Virtual Design Review II

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Team 4: Visual Monitoring System for Danfoss Turbocor Compressor IGVs

Danfoss IGV Monitoring System

Team 4

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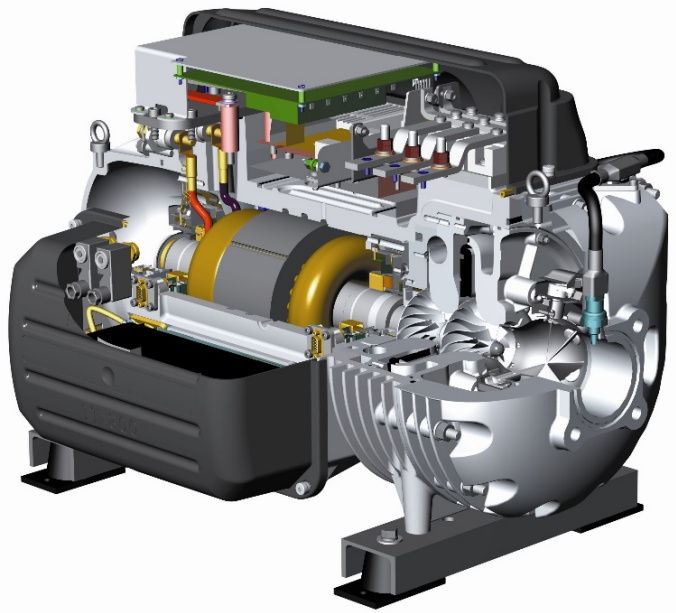
Project Overview

- Currently No Visual for Inlet Guide Vanes (IGVs)
- Limited Angle Measurement
  - Stepper Motor is Used for Angle Control
  - No Feedback
- Problems with IGVs
  - IGVs Might Flutter or Vibrate
  - Possible IGV Breakdown



Inside Cutout of Turbocor Compressor

Presenter: Travis Carter

Project Goals

- Danfoss Turbocor Inlet Guide Vane (IGV) Monitoring System Goals:
  - Provide detailed monitoring of low and high cycle failures
  - Produce a system to detect position of individual IGVs
  - Minimize impact on the fluid flow

Compressor Inlet Cross-Section

Presenter: Travis Carter

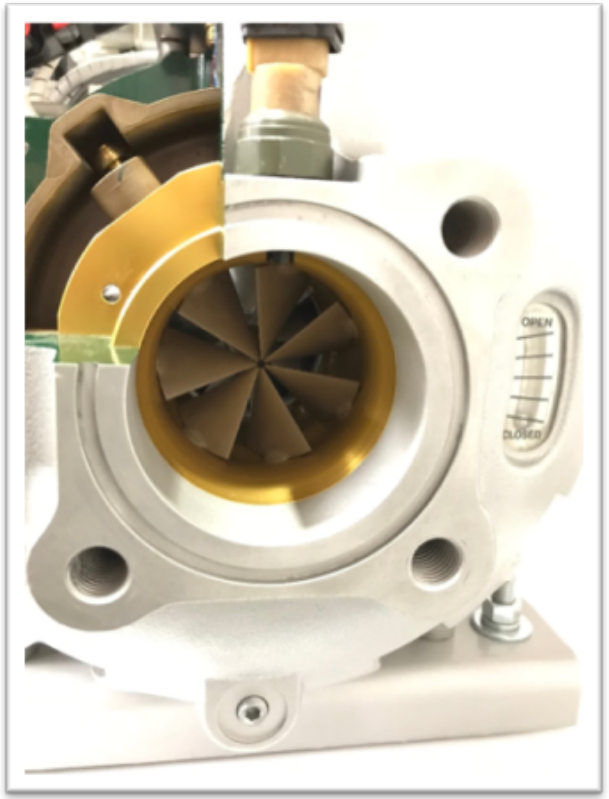
Main Interpreted Needs

Customer Statements	Customer Needs
We want a visual of the inlet to monitor guide vane, slip, impedance, flutter and vane loss	Visual monitor allows for qualitative analysis of IGVs' status
The compressor inlet flow should not be impacted	The system allows normal flow into compressor
The vanes need to be lit to see them	Vanes are all clearly visible

Presenter: Travis Carter

Types of Failure

- High Cycle Failure from Vibrations of the IGV
- Low Cycle Failure from Latching
- Low Cycle Failure from IGV Blade Lock



Compressor Inlet Guide Vanes

Presenter: Travis Carter

Arnold Schaefer

PROJECT TARGETS AND INTRODUCTION TO CONCEPT GENERATION SUBSYSTEMS

Targets: Resolution and Frame Rate

Description	Target Value
Minimum View Resolution	720 x 720 pixels
Minimum Sample Rate for Measuring Vane Low Cycle Failure or Latching	1 Hz
Minimum Sample Rate for Measuring Vane High Cycle Failure	1 kHz
Minimum Sample Rate for Measuring Angle	1 Hz

Presenter: Arnold Schaefer

Design Target Conditions

Description	Target Value
Minimum Angle Sensor Accuracy (In terms of percent open)	± 10%
Min/Max Absolute Refrigerant Pressure	10 to 110 psi
Min/Max Refrigerant Temperature	-10 to 80 °F
Min/Max Mass Flow Rate	0 to 2.5 Kg/s

Presenter: Arnold Schaefer

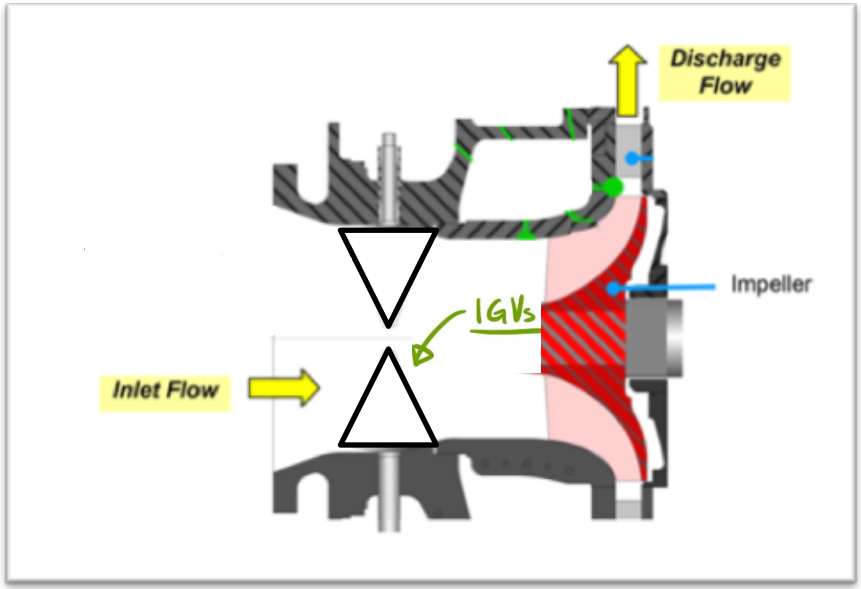
More Project Targets

Description	Target Value
Internal Pipe Illumination	1000 lux
Maximum Monitoring System Length	50 cm
Maximum Allowable Pressure Drop across Monitoring Device	0.02 psi
Allowable Flow Impact	No Detectible Swirl

Presenter: Arnold Schaefer

Subsystems for Concept Generation

- High Cycle Monitoring
- Low Cycle Monitoring
- IGV Angle Monitoring
- IGV Lighting



Compressor Inlet Details

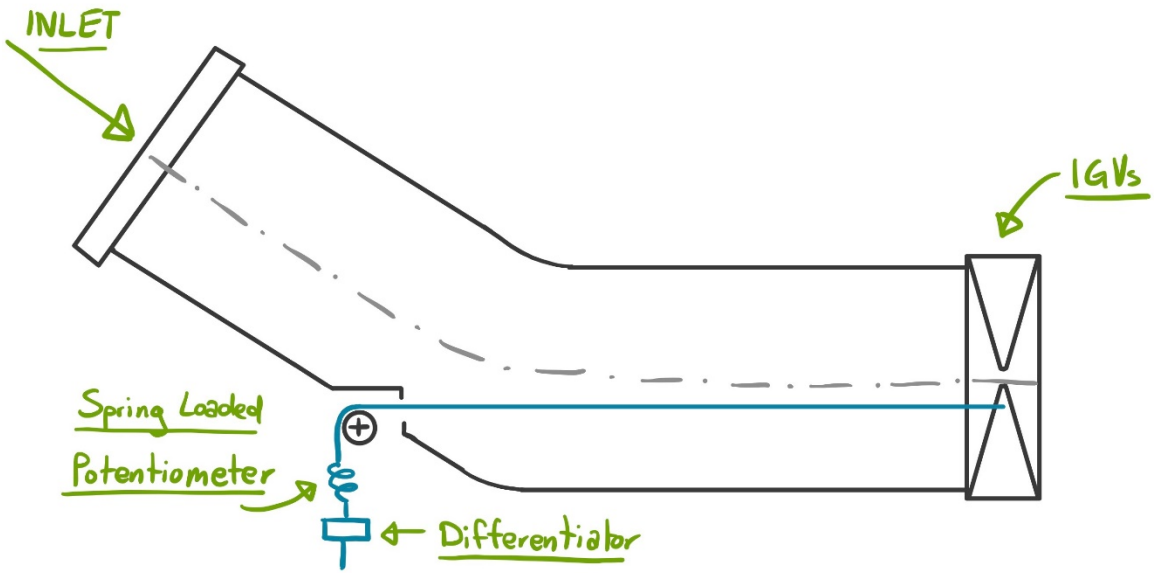
Compressor Inlet Cutout

Presenter: Arnold Schaefer

Travis Carter

CONCEPT GENERATION: HIGH AND LOW CYCLE MONITORING SUBSYSTEMS

High Cycle Detection Subsystem

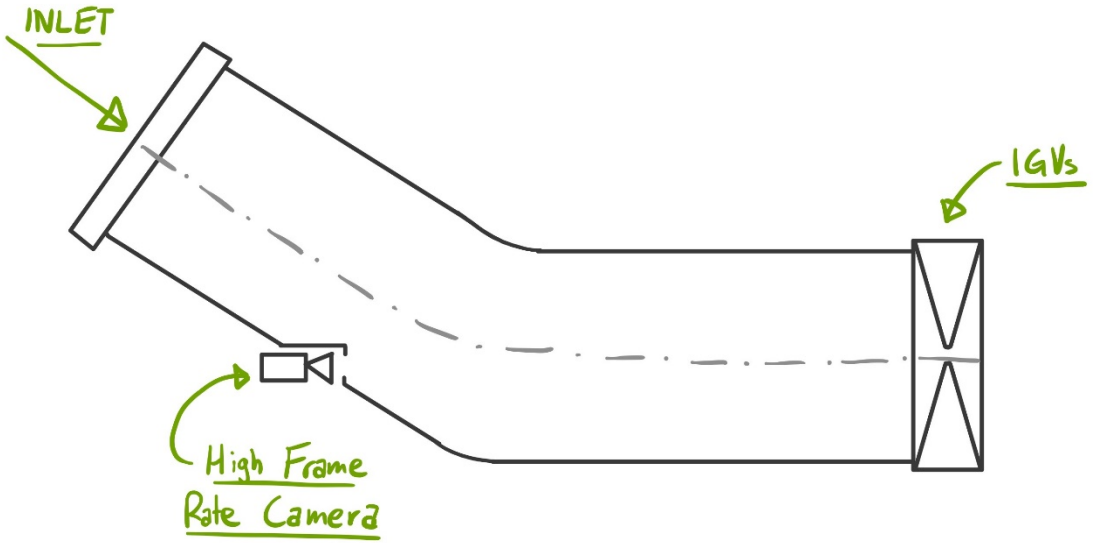


Potentiometer with Differentiator

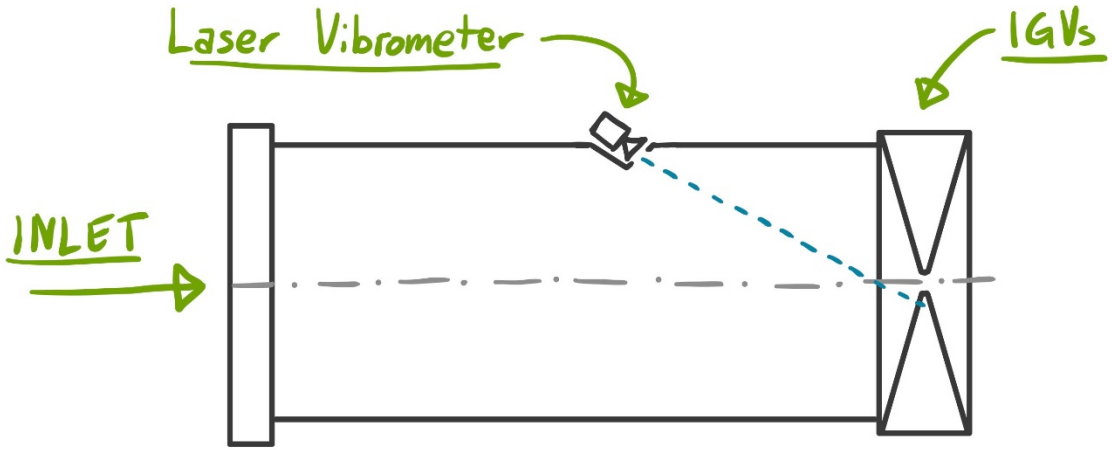
Accelerometer on IGV

Presenter: Travis Carter

High Cycle Detection Subsystem



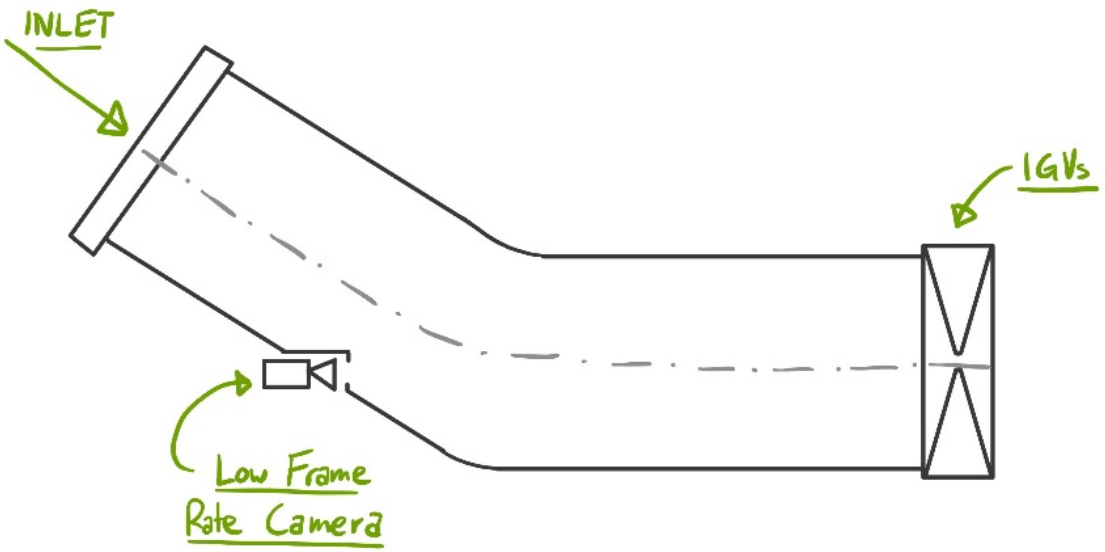
High Frame Rate Camera



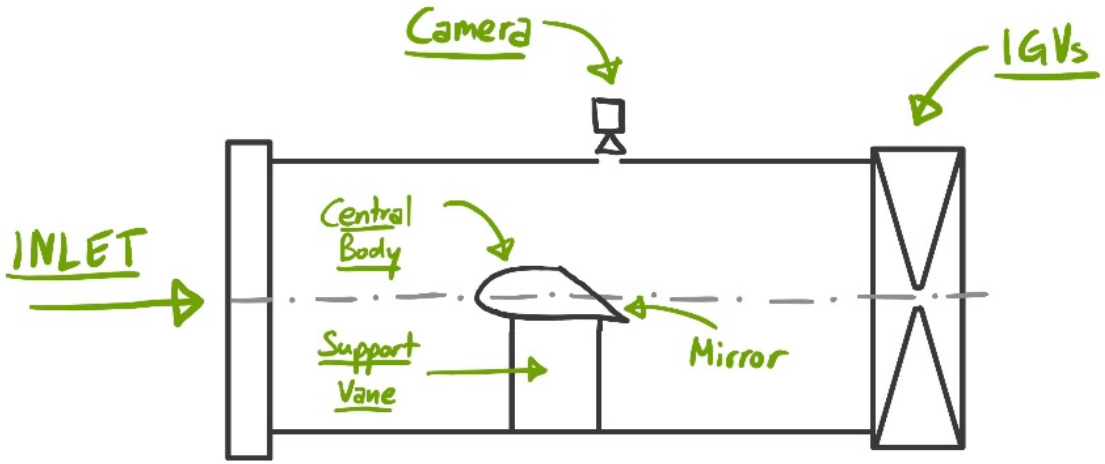
Laser Vibrometer

Presenter: Travis Carter

Low Cycle Monitoring Subsystem



Camera in Pipe Elbow



Mirror in Central Body of Pipe

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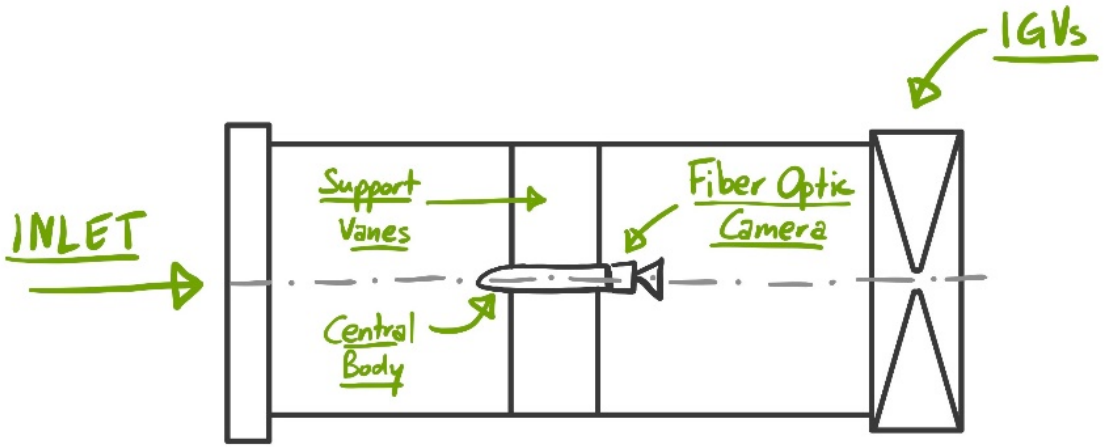
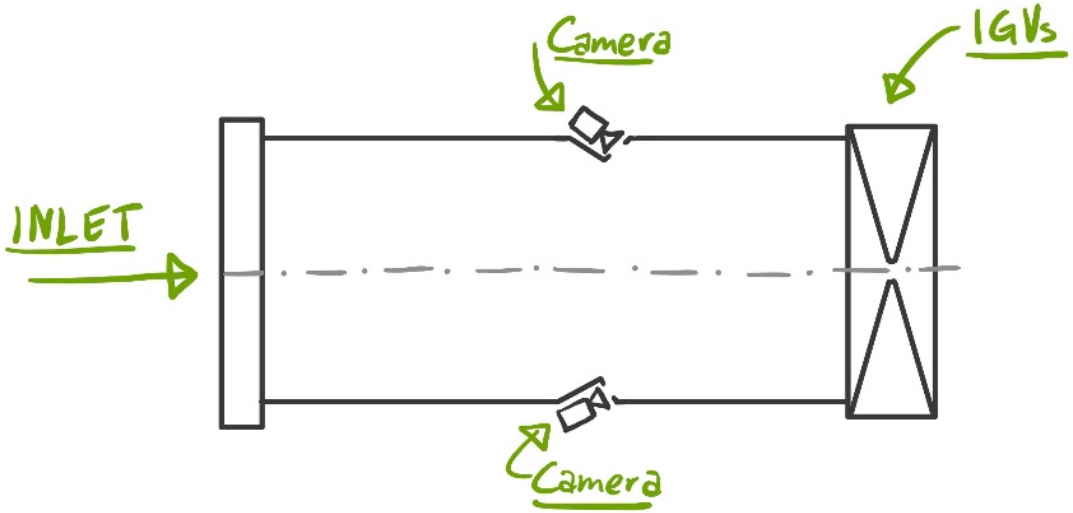
Low Cycle Monitoring Subsystem



Camera in Central Body of Pipe



Composite Imaging

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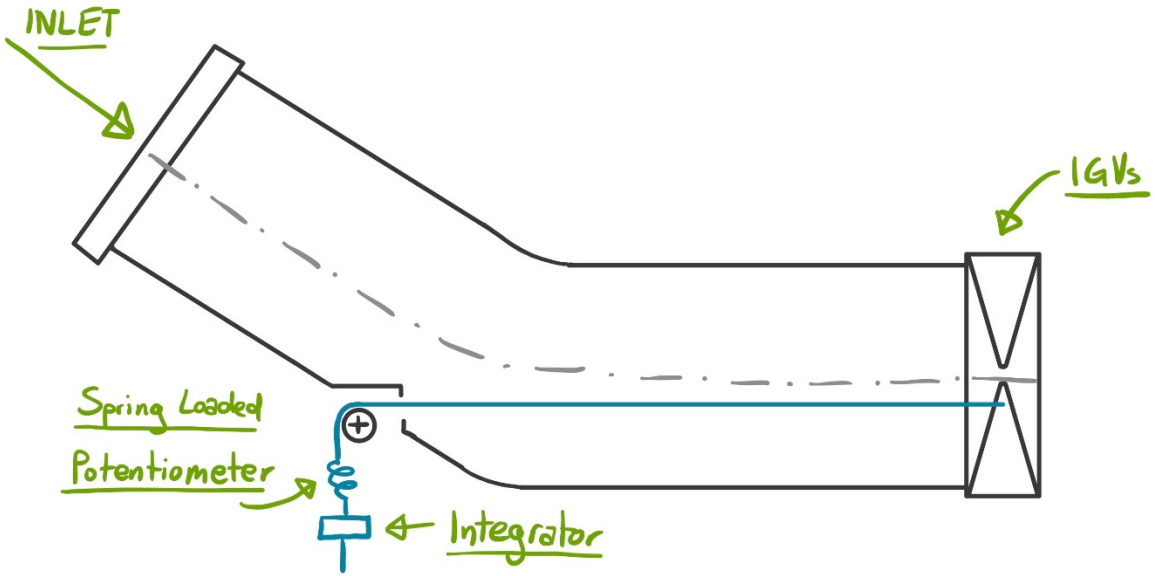
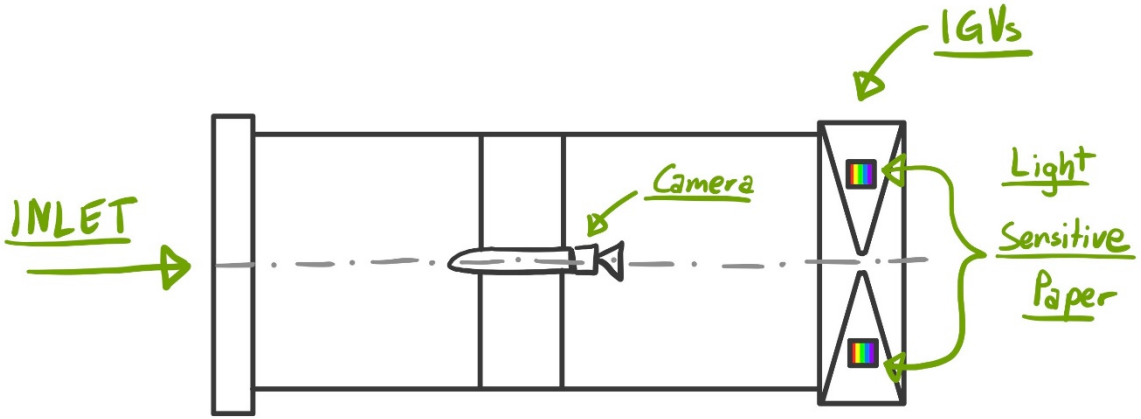
Arnold Schaefer

CONCEPT GENERATION: IGV ANGLE MONITORING AND LIGHTING SUBSYSTEMS

IGV Angle Monitoring Subsystem



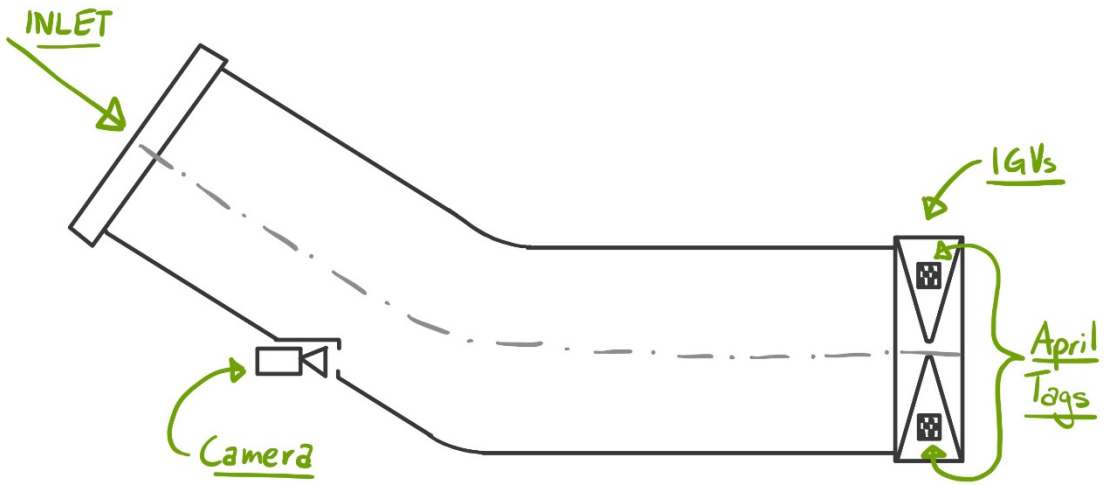
Potentiometer with Integrator



Camera with Light Sensitive Paper

Presenter: Arnold Schaefer

IGV Angle Monitoring Subsystem

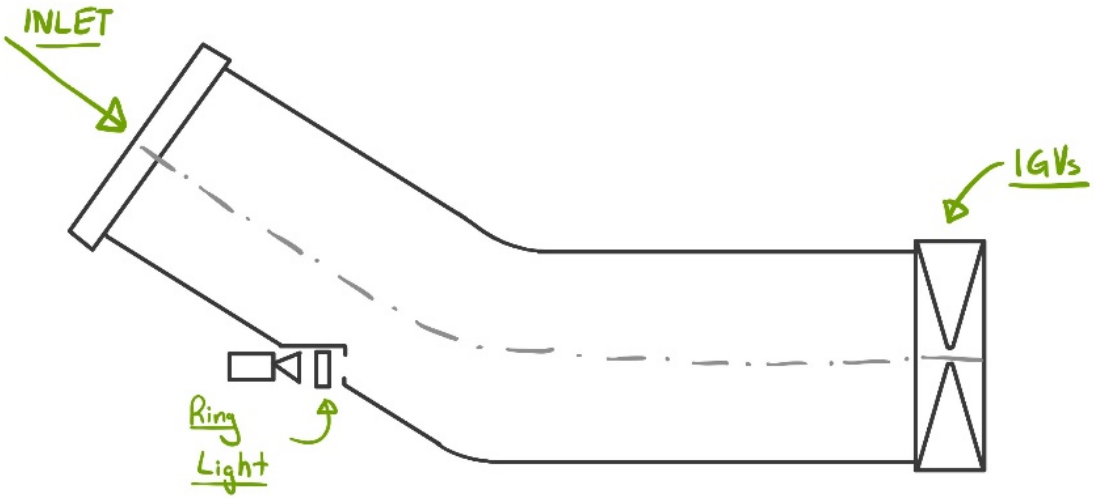


Camera with April Tags

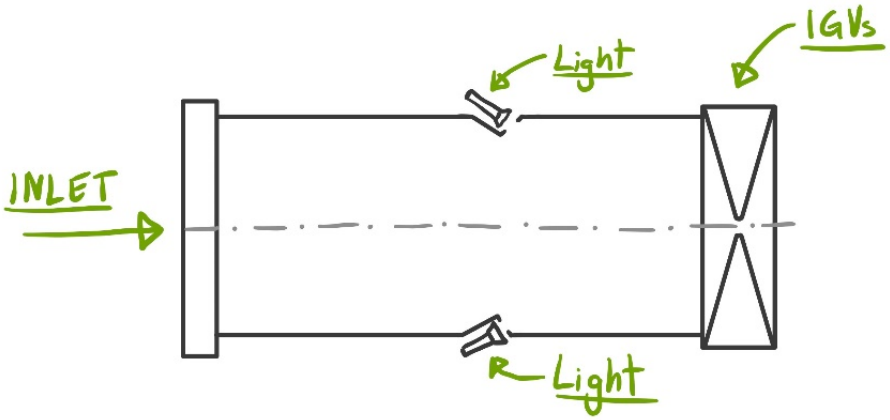
Gyroscope Angle Measurement

Presenter: Arnold Schaefer

Inlet Guide Vane Lighting



Ring Light around the Camera



Lights Near IGVs

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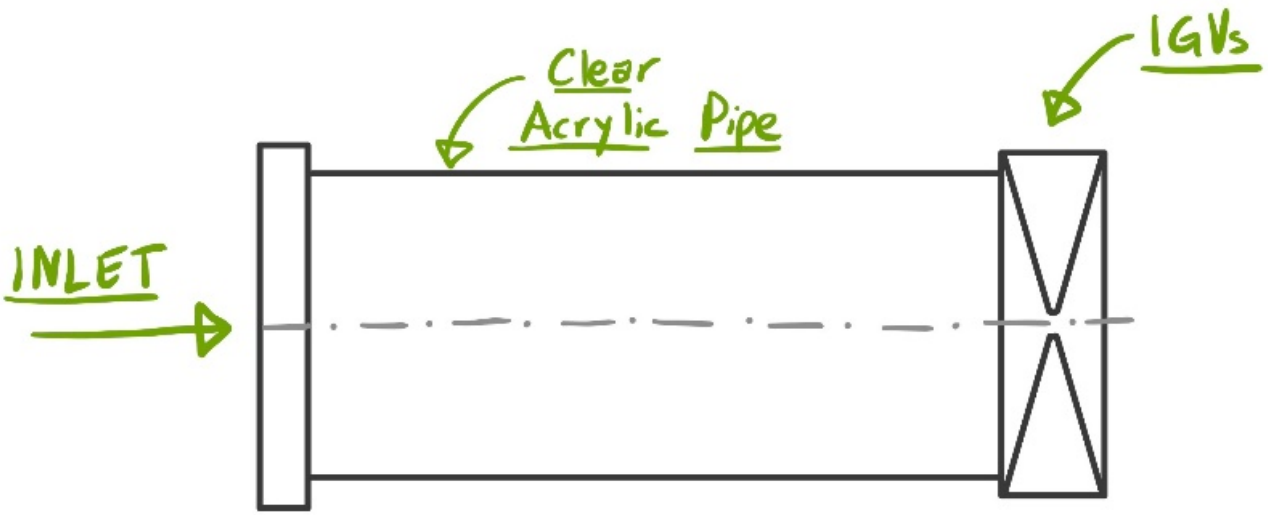
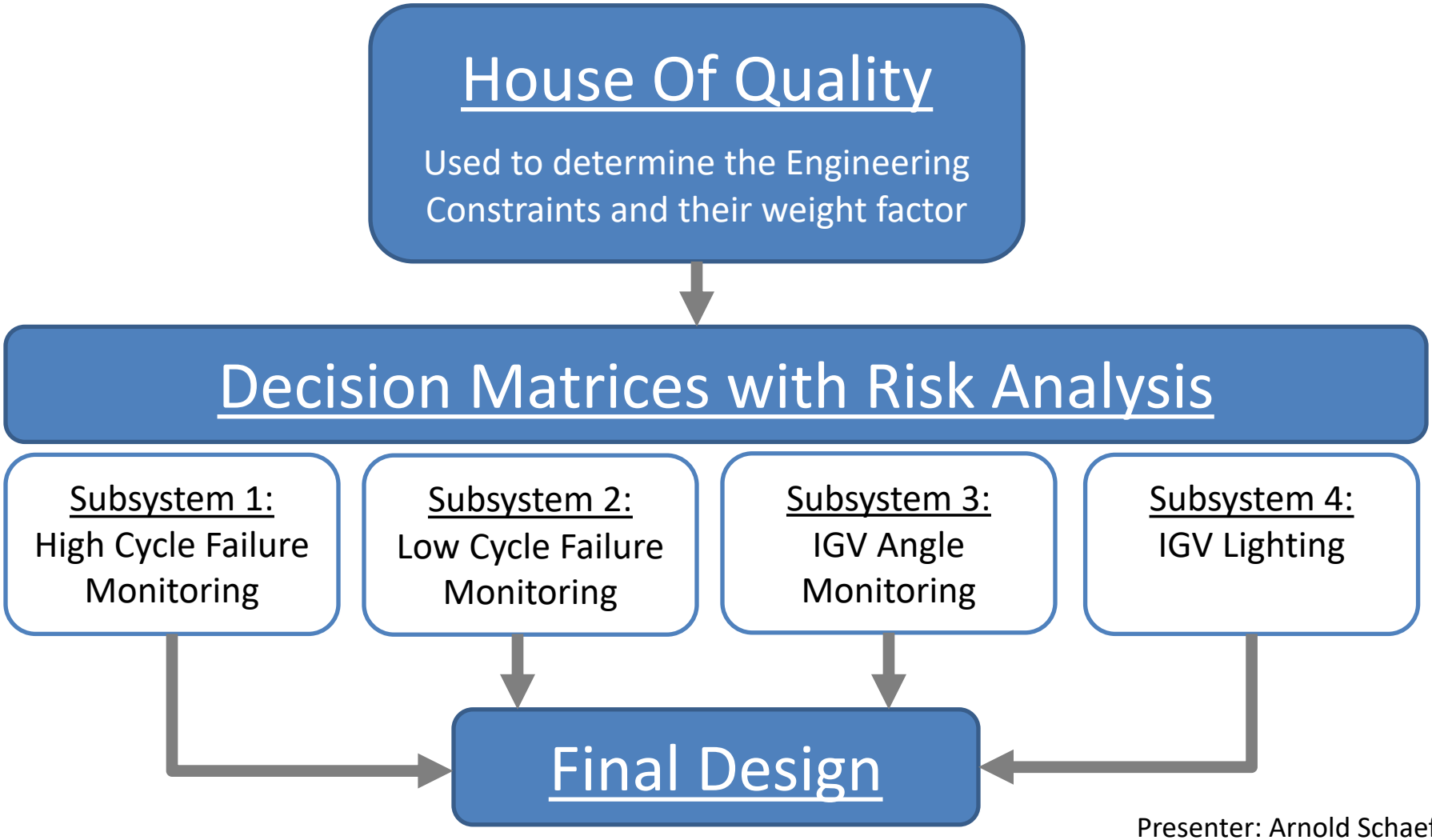
Inlet Guide Vane Lighting



Clear Acrylic Pipe
with Ambient Lighting

Presenter: Arnold Schaefer

Concept Selection Strategy



Presenter: Arnold Schaefer

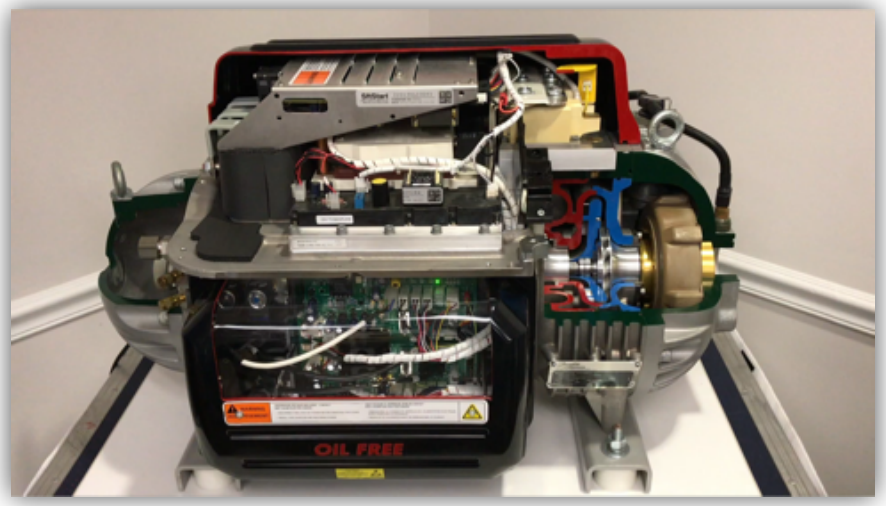
Summary

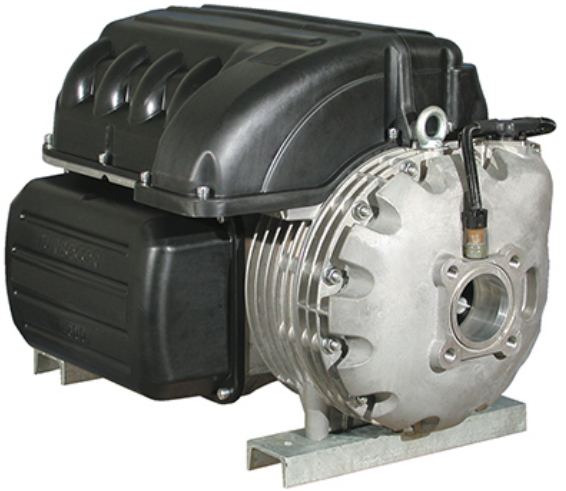
- Types of Failure
  - High Cycle Failure
    - Vibration
  - Low Cycle Failure
    - Latching
    - Blade Lock
- Project Subsystems for Concept Generation
  - High Cycle Monitoring
  - Low Cycle Monitoring
  - IGV Angle Monitoring
  - IGV Lighting

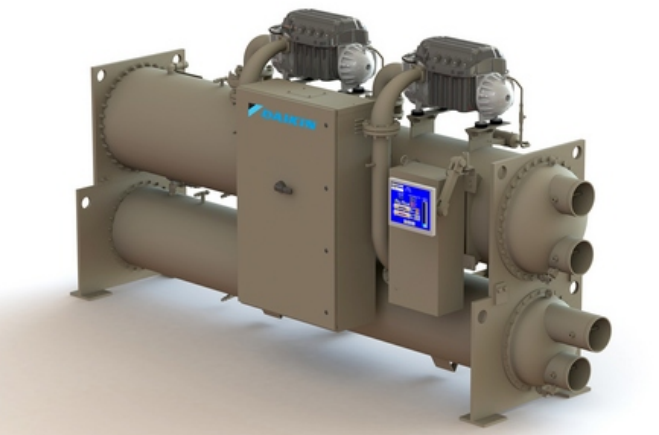
Notable Project Targets	Target Value
Allowable Flow Impact	No Detectible Swirl
High Cycle Sampling Rate	1 kHz
Low Cycle Sampling Rate	1 Hz
Minimum Sample Rate for Measuring Angle	1 Hz

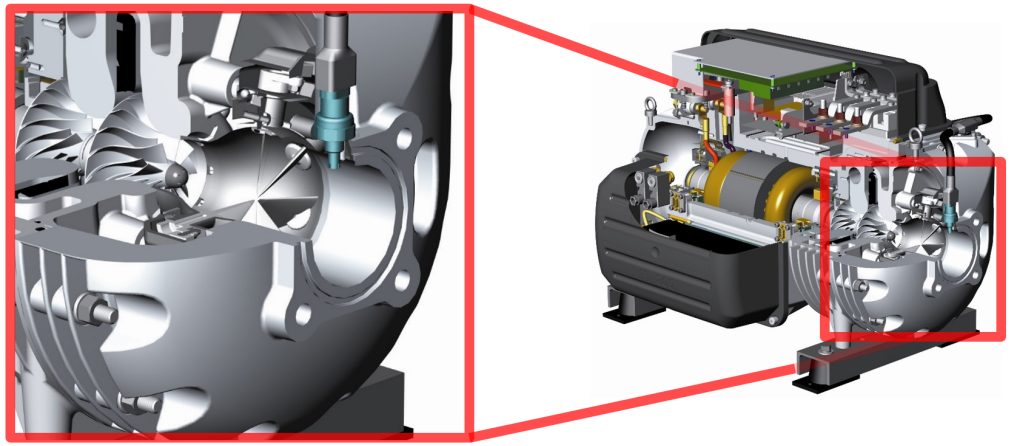
Presenter: Arnold Schaefer

Thank You for Your Time. Questions?









Work Cited

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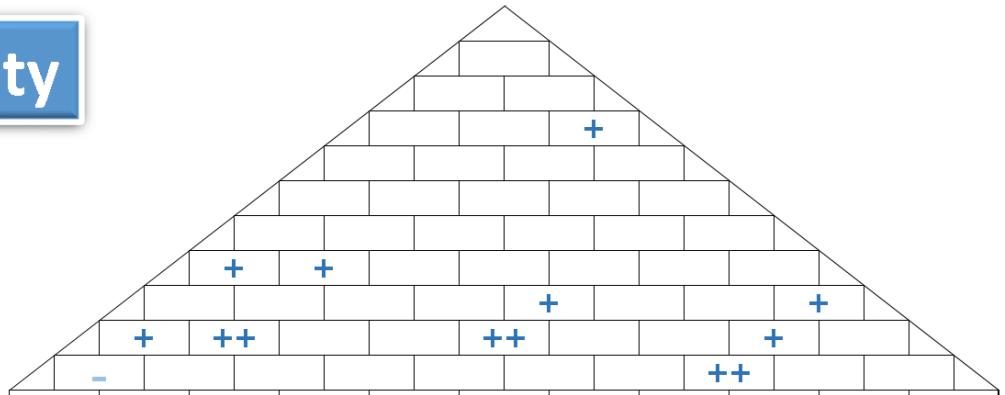
Jenny, P., & Bidaut, Y. (2017, March 01). Experimental Determination of Mechanical Stress Induced by Rotating Stall in Unshrouded Impellers of Centrifugal Compressors. Retrieved November 07, 2017, from http://turbomachinery.asmedigitalcollection.asme.org/article.aspx?articleid=2571404

Concept Selection Preview

House of Quality

Legend

Symbol	Meaning
++	Very Strong Relationship
+	Strong Relationship
-	Weak Relationship
--	Very Weak Relationship
▲	Increasing is Better
▼	Decreasing is Better
Darker	Higher Importance
Lighter	Lower Importance



Row Number	Relative Weight	Weight / Importance	Engineering Characteristics / Customer Requirements	1 Camera Resolution ▲	2 Camera Frame Rate ▲	3 Angle Measurement Accuracy ▲	4 Angle Measurement Refresh Rate ▲	5 Vibration Sensing Accuracy ▲	6 Vibration Sensing Refresh Rate ▲	7 System Stability ▲	8 System Length ▲	9 Ease of Integration ▲	10 Pressure Drop ▼	11 Pipe Illumination ▲
1	14.7	5.0	Qualitative analysis of IGV's low cycle failure	9	3	1	1			9	3	1	1	9
2	5.9	2.0	Qualitative analysis of IGV's high cycle failure	3	3	1	1	9	9	9	3	1	1	3
3	8.8	3.0	The angle reading is accurate	3	3	9	9			9	3	1	1	3
4	11.8	4.0	The view is of the center			3	1	1		3				
5	14.7	5.0	Malfunction will not damage compressor							9			1	
6	11.8	4.0	Allows for normal flow into the compressor							3	3	1	9	
7	8.8	3.0	Components can be replaced or serviced							1	1	3		
8	14.7	5.0	The vanes are clearly visable	9	3	1	1			9	3			9
9	8.8	3.0	Ease of use by test lab								9	9		
			Technical Importance: Absolute	309	132	150	126	65	53	609	256	147	150	309
			Technical Importance: Relative	13.4	5.7	6.5	5.5	2.8	2.3	26.4	11.1	6.4	6.5	13.4