NPOI Nitrogen Distribution Project Proposal

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Presentation Overview

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Presentation Overview

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  - Component List
- Cost Analysis
  - Parts
  - Installation
  - Bill of Materials
- Conclusion

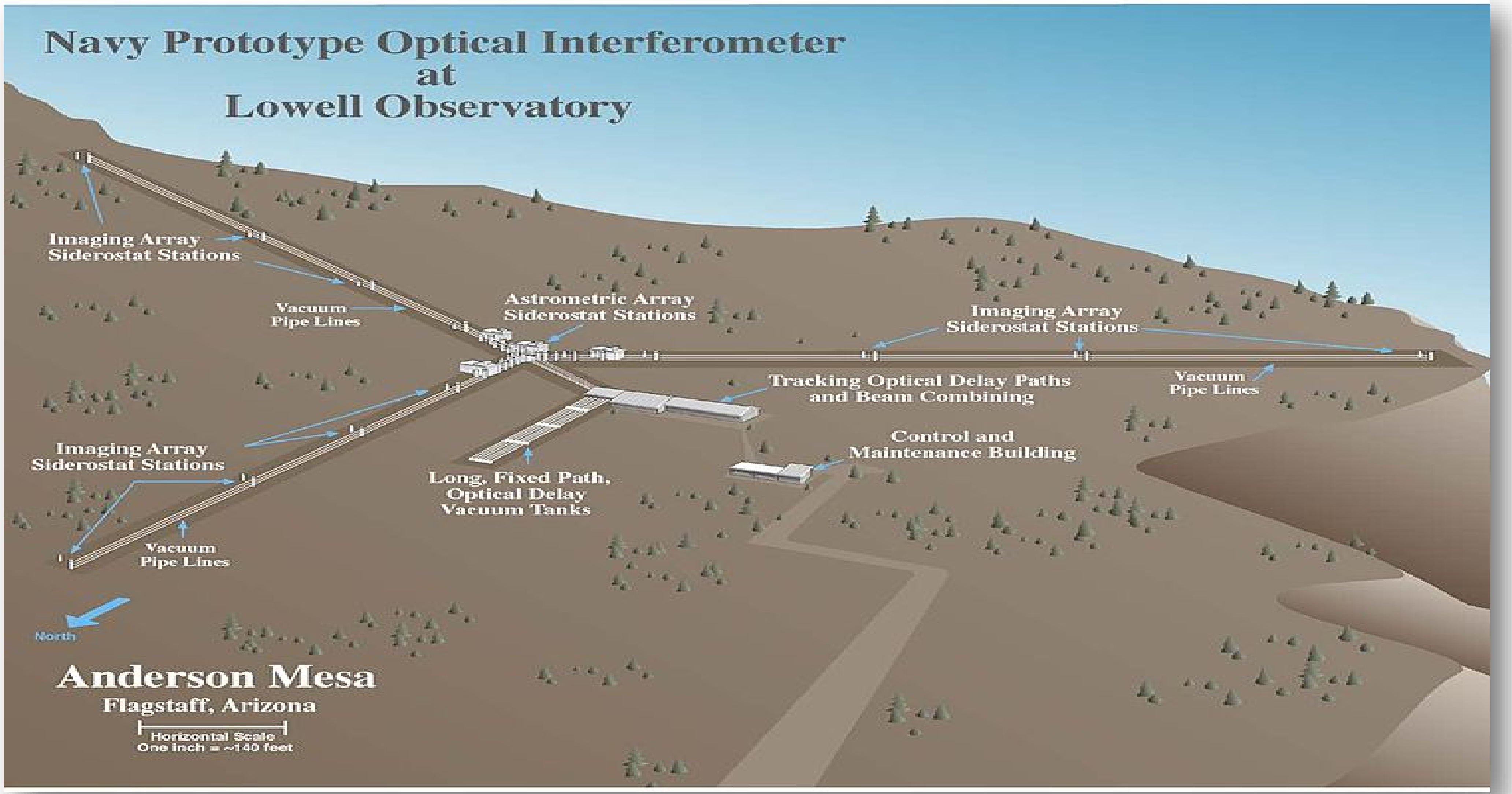
U.S. Naval Observatory

- Naval Research Laboratory
  - Navy bases navigation on astrometric position (positioning of the stars)

- Remapping is continuously required

- Navy Precision Optical Interferometer
  - Sponsored by facility operators
  - Anderson Mesa near Flagstaff

Navy Precision Optical Interferometer



www.nofs.navy.mil/

Current Nitrogen System

- 11 stations along each of the three 300 meter runs

- Multiple stations
  - 150lb canisters at each
  - Replaced routinely

- Nitrogen is wasted at purge when cover is off

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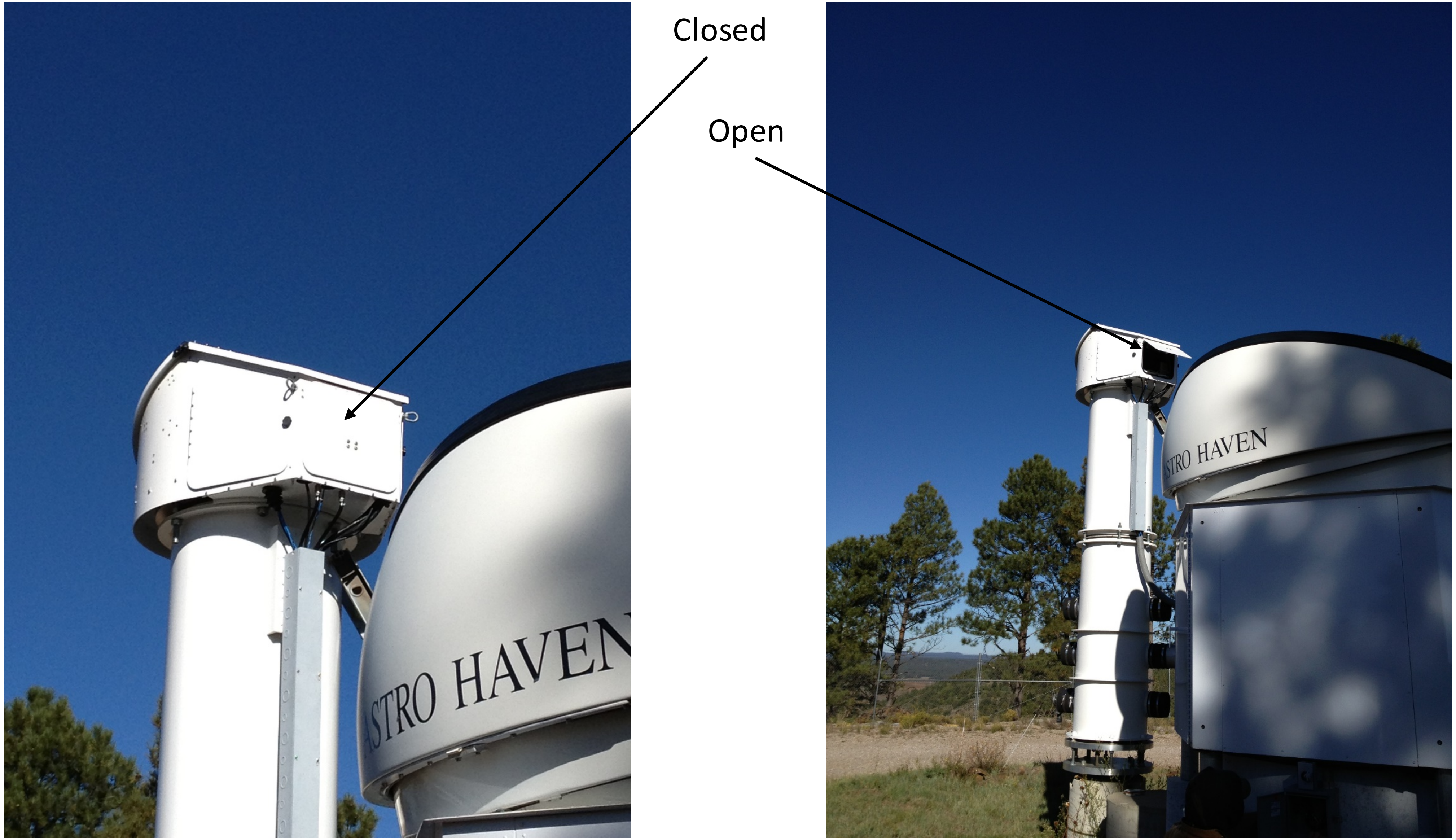

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Needs Statement

NPOI needs an improved Nitrogen supply system that is easier to maintenance, withstands harsh environment changes, and is less expensive than current design.

Project Goal

- Design a nitrogen supply system that provides easier operation of each station and provides efficient moisture control

- One single supply station

- Shuts off when not in use

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Operating Environment

- Exposed to elements
  (rain, snow, ice, UV light, animals)

- Temperature range -20ºF to 120ºF

- Vibrating cable trays
  - Wind
  - Operating Machinery

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Objectives

Objective	Measurement Basis	Units
Tubing size	Diameter	m
No significant change in size	Length	m
Vibration resistant	Cycle life	# of cycles

Constraints

- Tubing must be 300m long across 3 runs
- Purge in mirror cover requires 9PSI
- Lizard head requires 30PSI
- Gate valves require 40PSI
- Maximum flow rate along each arm 25CFH
- Manual shutoff valve prior to each manifold

Design Considerations

- Solenoid to shut purge system when cover is off
- Withstand movement between manifold and device
- Use off the shelf parts whenever possible

Concept Generation

- Tubing material
  - Supply line from tank
  - Flexible line from tee to manifold has been selected by client
- Manual shutoff valve
- Distribution system

Decision Matrix Weighting Criteria

	Current Supply	Cost	Ease of Installation	Maintenance	Resistance to Surroundings		Final Weight (%)
Current Supply		0	0	0	0	0	0
Cost	1		0	0	0	1	10
Ease of Installation	1	1		0	0	2	20
Maintenance	1	1	1		0	3	30
Environmental Constraints	1	1	1	1		4	40

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Copper

- Available as cleaned and capped
- Solder connections
- Good UV and weather resistance
- Soft temper is easily bendable
- ~$2 per foot

Cerro Flow Products

316 Stainless Steel

- Available as cleaned and capped
- Butt weld fittings
- Extremely resistant to UV and weather
- ~$7 per foot

Micah & Co.

EPDM

- Extremely flexible
- Excellent vibration resistance
- Not as resistant to UV or weather
- ~$2 per foot

Tee to Manifold

- Tee in supply line feeds multi-port manifold
- Least restrictive
- One valve per manifold
- Very simple and easy to install

www.polyconn.com

Individual Tees & Flow Through Manifold

- One valve per regulator
- Increased weight and complexity inside cable tray

www.directpex.com

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Ball Valve

- Easiest to use
- Least restrictive
- K= 0.05

Zoro Tools

Gate Valve & Angle Valve

- Adjustable flow rate
- Relatively free flowing
- K= 0.15

Sears

- Includes 90^{o} bend
- Very restrictive
- K= 2

NIBCO

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Tank Implementation

- 5-gallon tanks will reduce load on system
- 5-gallons≅405 ft of supply tubing
- Allows gate valves to react instantly
- Reduces stress in tubing

www.rakutken.com

Needed Flow Rate

- 2 Active imaging stations
  - 2 mirror cover purges
  - 5 1in bore pneumatic cylinders
- 1 Astrometric hut
  - 2 mirror cover purges
- Gate valve Station
  - 3 3in bore pneumatic cylinders

Mirror Cover Purge

- 9PSI line pressure
- 0.004in diameter orifice
- $Q = CA_o\sqrt{\frac{2\Delta P}{\rho}}$
- C= 0.75
- 0.5CFH flow rate

www.astronomy.net

Pneumatic Cylinder Flow Rate

- $Q = \frac{V \times P_{abs}}{28.8 \times t \times P_{atm}} \left[\frac{in^3}{s}\right]$
- $P_{atm} = 11.3PSI\ at\ 7000ft$
- $Q = \frac{Vin^3 \times P_{abs}PSI}{28.8 \times t[s] \times 11.3PSI} \times \frac{25}{12} = Q[CFH]$

www.airoil.com

Pneumatic Cylinders cont.

- Gate valves
  - Bore= 3in, stroke= 15in
  - Line length= 5ft, diameter= 0.375in
  - $Q = \frac{119.282in^3 \times 56.3PSI}{28.8 \times 2s \times 11.3PSI} \times \frac{25}{12} = 21.495 \rightarrow 22CFH$
- Imaging station
  - Bore= 1in, stroke= 5in
  - Line length= 10ft, diameter= 0.375in
  - $Q = \frac{30.434in^3 \times 56.3PSI}{28.8 \times 2s \times 11.3PSI} \times \frac{25}{12} = 5.484 \rightarrow 6CFH$

www.vatvalve.com

Total Flow Rate

- Max flow rate in each arm= 25CFH
  - 6 purges= 3CFH constant flow
  - 3 consecutive gate valves= 22CFH
- Max flow rate after tank= 20CFH
  - 4 purges= 2CFH constant flow
  - 3 simultaneous actuators= 18CFH

Pressure Drop Equations

- $\Delta P = f \frac{L_{eq}}{D} \frac{\rho V^2}{2}$
- f from Moody diagram using Re and (ε/D)
- L_{eq} accounts for bends, tees, and valves
- V is found using $V = \frac{Q}{A_c}$

Actual Pressure Drop

Location	**Tubing ID (in)**	**ΔP (PSI)**	**Tubing ID (in)**	**ΔP (PSI)**
Total arm (no tank)	0.555	2.9951	0.68	1.1760
Prior to tank	**0.555**	**1.3678**	0.436	4.1693
After tank	**0.555**	**1.2872**	0.436	3.9095
Main line (if feeding all 3 arms)	**0.555**	**1.2766**	0.68	0.4992
Main line (if feeding 2 arms)	0.555	1.0878	0.68	0.4260

Pressure Drop continued

- Pressure drop from tee to manifold= 0.2751PSI
- Large ΔP= Wasted nitrogen
- Goal for ΔP_{max}= 5PSI
- Actual ΔP_{max}= 4.2067PSI
- Use of ½in tubing everywhere means all components will be the same

Thermal Expansion Calculation

- $\Delta L = L_o \alpha (T_{max} - T_{install})$
- $\Delta L_{hot} = 700ft \times 9.3E^{-6}(120 - 70°\text{F})$=0.3255ft=**3.906in**
- $\Delta L_{cold} = 700ft \times 9.3E^{-6}(70 - -20°\text{F})$=0.5859ft=**7.0308in**
- $\sigma = \alpha \Delta T E$
- Modulus of elasticity= 16MPSI
- $\sigma_1 = 9.3E^{-6} \times (120 - 70°\text{F}) \times 16E^{6}$ =**7.44KSI**
- $\sigma_2 = 9.3E^{-6} \times (70 - -20°\text{F}) \times 16E^{6}$ =**13.392KSI**

Expansion loops

- Absorbs the change in length to reduce stress
- $L = \frac{1}{12}\left(\frac{3E}{P}\right)^{\frac{1}{2}}(d_o \Delta L)^{\frac{1}{2}}$
- $L = \frac{1}{12}\left(\frac{3 \times 16E^6 PSI}{6000PSI}\right)^{\frac{1}{2}}(0.625in \times 7.031in)^{\frac{1}{2}}$
- L= 16.098in

Tubing

Location	Size (in)	Length (ft)
Main supply	½	350
Prior to tank (All 3)	½	1250
After tank (All 3)	½	2100
Fourth astrometric hut	½	65
External gate valves	½	164
Supply to manifold	$^{3}/_{8}$ PVC	500

Tubing

Description	Size	Length (ft)	Quantity	Cost $	Total Cost $
Copper	½in	100ft	40	202.80	8112.00
Black PVC	$^{3}/_{8}$in	100ft	5	44.00	220.00
					8332.00

Conversion to Barb Fitting

First Fitting	Second Fitting	Third Fitting	Total cost ($)
½in to $^3/_8$ in tubing reducer	$^3/_8$ in tube-$^3/_8$ in female NPT	$^3/_8$ in female NPT to $^3/_8$ in barb	7.40
½in to $^3/_8$ in tubing reducer	$^3/_8$ in tube-$^3/_8$ in male NPT	$^3/_8$ in male NPT to $^3/_8$ in barb	5.85
½in tube to ½in female NPT	**½in male NPT to $^3/_8$ in barb**		**4.69**
½in tube to ½in male NPT	½in female NPT to $^3/_8$ in barb		5.66
½in tube to $^3/_8$ in female NPT	$^3/_8$ in male NPT to $^3/_8$ in barb		5.37
½in tube to $^3/_8$ in male NPT	$^3/_8$ in male NPT to $^3/_8$ in barb		5.31

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Manifolds

# of ports	Quantity	Cost ($)	Total Cost ($)
7	31	21.30	660.30
5	3	18.84	56.52
2	4	14.87	59.48
5*	1	26.22	21.85
	39		**798.15**

Fittings

Inlet	Outlet	Quantity	Cost ($)	Total Cost ($)
$^{5}/_{8}$in coupling		3	1.27	3.81
½in coupling		35	0.37	12.95
½in tee		37	1.45	53.65
½in ball valve		38	4.33	164.54
$^{1}/_{2}$in tube	$^{1}/_{2}$in female NPT	37	1.79	66.23

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Fittings cont.

Inlet	Outlet	Quantity	Cost ($)	Total Cost ($)
$^{1}/_{2}$in male NPT	$^{3}/_{8}$in barb	37	3.19	118.03
$^{3}/_{8}$in barb	$^{3}/_{8}$in male NPT	38	1.90	72.20
$^{3}/_{8}$in male NPT	Plug	38	1.38	52.44
¼in male NPT	¼in barb	240	1.383	331.92
$^{1}/_{4}$in male NPT	Plug	67	1.23	82.41
$^{1}/_{2}$in male NPT	$^{1}/_{2}$in tube	4	1.79	7.16
$^{1}/_{2}$in male NPT	Plug	1	2.58	2.58
		572		**964.11**

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Storage Tank Supplies

Description	Quantity	Cost ($)	Total Cost ($)
5-gallon tank	3	84.99	254.97
½in tube to ½in male NPT	6	1.07	6.42
½in NPT plug	12	2.58	30.96
			292.35

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Mounting Hardware

Description	Quantity	Package Qty.	Cost ($)	Qty. of packages	Total Cost ($)
¼-20 SS316 bolt	320	25	7.22	13	93.86
¼in SS316 washer	320	100	8.25	4	33.00
¼-20 nylon-insert locknut	320	50	9.26	13	120.38
TPR Vibration-damping clamp	320	25	10.56	13	137.28
	1280			46	**384.52**

Installation Supplies

Description	**Size**	**Cost**
Tubing Bender	$^{5}/_{8}$in OD	148.33
Tube Cutter	$^{1}/_{8}$in to $^{3}/_{4}$in OD	15.50
Stay-Brite #8 Solder	$^{1}/_{8}$in diameter, 8oz	50.26
Prest-O-Lite Torch Kit	N/A	179.63
Acetylene Tank	$10ft^3$	N/A (Industrial pricing)
		393.72

Total Bill of Materials

Description	Quantity	Cost
Tubing	45	8332
Manifolds	39	798.15
Fittings	572	966.81
Installation		393.72
Mounting hardware	1280	384.52
Tank Supplies	21	292.35
		11167.55

Conclusion

- Navy requires remapping of the stars for navigational purposes
- The NPOI is an array telescope that has three 300 meter long arms
- Current facility uses 150lb nitrogen tanks to operate each station
- Alternative nitrogen supply system is needed that uses a single supply tank
- Each arm requires constant 3CFH and an additional 22CFH at certain times
- Clean and capped copper tubing was chosen for the main supply lines

Conclusion cont.

- Pressurized storage tanks will lessen the load on the supply line
- Black PVC tubing at each station leads to manifolds of various port sizes
- Analysis shows that 0.55in ID tubing is needed for supply line
- Coils of tubing will dampen the effects of thermal expansion
- Installation materials may include additional costs
- Total cost is $11,167.55

References

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- [2] Loss coefficients for various components pg. 439: Munson, Okiishi et all. (2013). *Fundamentals of Fluid Mechanics (7th edition).* Danvers, Ma. Wiley & Sons, Inc.
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- [7] Manifolds: http://www.polyconn.com/black-anodized-manifolds-p-2626-l-en.html