NPOI Nitrogen Distribution

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Background Information

Abstract- The goal of this project is to provide the Navy Precision Optical Interferometer (NPOI) with a central nitrogen supply system. NPOI requires compressed nitrogen to operate pneumatic actuators, purge siderostat mirrors of moisture, and operate pneumatic gate valves. In the current configuration, each of the 30 stations in the interferometer array requires a separate nitrogen tank. Due to the development of the NPOI facility and a request for easier operation, a central nitrogen supply system has been proposed. A 1000L liquid nitrogen Dewar will satisfy the volume requirements of the system while reducing the frequency of refills. The Dewar will be installed near the center of the array, and attach to copper tubing that supplies compressed nitrogen along each of the three 250m arms. Due to the differences in pressure and volumetric flow rate of each item, a manifold system will provide each station with a dedicated regulator and shutoff valve. The proof of concept prototype is setup at NPOI, along a 30m section of the west arm and uses the same distribution system as the final design. The performance of the prototype provides confidence in the numerical predictions of pressure drop and volumetric flow rate for the final design.

Need Statement- The system to be created must handle necessary flow rates and pressures while still maintaining manageability. Any materials used must operate within an extreme climate setting of high winds, and drastic temperature range. Designs proposed must be easily installed and ready for periodic maintenance.

Problem Statement

A new system needs to be designed to limit the physical exertion of the NPOI staff, lower operating cost of nitrogen supply, and simplify the basic operation of the array telescope.

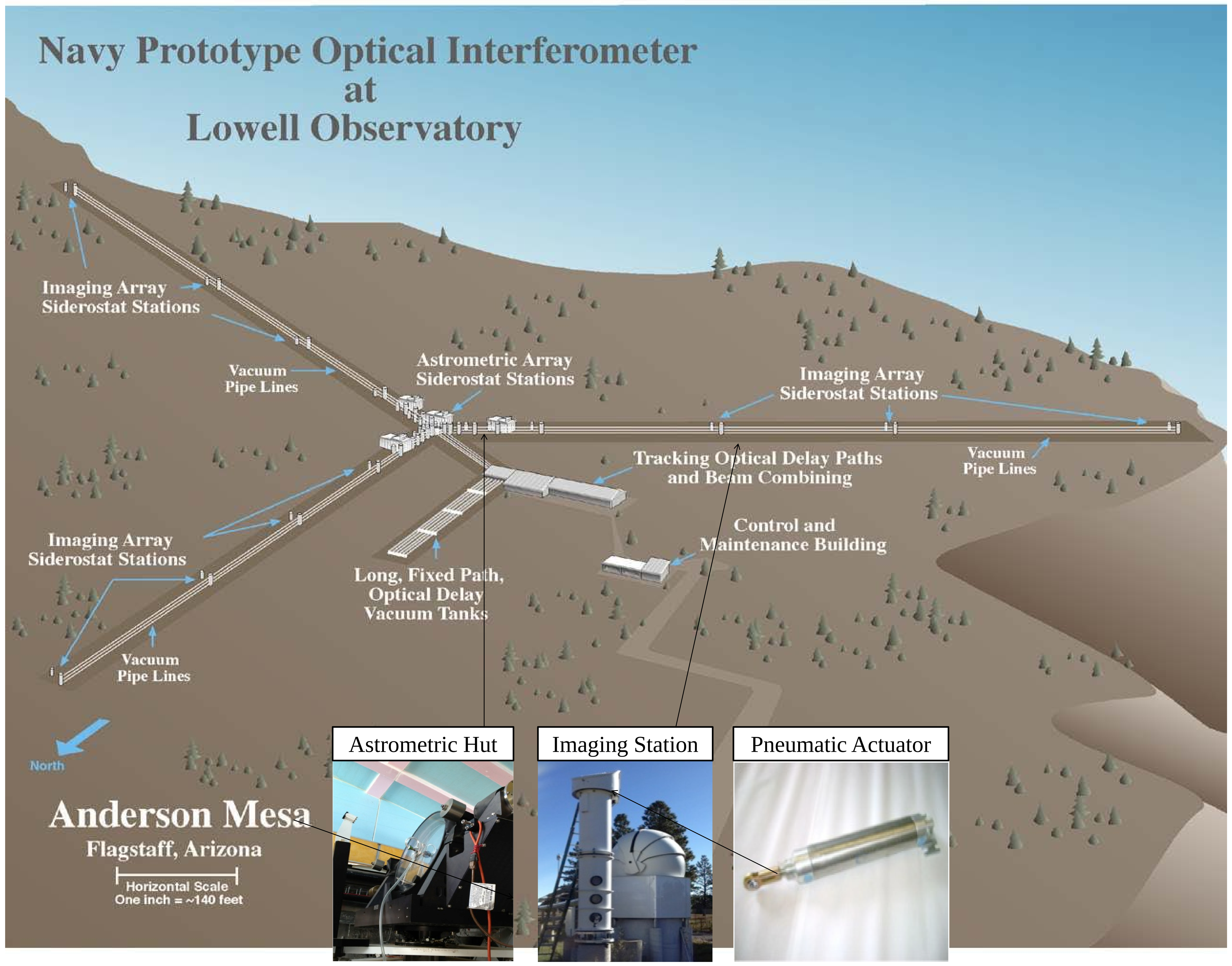
Objectives

Array

- 3 arms of 250m each
- On each arm:
  - Astrometric hut with two mirror purges
  - Gate valve station with three gate valves each
  - Ten imaging stations with three actuators and two mirror purges

	Pressure [PSI]	Flow Rate [CFH]
Astrometric purge	9	0.5
Pneumatic actuators	40	18
Gate valves	40	22

Engineering Design



Final Design

To provide nitrogen along the array, a 1000L Dewar tank will be installed with an outlet pressure of 50PSI. The main supply line along each arm is ½in cleaned and capped copper tubing, with an inner diameter of 0.555in. At each location, a copper tee fitting will be soldered in place with a series of brass fittings to convert the branch to a ¼in barb fitting. 1/4in black polyvinyl hose is then used to attach an in-line regulator appropriate for the device. At stations requiring both high and low pressure a ¼in barb tee will be installed to allow for two regulators, one for each required pressure. All of this is designed to be easily installed using insulated brackets mounted within a pre-existing cable tray that spans the entire facility.

Prototype

A proof of concept prototype was designed and built that stretches 100ft of the west arm and incorporates one of every nitrogen operated device on site. The prototype utilizes the same tubing, fittings, and installation methods as the proposed final design. This design is supplied by a single nitrogen tank and uses a 100ft copper coil to increase the tubing length while keeping installation time low.

Numerical Equations

Colebrook equation to obtain Darcy friction factor [1]:

$$\frac{1}{\sqrt{f}} = -2\log_{10}\left(\frac{\epsilon}{3.7D} + \frac{2.51}{Re\sqrt{f}}\right)$$

Darcy-Weisbach equation to obtain pressure drop [1]:

$$\Delta P = f_d \frac{L}{d}\frac{\rho V^2}{2}$$

Testing & Results

A MATLAB code was created that uses the Darcy-Weisbach equation to predict pressure drop in the prototype and final design. This was then compared to actual pressure drop in the prototype to predict pressure drop in the final system:

Prototype:

Predicted pressure drop for prototype= 0.33PSI
Actual pressure drop for prototype= 0.50PSI
Error= 34%

Final Design:

Numerical prediction= 1.95PSI
Maximum predicted pressure drop= 2.61PSI

Cost Analysis

The current system requires NPOI to refill each of the 30 tanks every 25-30 days. One of the advantages to this system is the greatly decreased cost of nitrogen per day. The site consumes 5.95ft^3 of nitrogen at 40PSI per day.

Current Tank System:

- Equivalent volume per tank= 105ft^3 at 40PSI
- $35.00 per refill

1000L Dewar Tank

- Equivalent volume= 9037ft^3 at 40PSI
- $1,000 per refill
- 1000L Dewar is equal to 86 tanks

Proposed system is only 1/3 the cost of current design

Conclusion

Building the proof of concept prototype and comparing the results to the numerical calculations has provided confidence in the proposed final design. All data will be sent to the staff at NPOI to begin the planning of the final design.

References

Munson, Bruce, et. al. 2013, Fundamentals of Fluid Mechanics, 7th ed.;USA

"Research." NPOI Telescope. N.p., n.d. Web. 14 Apr. 2014.

Acknowledgements

- Jim Clark, Naval Research Lab
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