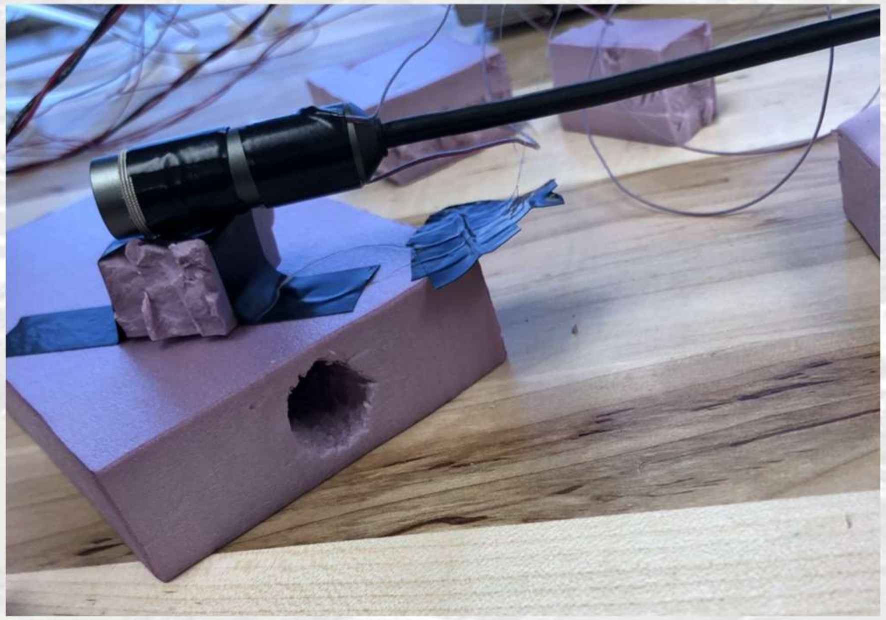
Validation

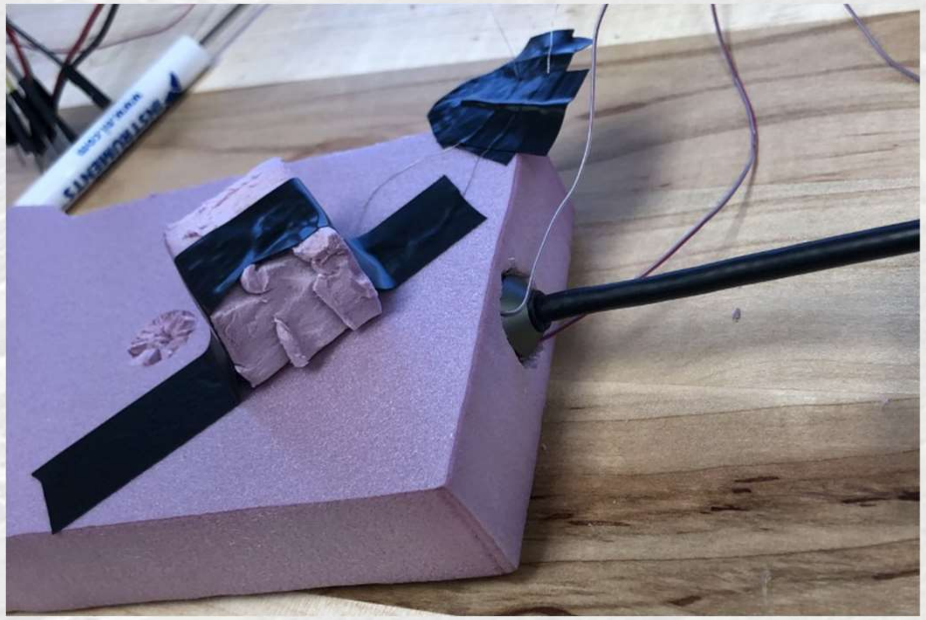
- Approximating camera heat generation with thermocouples to validate its heat contribution to the system is negligible



$T_{insulation}$ = 28.5°C

T_{camera} = 33 °C





$$Heat\ Flux = \frac{Q}{A} = \frac{k\Delta T}{thickness}$$

$$Heat\ Flux = 27\ \mathrm{W/m^2}$$

$Q = 27\ \mathrm{W/m^2} \times A_s \approx$ **0.0025 W**

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Validation

Target	Metric	Simulated Results
Camera Temperature	0 ≤ T ≤ 45ºC	14.1 ≤ T ≤ 34.8ºC
Days of operation	71	Indefinite
Adequate Lighting	Yes	N/A
Inexpensive camera	< $100	$49.99
Lens Condensation	0 mL	0mL
Camera Heat Generation	Negligible	Negligible

Nash Bonaventura

References

McConomy, S. (2019, February 2). Engineering Characteristics, Functions, Targets, and Metrics. FAMU-FSU College of Engineering.’

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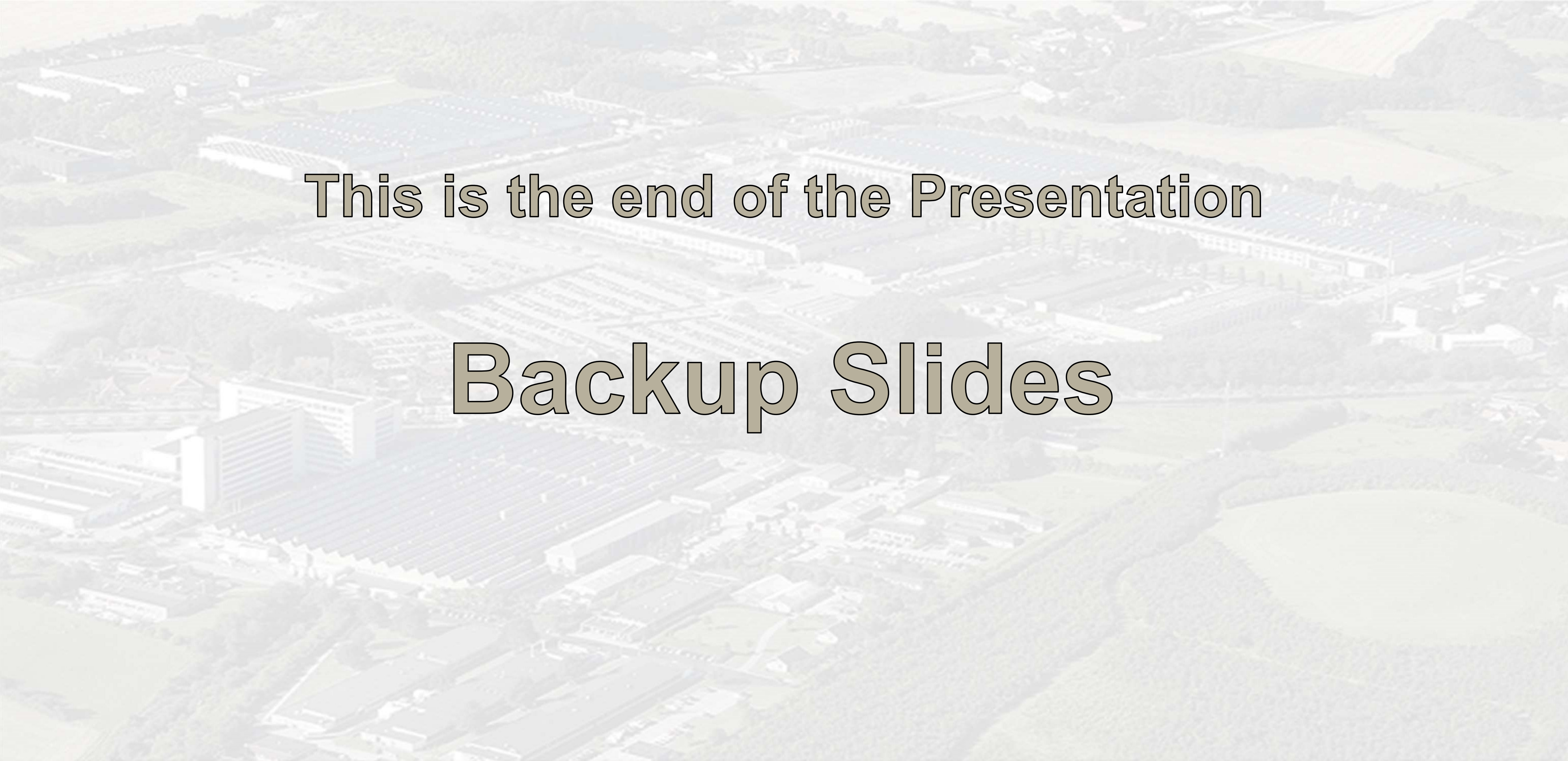
“It’s not a problem it’s an opportunity”



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