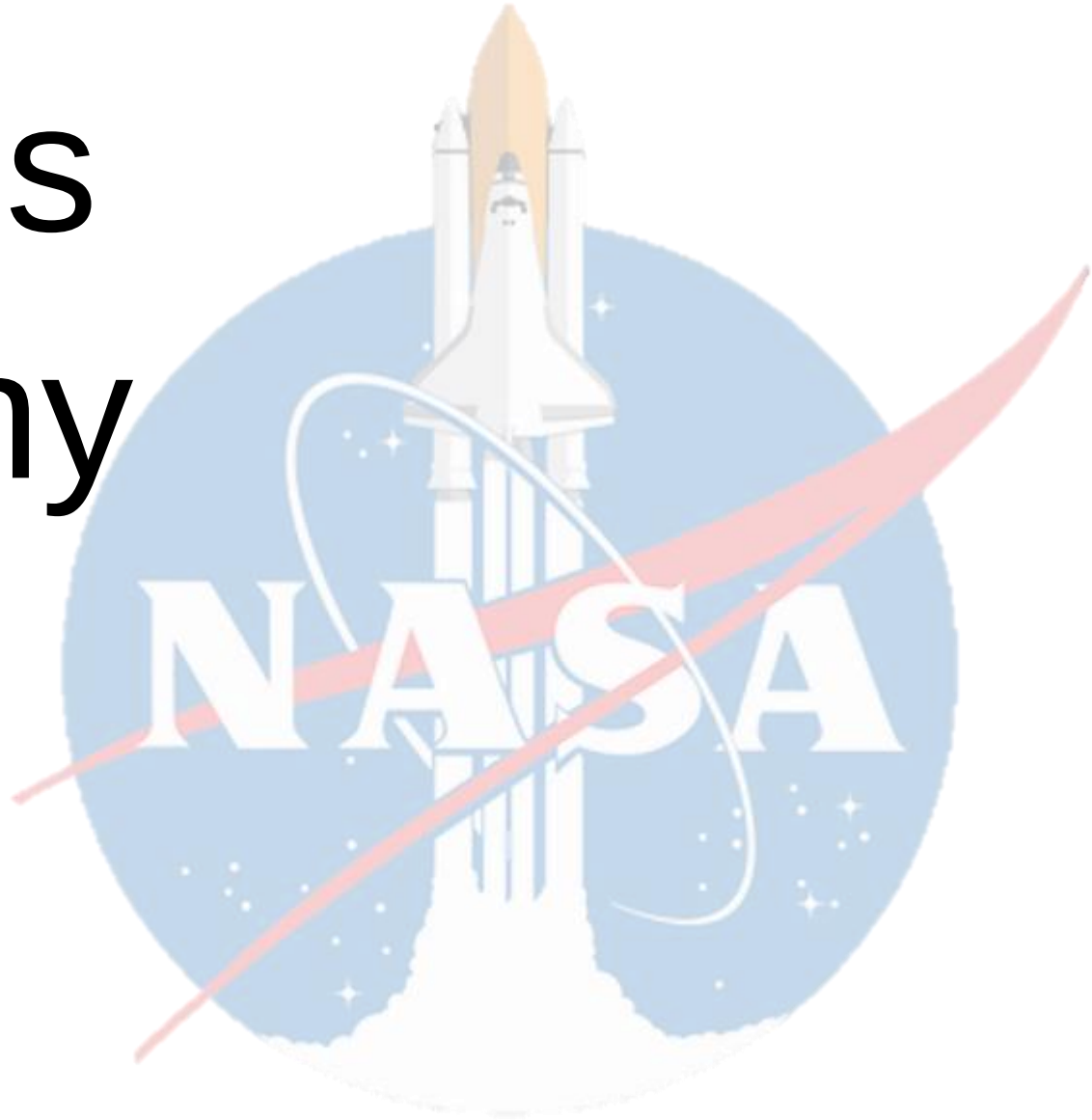
CryoMATI

Jean Ambrose | Gabrielle Mayans | King Paul | Aaron Wolfson

Cryogenic **M**ass **A**nd **T**omography **I**ndicator



Jean Ambrose | Gabrielle Mayans | King Paul | Aaron Wolfson

Meet Team 514

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FAMU-FSU Engineering

Gabrielle Mayans

Project Objective

Develop a device to accurately monitor and gauge cryogenic propellants situated in a microgravity environment.

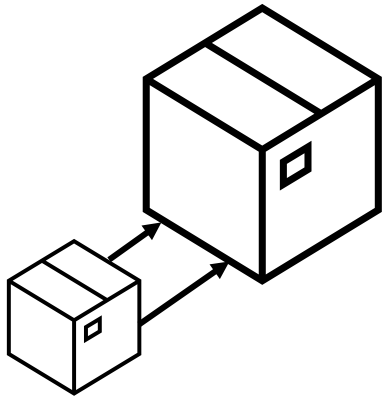
Gabrielle Mayans

Background

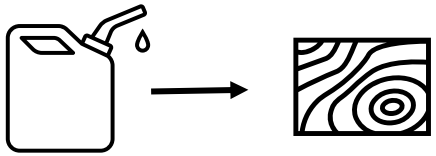
There are no reliable methods to accurately measure the amount of unsettled cryogenic fluid within a tank undergoing microgravity.

It is important to be able to accurately measure the amount of cryogenic fluid within the tank so that fuel intake can be optimized as well as sizing of tank.

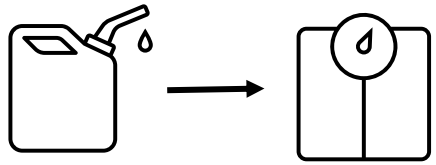
Project Scope



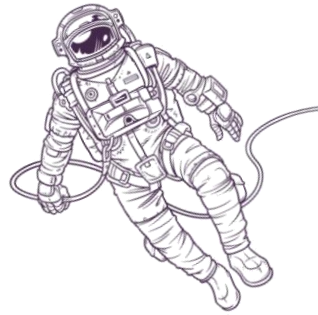
Design can be extrapolated to a larger scale



Gauges the tomography of cryogen in microgravity



Gauges the mass of a cryogen in microgravity



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Cryogenics

- Cryogenic propellants:
  - Liquid Hydrogen LH_2
  - Liquid Oxygen LO_2
  - Liquid Methane LCH_4
- These cryogenic propellants need to be held below -252.9°C to remain in a liquid state

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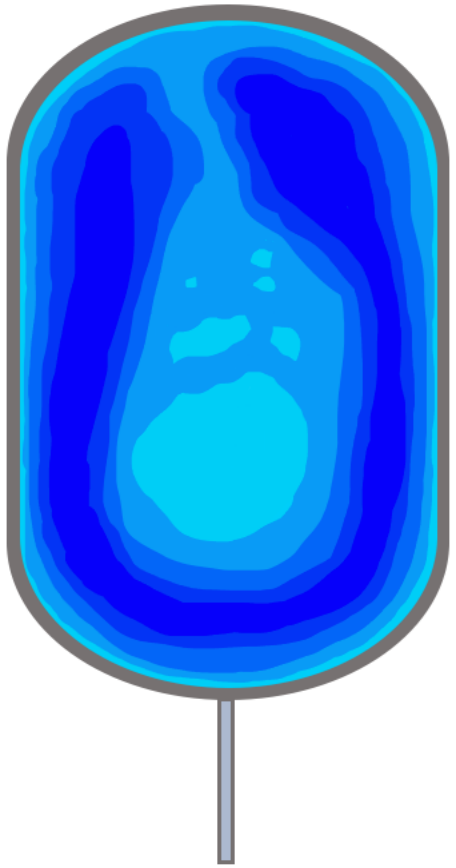
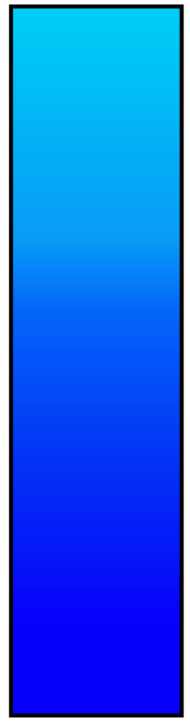
Tomography

- Determines the 3D shape of a fluid
- Determines what state the fluid is in as well
- Expressed in radial position axis, vertical position axis, and color communicates state of fluid





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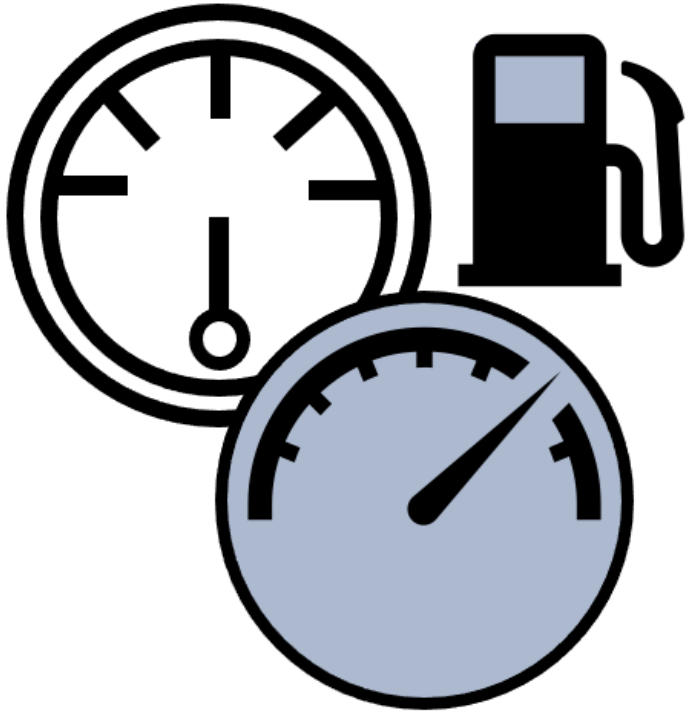
Mass Gauging

- Will be dependent on the tomography readings
- Uses tomography and density library to calculate the mass of the fluid



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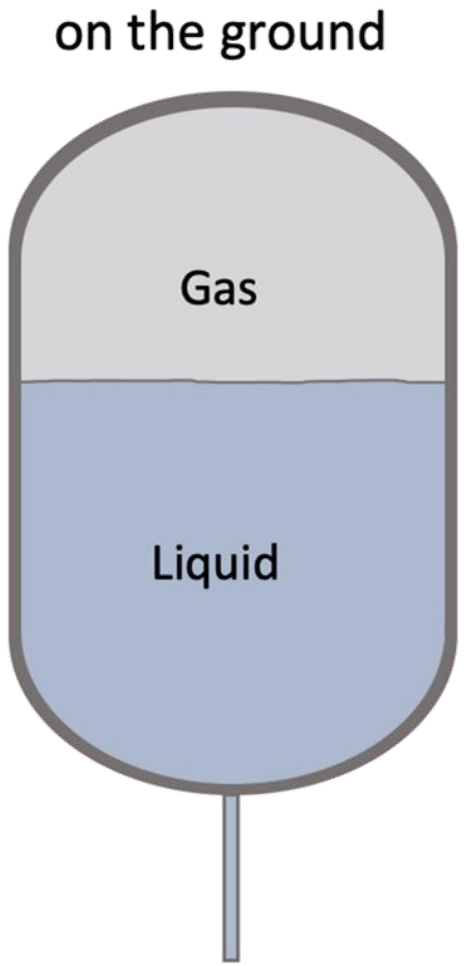
Challenges

- Material selection
- Heat leak from tank walls
- Installation of device



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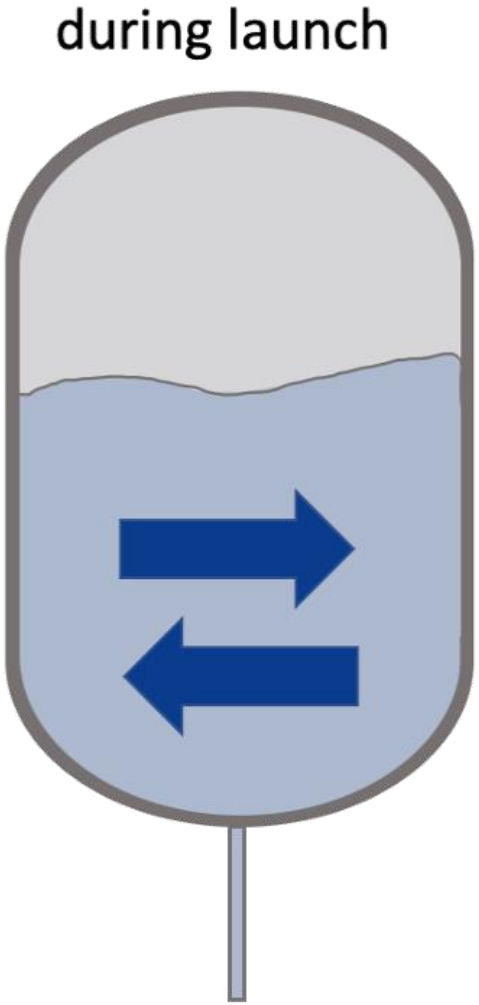
Challenges

- Material selection
- Heat leak from tank walls
- Installation of device
- Vibrations and sloshing



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Challenges

- Material selection
- Heat leak from tank walls
- Installation of device
- Vibrations and sloshing
- Liquid to gas phase

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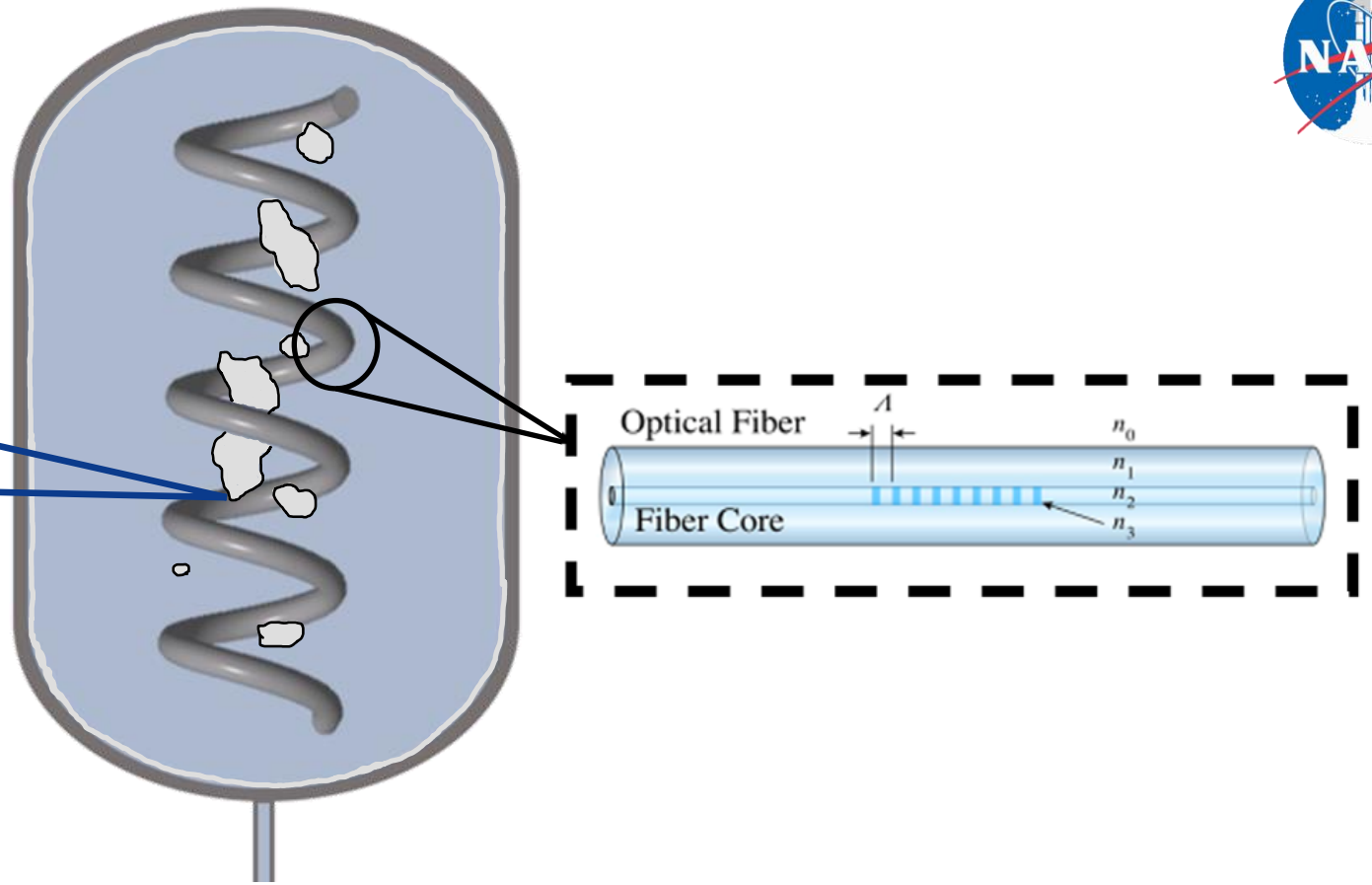
Final Selection

Helical Sweep Fiber Optic cable

Gabrielle Mayans

Final Selection

Gas bubbles collect at center of tank



Helical Sweep Fiber Optic cable

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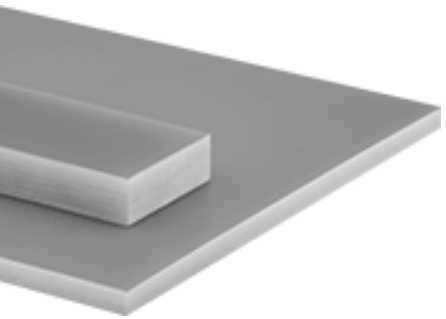
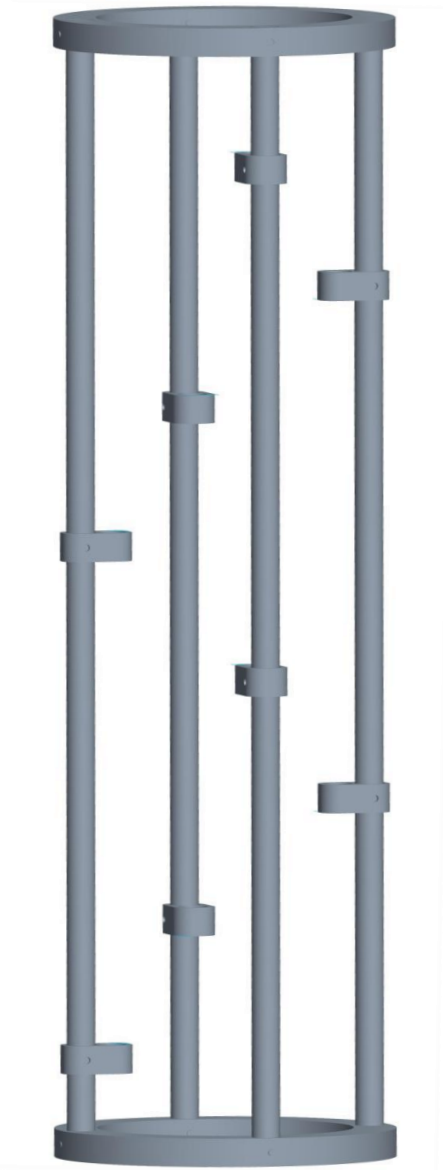
Supporting Structure

- Structure will support a helical sweep shape of fiber optic cable, not a helical sweep itself.
- Prefabricated Garolite G-10/FR4 rods.
- Garolite G-10/FR4 machinable sheets





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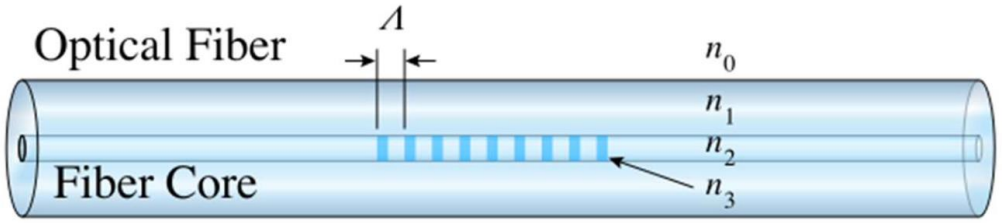
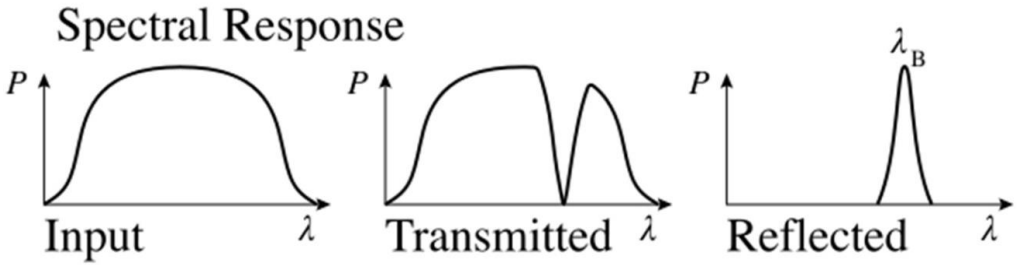
Fiber Optics

- The sensing system uses fiber optic Bragg sensors located along a single fiber optic cable
- These sensors discern between liquid and gas states along a continuous fiber





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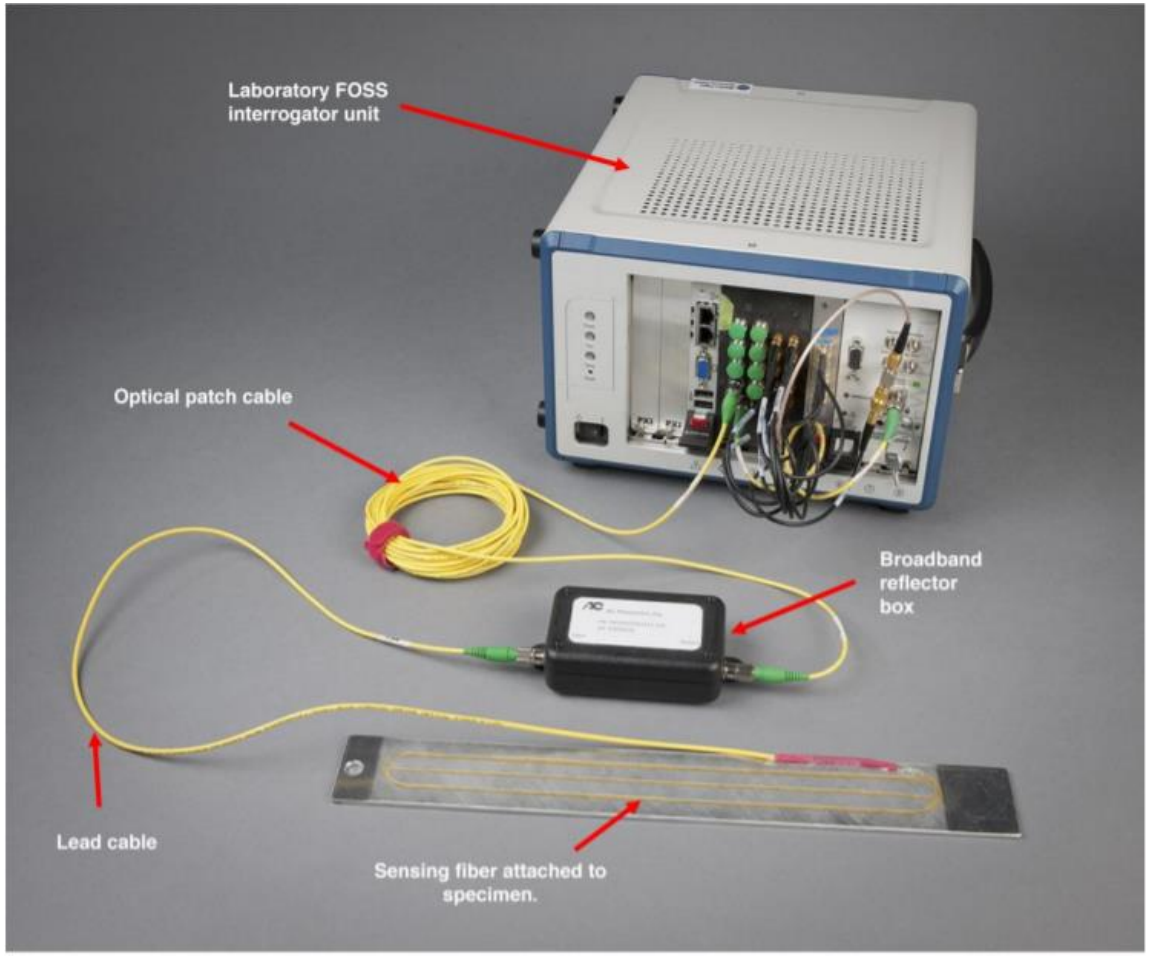
Fiber Optic Sensing System - FOSS

- The entire unit reads and measures the data
- NASA will be providing a loaner FOSS unit



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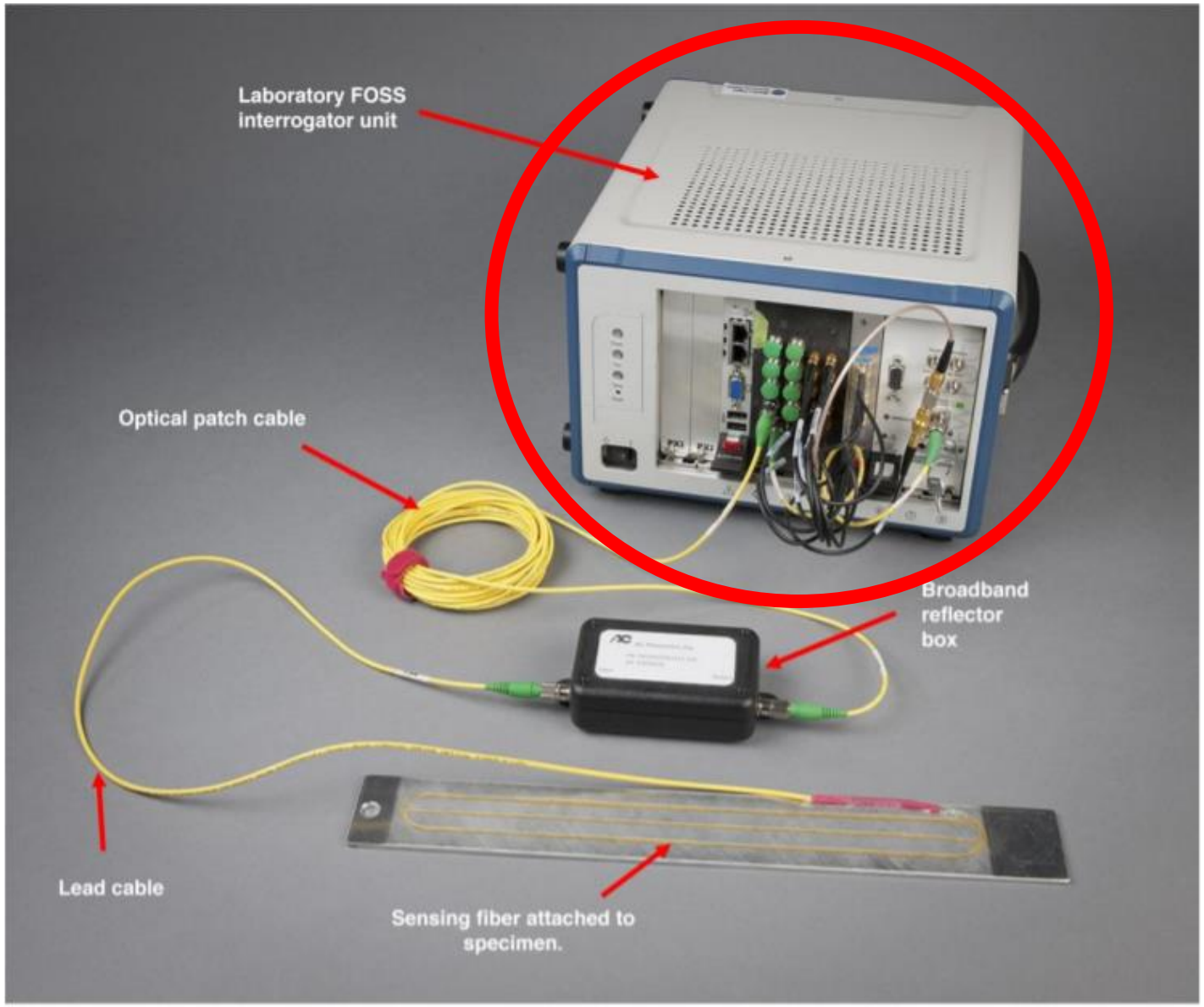

Interrogator unit:

- Ingests sensor readings
- Outputs the corresponding temperature readings at the respective sensors

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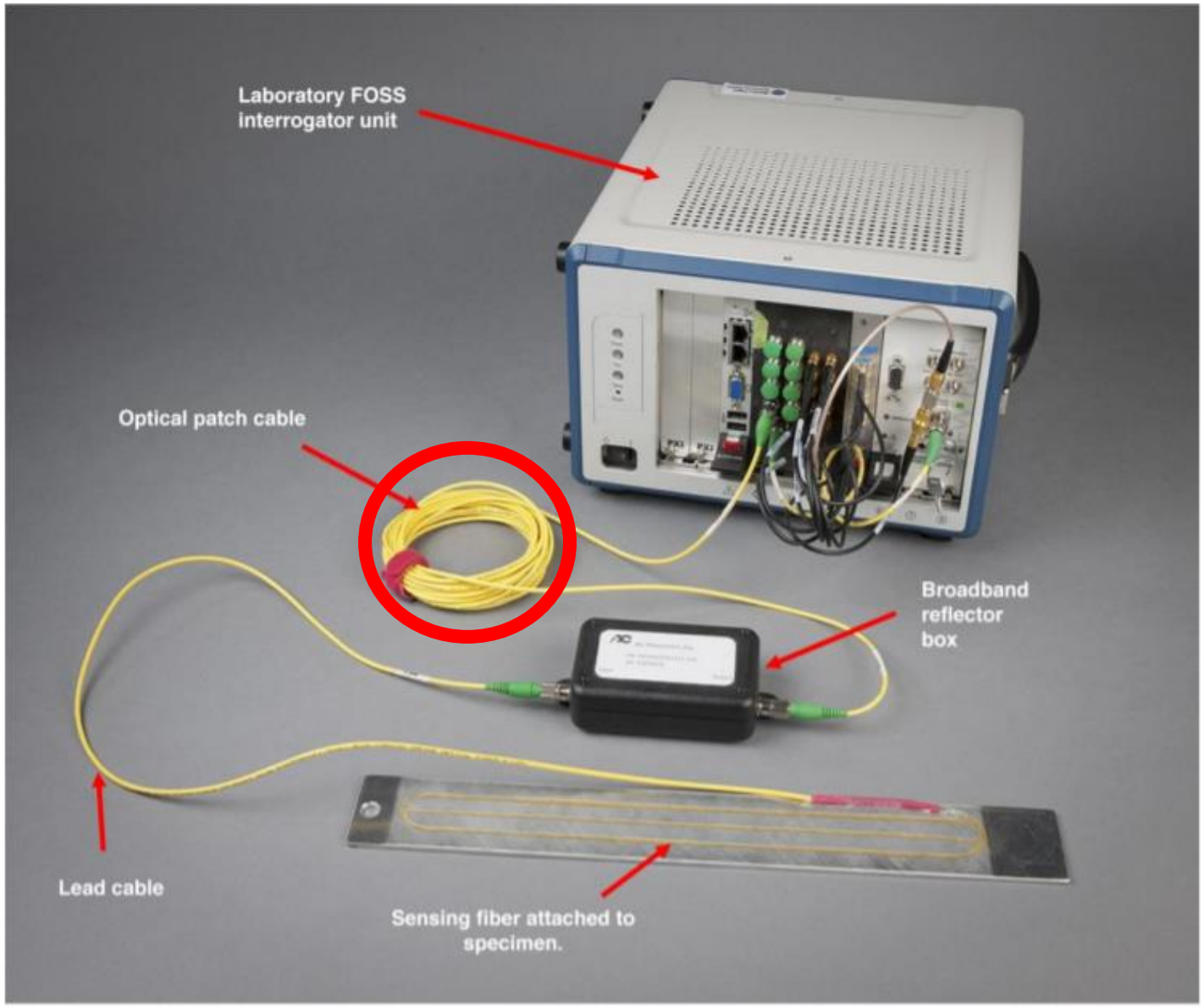

Optical patch cable:

- Used to transmit the information to interrogator unit

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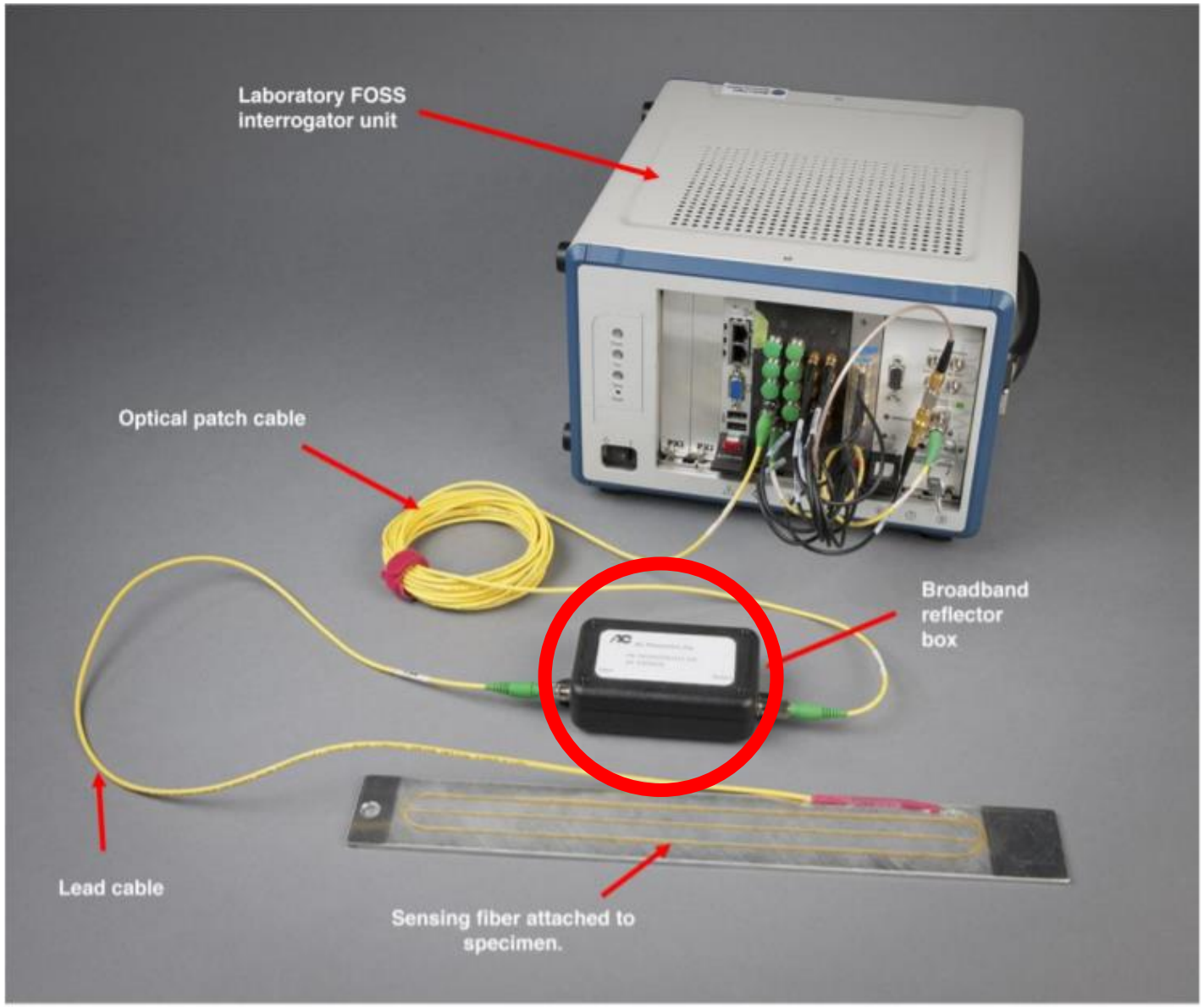

Broadband reflector box:

- Reflects a specific wavelength of light to the sensors
- Transmits all other wavelengths not in range

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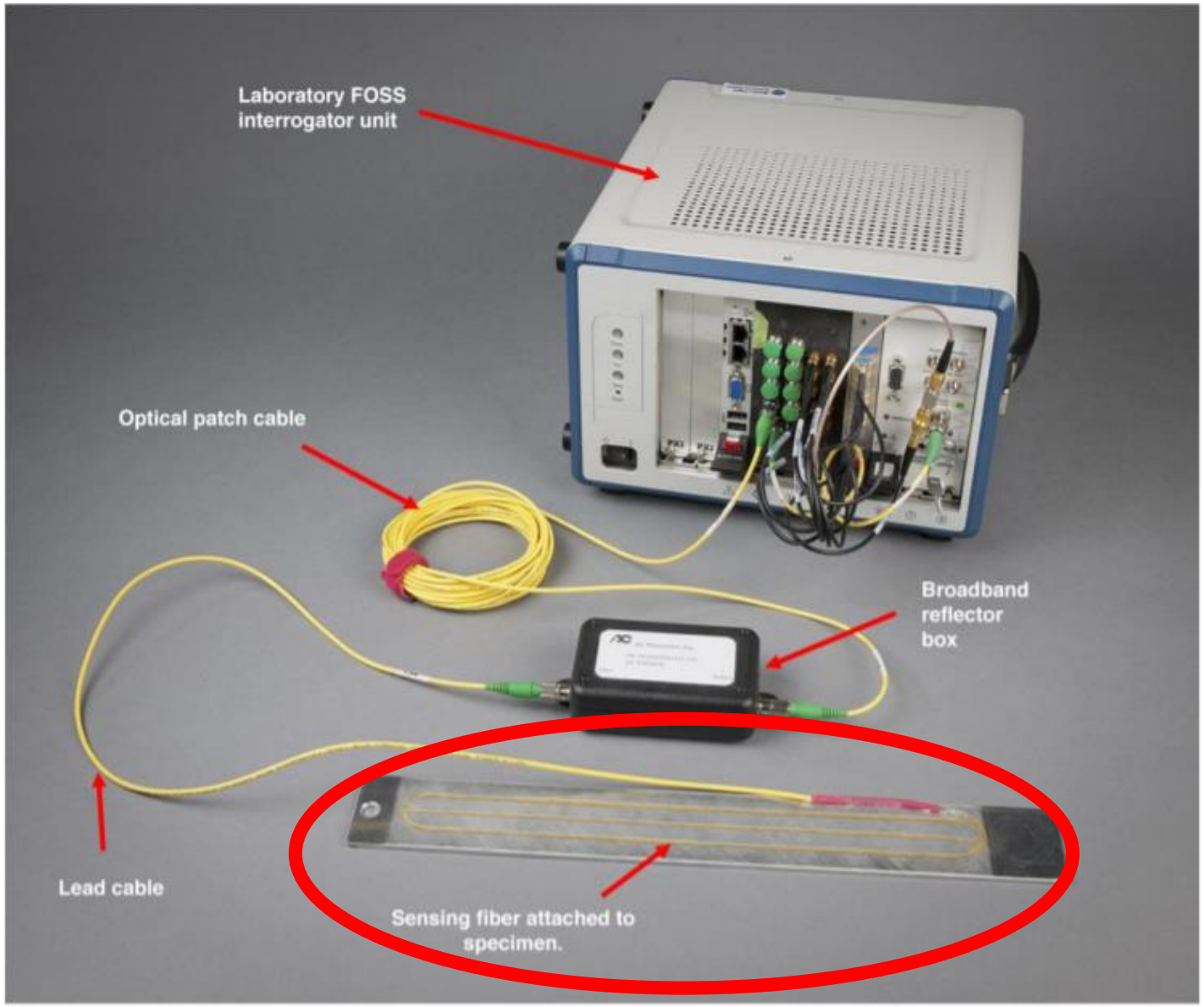

Sensing fibers:

- Coated in a polytetrafluoroethylene (PTFE) shrink sleeve

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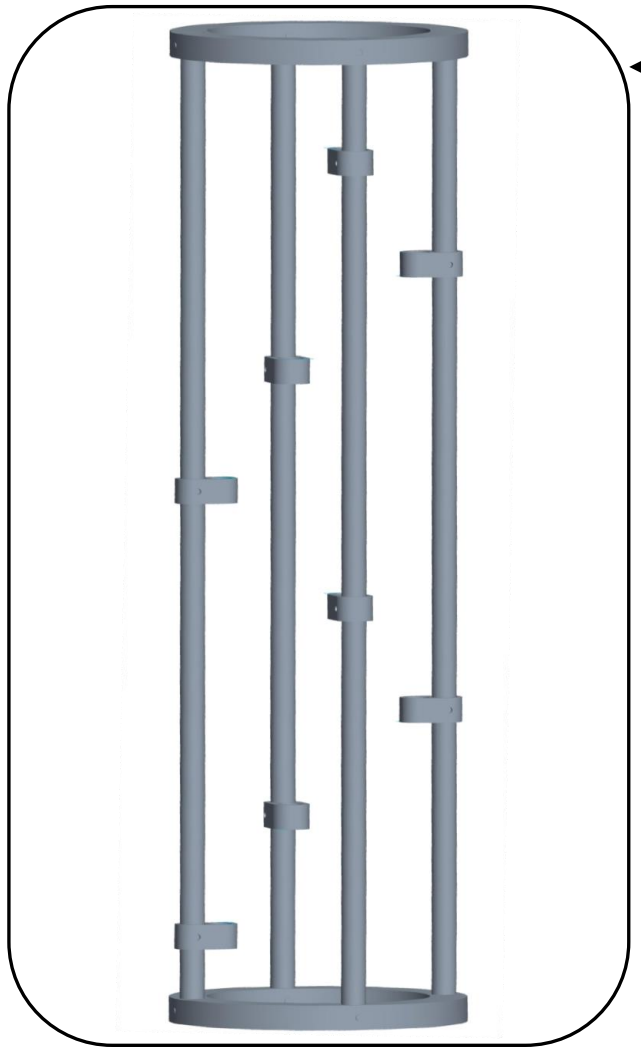
Assembly

- Pins hold rods and rings together
- Epoxy will be used to glue the pins in place
- A Vacuum Chamber is required to seal the epoxy for cryogenic use



Acrylic Vacuum Chamber

Epoxy

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Assembly

- Pins hold rods and rings together
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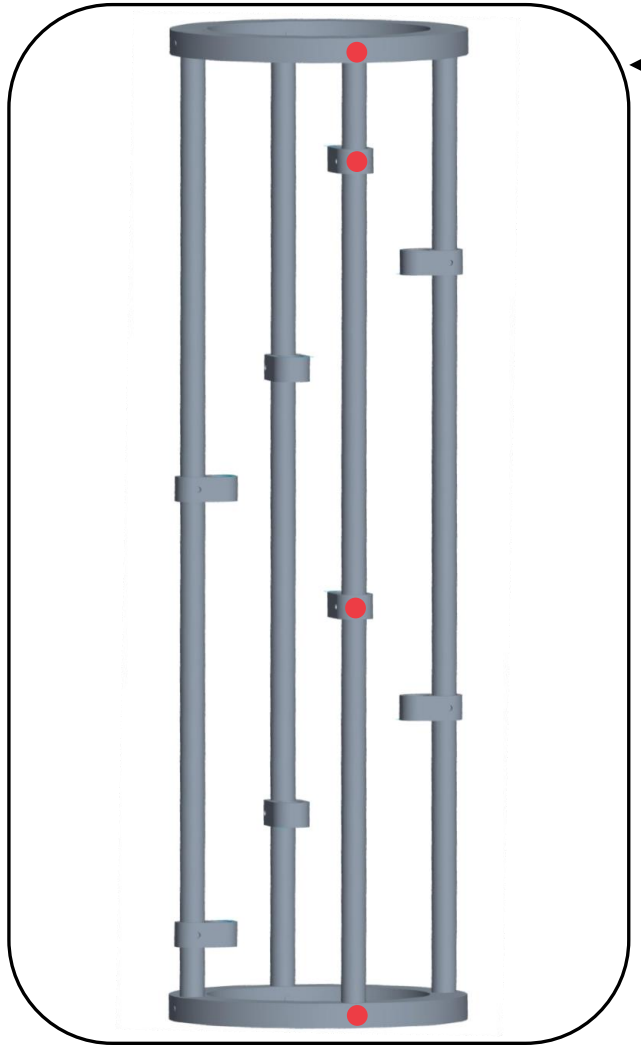

Acrylic Vacuum Chamber

● Pin location

Epoxy

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Testing Dewar

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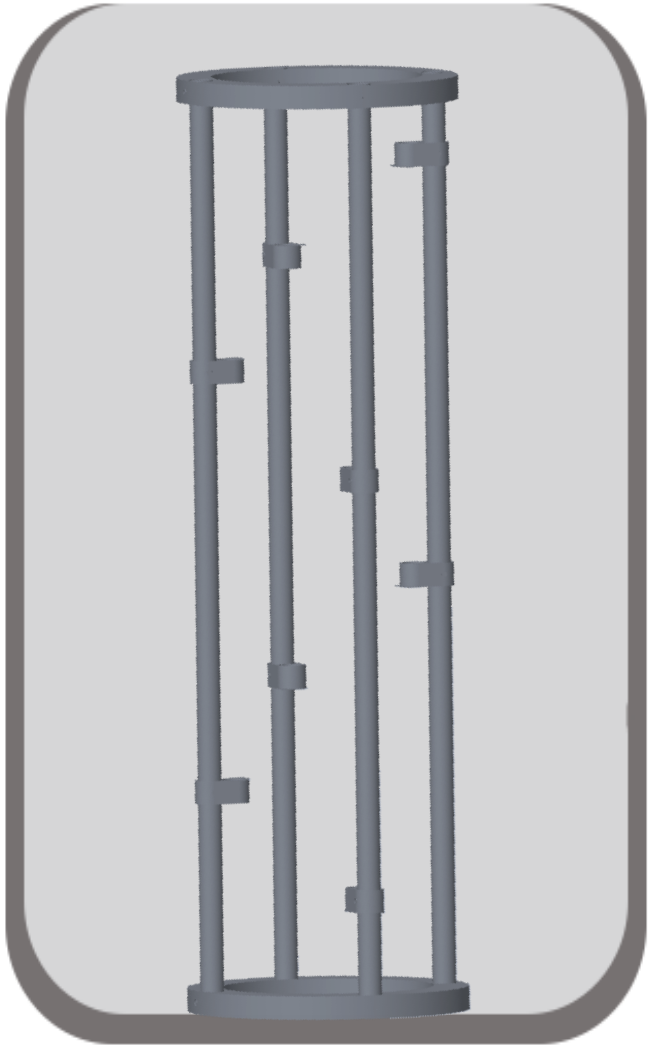
Testing Procedure

1. Precool device with a dry ice and salt bath
2. Move device to empty Dewar
3. Fill Dewar with Liquid Nitrogen
4. Take in readings until Liquid Nitrogen evaporates



← Dewar

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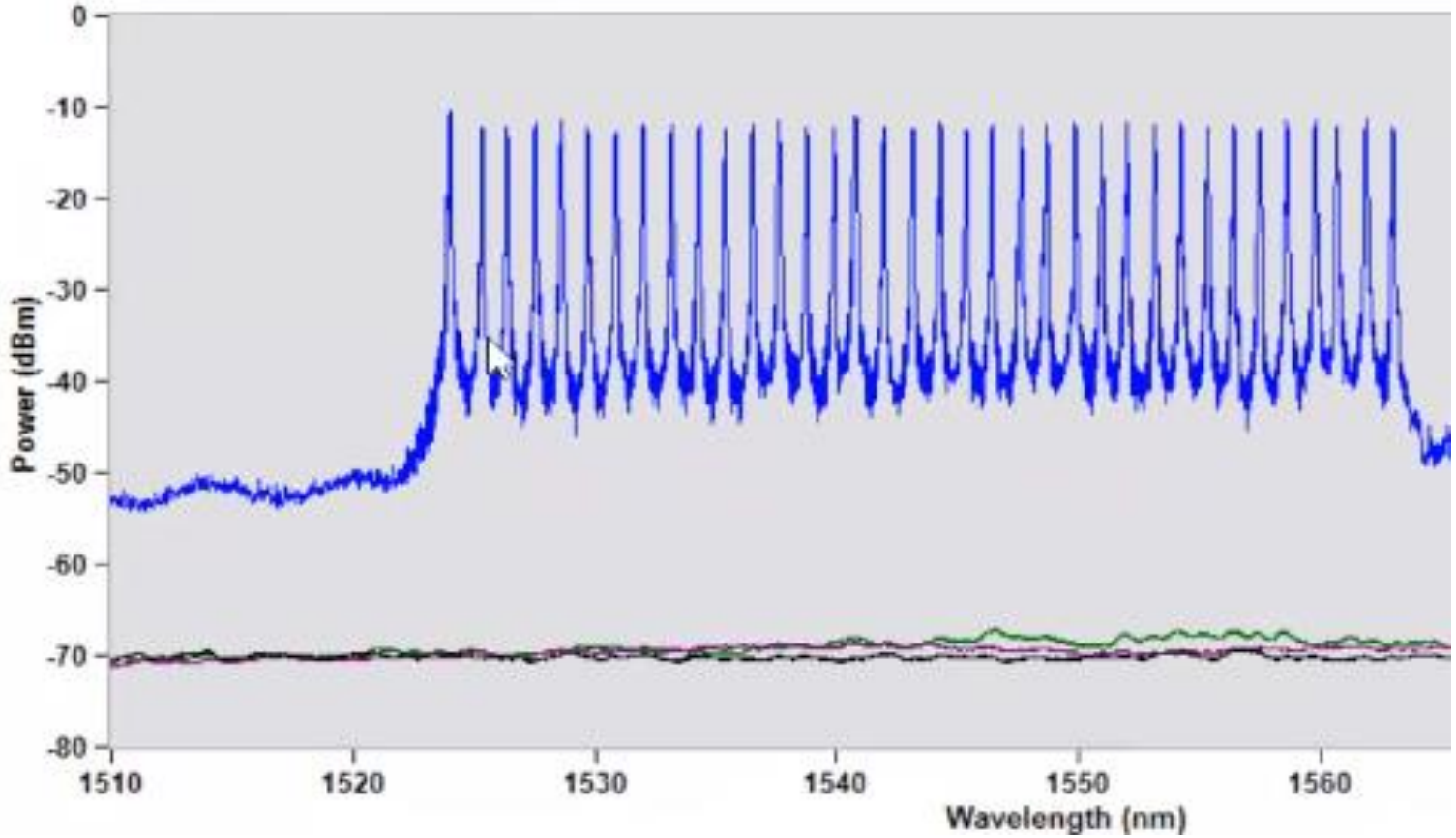
Data Collection And Validation

- Interrogator is a Micron Optics sm125 wavelength multiplex unit
- Runs on Enlight Software
- Outputs Bragg wavelength at each sensor

Aaron Wolfson

Data Collection

- Each spike in amplitude is a FBG sensor
- FOSS unit will have 32 sensors
- Sensor peaks will shift to the left in colder temperatures



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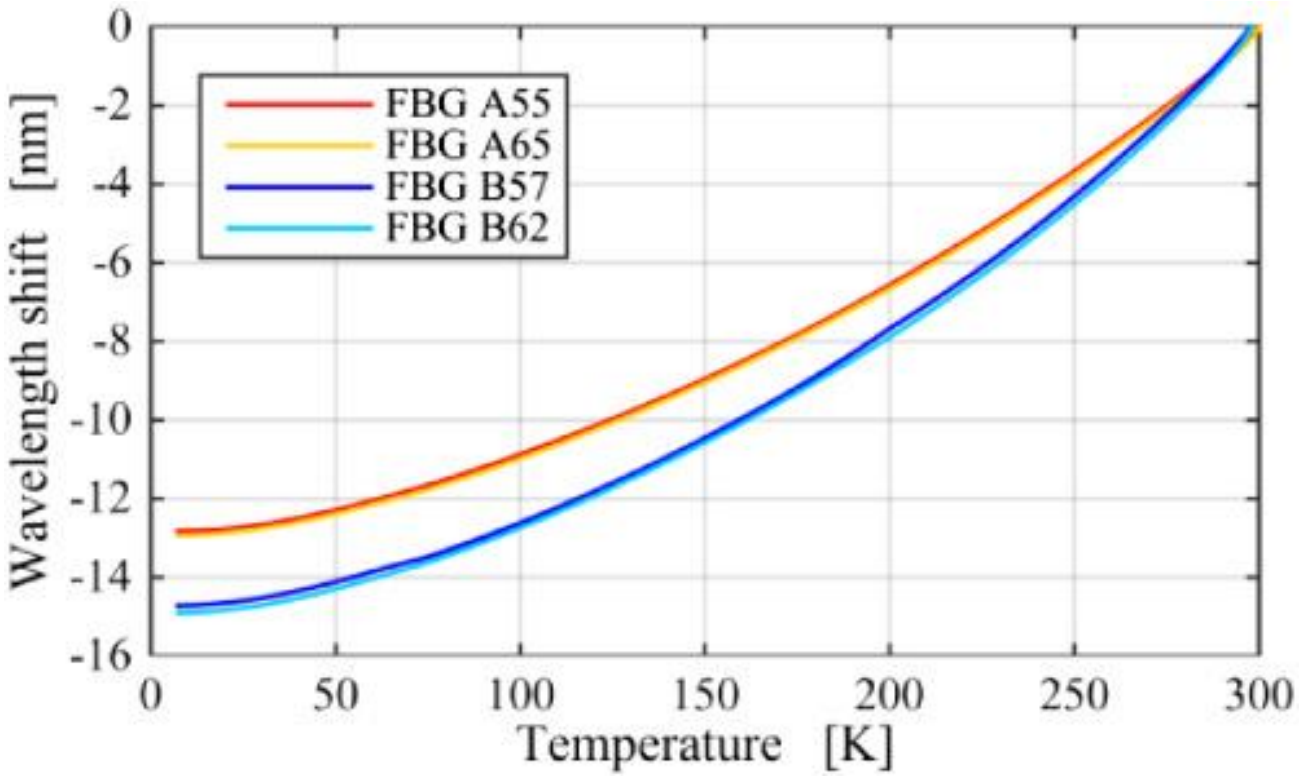
Data Validation

- Data collected will be exported to Excel
- Graph made using NIST standards for liquid nitrogen properties
- Calculated temperatures will be validated using thermocouple readings



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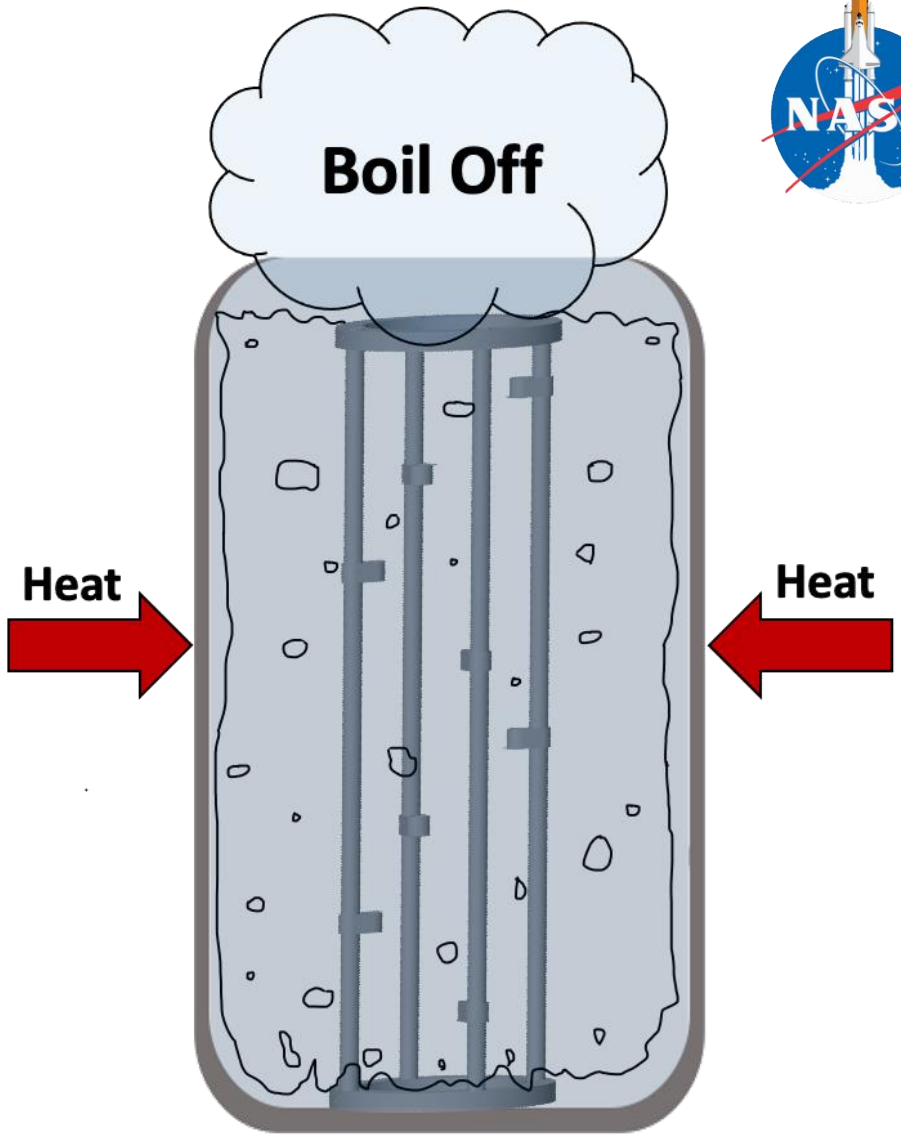
Validation

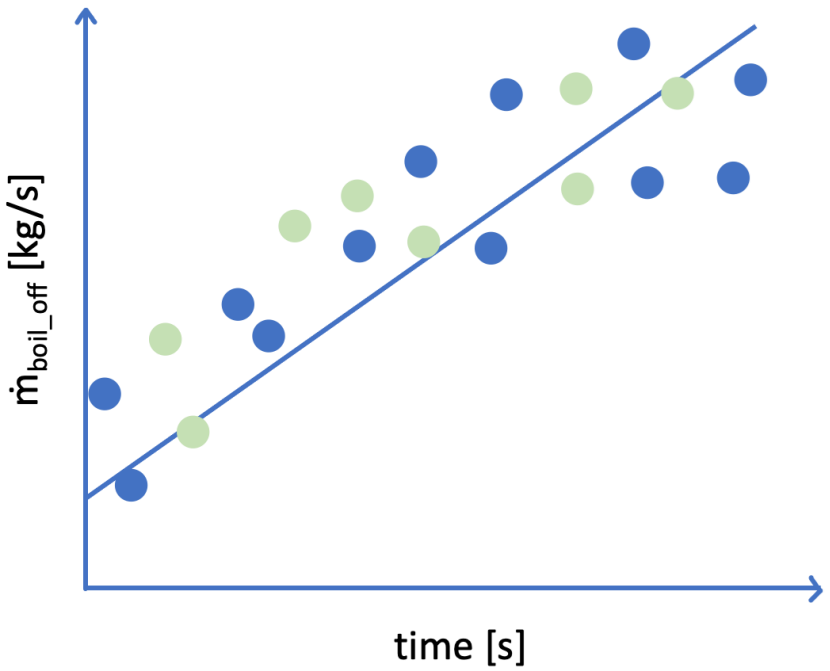
- Readings from testing compared to calculated theoretical mass boil off rate
- Calculation dependent on the ambient temperature recorded at time of test
- Expected mass boil off rate will be compared to the interrogator unit results



Jean Ambrose

Validation Results

- Difference of theoretical boil off rate and boil off rate read by interrogator unit is level of inaccuracy of device
- Inaccuracy level is a result of processing power
- Goal is for level of inaccuracy to be below the thermocouple validation error



Jean Ambrose

Interpreting Data

- Manipulate data from excel
- Density library to correlate from frequency readings
- Generate a 3-D plot encompassing inside of the tank

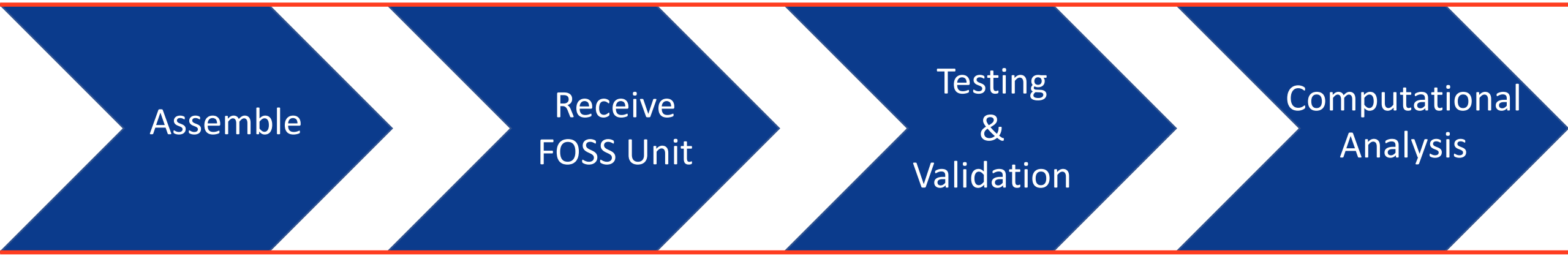
Jean Ambrose

Lessons Learned

- Purchase extra materials in first order in case original pieces are compromised
- Method for testing and validation can be developed as soon as the FOSS unit is chosen
- Material selection is significant when developing a product

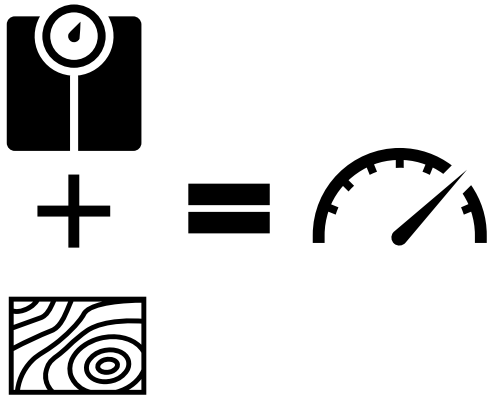
Jean Ambrose

Future Work

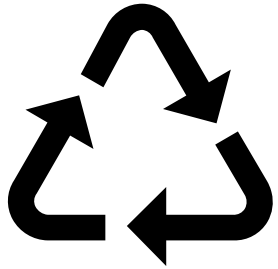


Jean Ambrose

Customer Needs



Gauges mass and tomography of a cryogenic fluid in zero gravity



The device should be reusable

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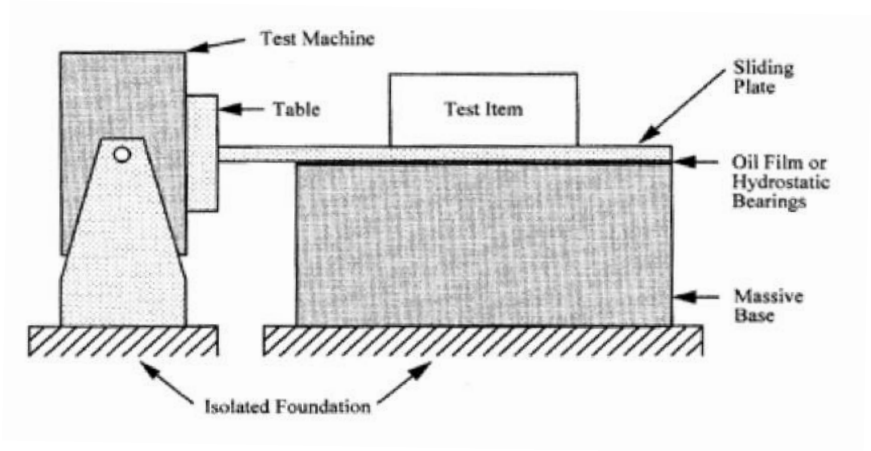
Durability

Thermal Cycling

MIL-STD-750
Method 1056



Vibration Test

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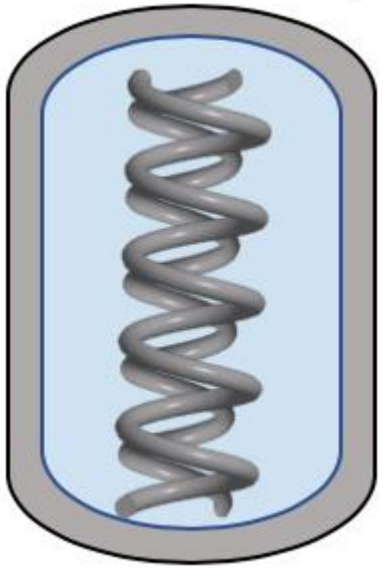
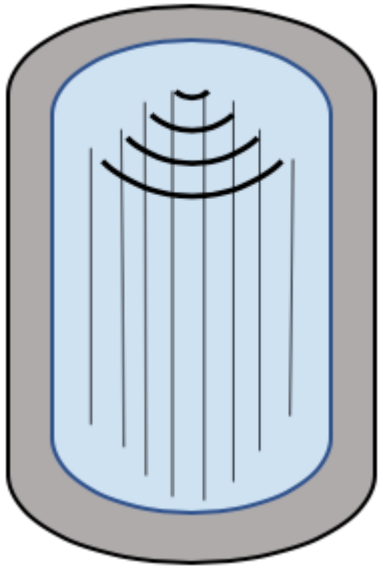
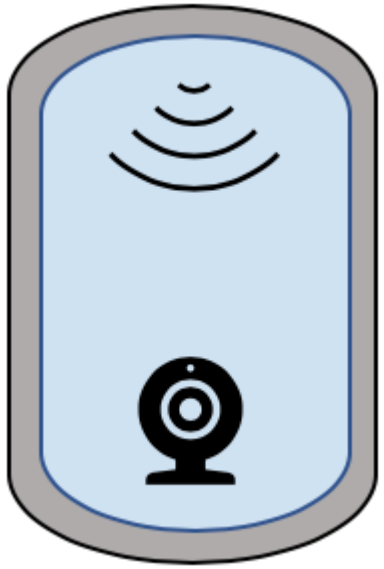
Concepts



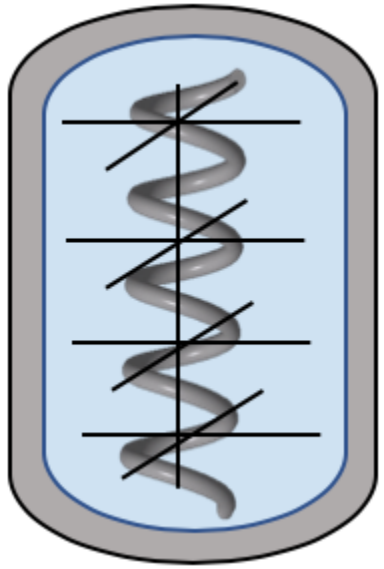
Multiple fiber optic cables layered, suspended in a helical sweep by structure



RMF transmitter on top of tank, combined with suspended, anchored fiber optic cables



RMF transmitter on top of tank, combined with camera



Fiber optic cable suspended in a helical sweep combined with thermocouple probes

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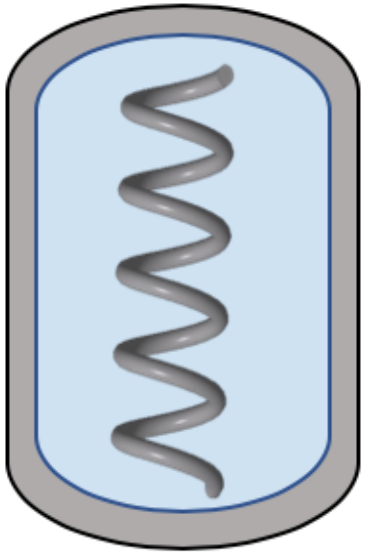
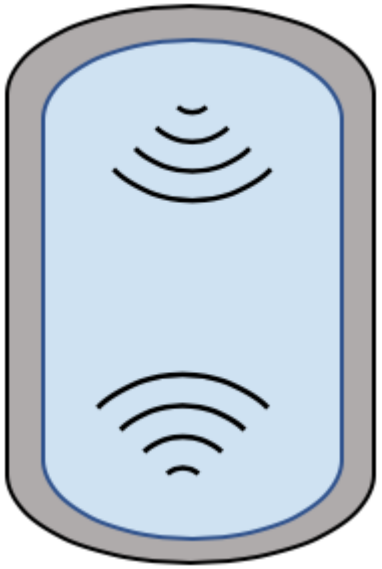
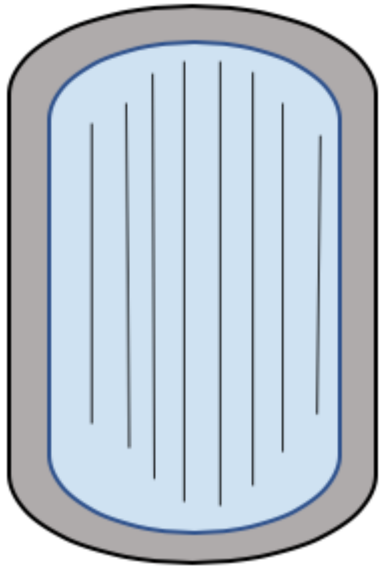
Concepts



Fiber optic cable suspended in a helical sweep by structure



RMF transmitter on bottom and top of tank



Multiple suspended fiber optic cables anchored at both ends of tank

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House of Quality

	Improvement Direction				
Sponsor Requirements	Importance Rating	Withstand Extreme Temperatures	Durability	Measures Mass in Zero Gravity	Measures Tomography
Cost Under $5000	2	3	3	3	3
Reusable	3	3	9	0	0
Accurate Output Values	4	0	0	9	9
Displays Output Values	5	3	3	3	3
	Raw Score (135)	30	48	57	57
	Relative Weight %	22.2%	35.6%	42.2%	42.2%
	Rank Order	4	3	½ (tie)	½ (tie)

Table 1: House of Quality

Pugh Charts

Selection Criteria	Concept #2 DATUM	Concept #8	Concept #59	Concept #62	Concept #83	Concept #1	Concept #33	Concept #78
Cost		-	+	S	-	+	-	-
Withstand Extreme Temperatures		+	+	S	+	S	S	-
Measures Mass in Zero Gravity		S	S	-	S	S	S	S
Measures Tomography		S	-	-	S	-	-	S
Durable		+	+	S	-	S	S	-
# of Pluses		2	3	0	1	1	0	0
# of Minuses		1	1	2	2	1	2	3

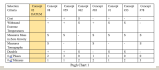
Pugh Chart 1

Selection Criteria	Concept #2	Concept #8 DATUM	Concept #59	Concept #62	Concept #83	Concept #1	Concept #33	Concept #78
Cost	+		+	+	S	+	S	-
Withstand Extreme Temperatures	-		S	-	S	-	S	-
Measures Mass in Zero Gravity	S		-	S	S	S	S	S
Measures Tomography	S		-	+	S	S	S	+
Durable	-		S	-	S	-	S	-
# of Pluses	1		1	2	0	1	0	1
# of Minuses	1		2	2	0	2	0	3

Pugh Chart 2

Selection Criteria	Concept #2	Concept #8	Concept #59 DATUM	Concept #62	Concept #83	Concept #1	Concept #33	Concept #78
Cost	-	-		-	-	-	-	-
Withstand Extreme Temperatures	-	S		-	S	-	S	-
Measures Mass in Zero Gravity	S	+		S	S	S	S	S
Measures Tomography	+	+		+	+	+	+	+
Durable	-	S		-	S	-	-	-
# of Pluses	1	2		1	1	1	1	1
# of Minuses	3	1		3	1	3	2	3

Pugh Chart 3



AHP

Sponsor Requirements	Cost under $5000	Reusable	Accurate Output Values	Displays Output Values	Total	Average
Cost under $5000	1	3	9	7	20	5
Reusable	0.333	1	5	5	11.333	2.833
Accurate Output Values	0.111	0.2	1	3	4.311	1.078
Displays Output Values	0.143	0.2	0.333	1	1.676	0.419
Total	1.587	4.4	15.333	16		
Average	0.39675	1.1	3.833	4		