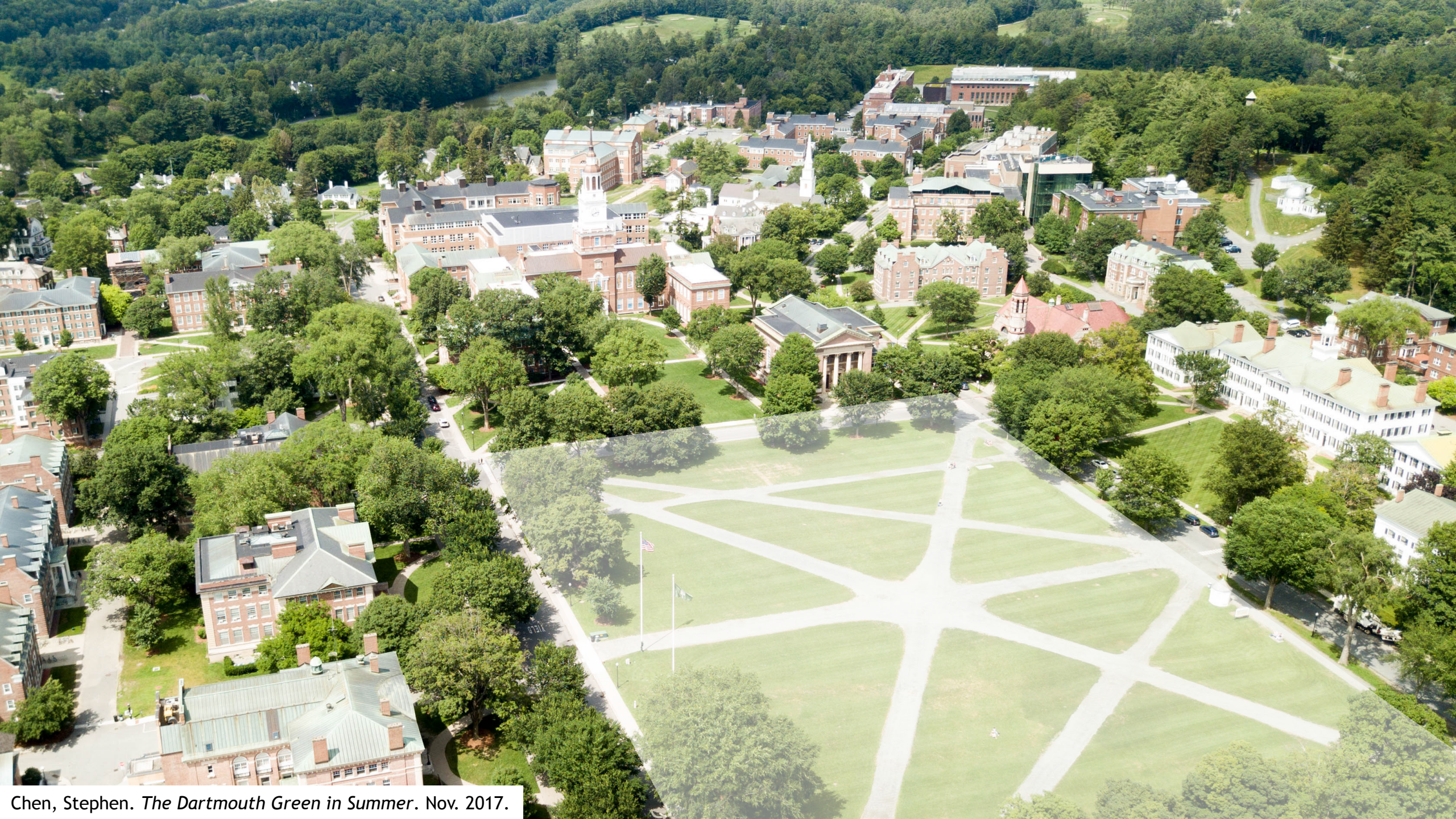
Outdoor Wi-Fi and Hybrid Powered Fiber Cabling

Bryan Ward

The DARTMOUTH Green



Chen, Stephen. *The Dartmouth Green in Summer*. Nov. 2017.

https://home.dartmouth.edu/events/commencement/families/main

https://home.dartmouth.edu/news/2023/10/homecoming-weekend-tours-treats-teams-and-traditions

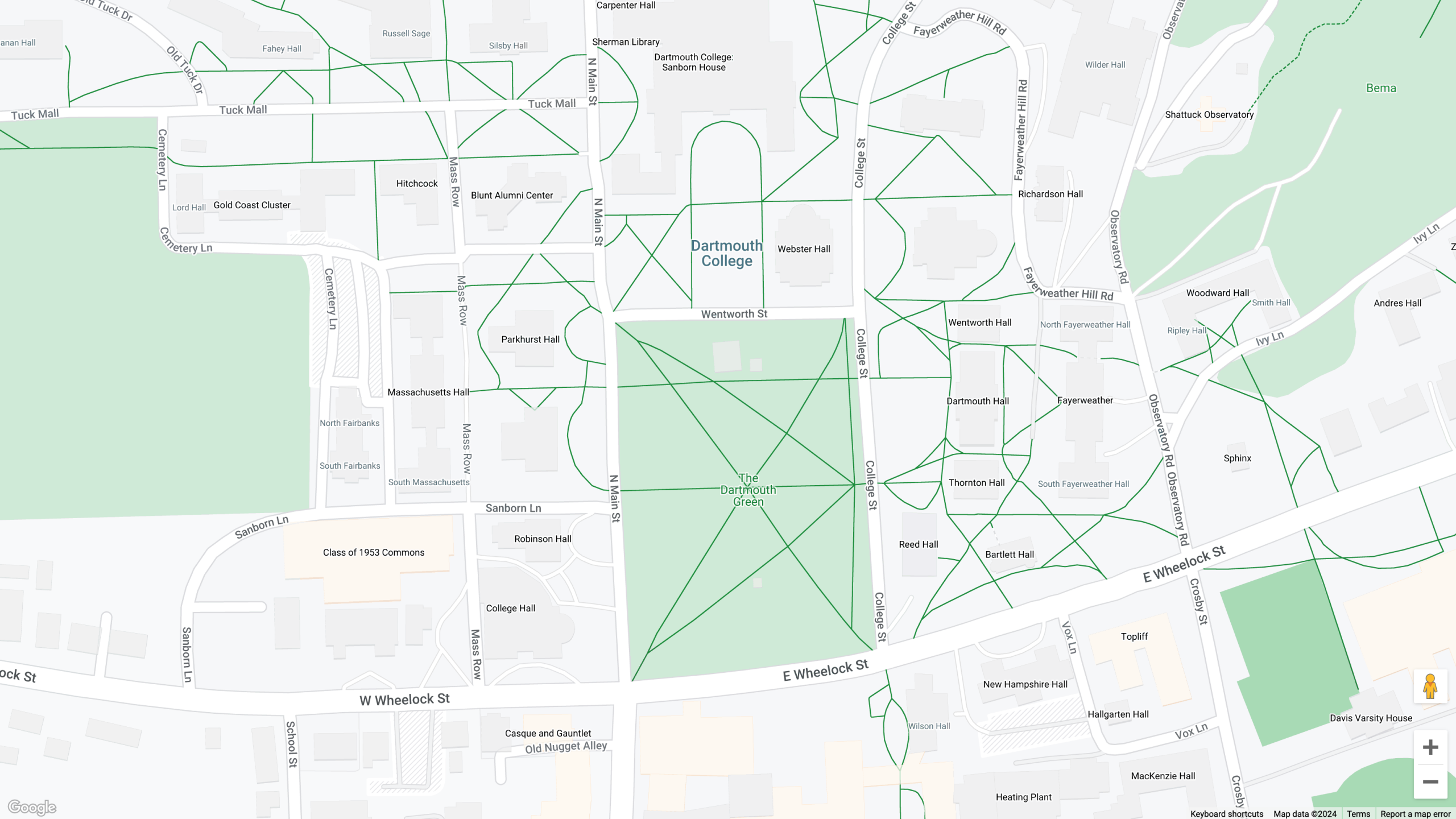
Photo by Eli Burakian, January 2022 <https://home.dartmouth.edu/news/2023/12/ice-skating-returning-green-winter>

Dartmouth Loves the Outdoors

Excited!

Puzzled

There’s a lot of wires in wireless


Carpenter Hall
Russell Sage
Silsby Hall
Fahey Hall
Sherman Library
Dartmouth College: Sanborn House
Old Tuck Dr
Tuck Mall
Tuck Mall
Tuck Mall
N Main St
College St
Fayerweather Hill Rd
Wilder Hall
Bema
Shattuck Observatory
Observatory Rd
Cemetery Ln
Hitchcock
Mass Row
Blunt Alumni Center
Lord Hall
Gold Coast Cluster
Richardson Hall
Dartmouth College
Webster Hall
Cemetery Ln
Cemetery Ln
Mass Row
Wentworth St
Parkhurst Hall
Wentworth Hall
North Fayerweather Hall
Woodward Hall
Smith Hall
Ripley Hall
Andres Hall
Ivy Ln
Massachusetts Hall
Dartmouth Hall
Fayerweather
North Fairbanks
South Fairbanks
South Massachusetts
Mass Row
The Dartmouth Green
College St
Thornton Hall
South Fayerweather Hall
Sphinx
Sanborn Ln
Sanborn Ln
Robinson Hall
Class of 1953 Commons
Reed Hall
Bartlett Hall
E Wheelock St
College Hall
Mass Row
Crosby St
Vox Ln
Topliff
Sanborn Ln
E Wheelock St
W Wheelock St
New Hampshire Hall
Hallgarten Hall
Wilson Hall
Davis Varsity House
School St
Casque and Gauntlet
Old Nugget Alley
Vox Ln
MacKenzie Hall
Heating Plant
Crosby
Google
Keyboard shortcuts
Map data ©2024
Terms
Report a map error

The Dartmouth

College to install Wi-Fi on the Green, cut back campus TV streaming access

The plan, set to cost around $250,000, is part of a larger effort to further spread Internet access to outdoor spaces on campus.

Photo by Hannah Li / The Dartmouth Senior Staff

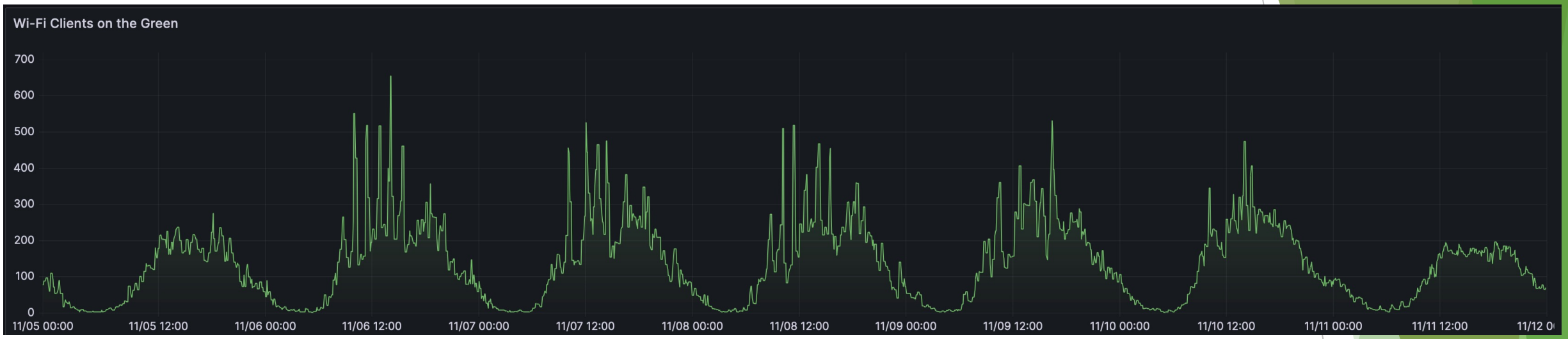
By Isabelle Han
Published January 12, 2023

Dartmouth Student Government announced that Wi-Fi would soon be available on the Green in a campus-wide email on Dec. 20, 2022, a result of a collaboration between the DSG Subcommittee on Technology and College Information, Technology and Consulting.

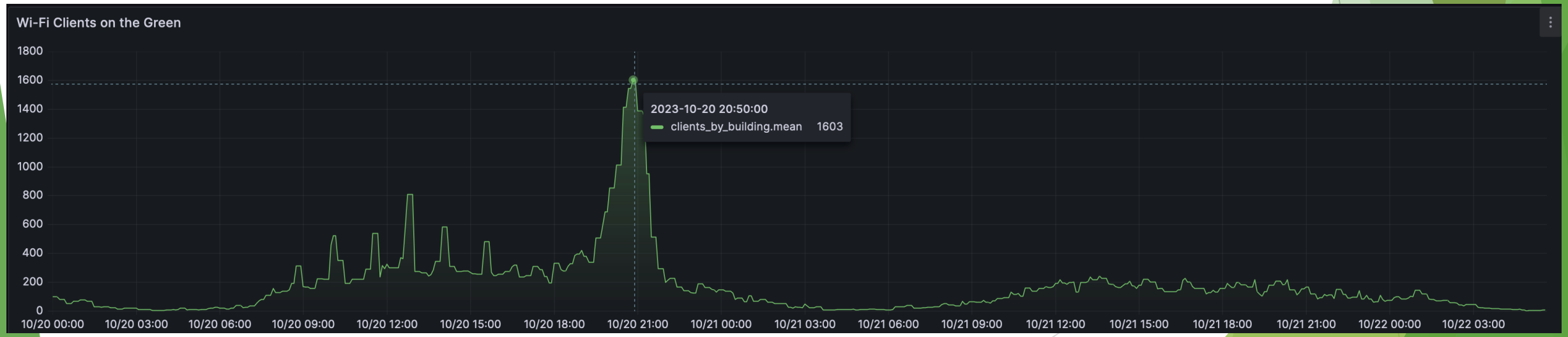
According to College chief technology officer Felix Windt, the service would likely be available to students within the calendar year and that it has been a request from students for "over a decade." Wi-Fi on the Green is just the first step toward making Wi-Fi available in other outdoor spaces across campus, such as Baker Lawn and Tuck Drive, Windt added.

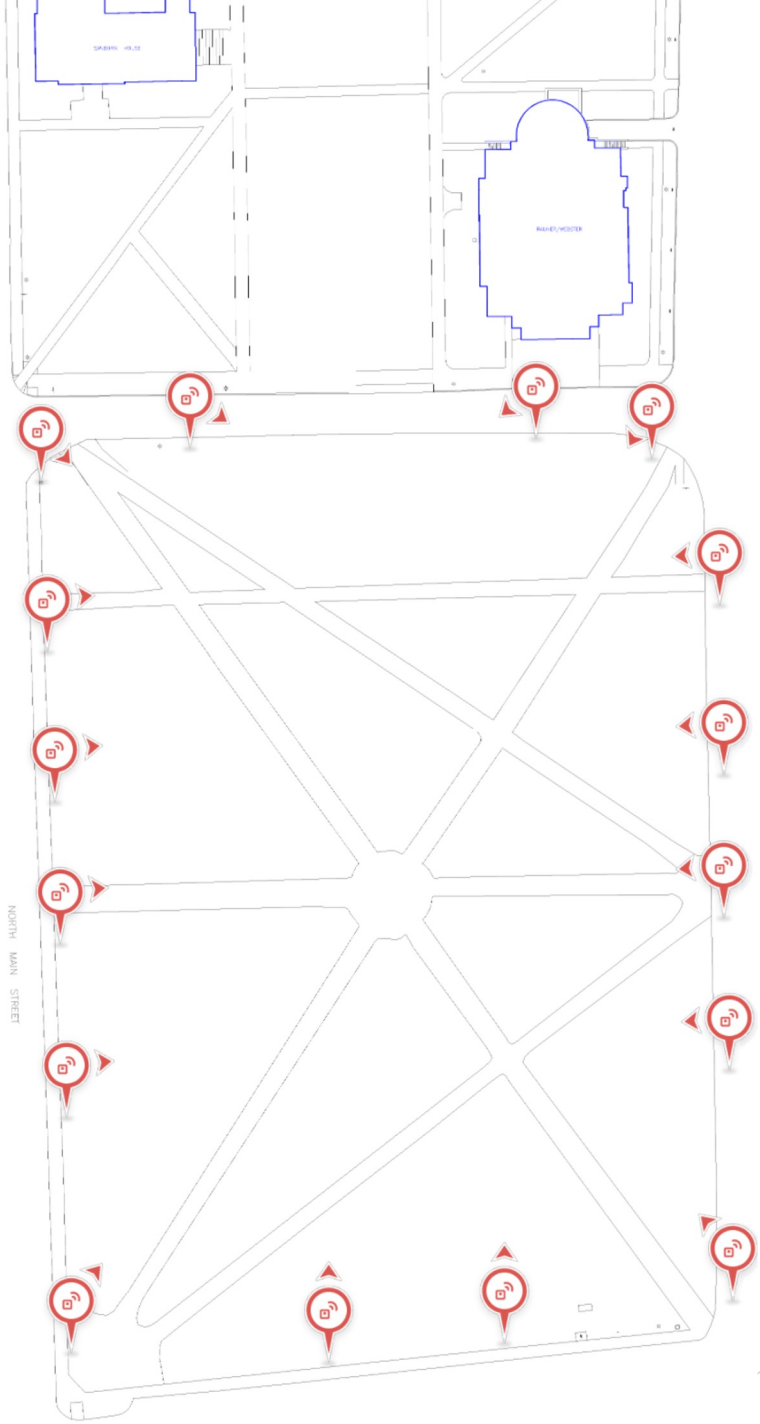
https://www.thedartmouth.com/article/2023/01/college-to-install-wi-fi-on-the-green-cut-back-campus-tv-streaming-access

- Design for 400 casual users (email, web. Some VoWiFi, some video playback)



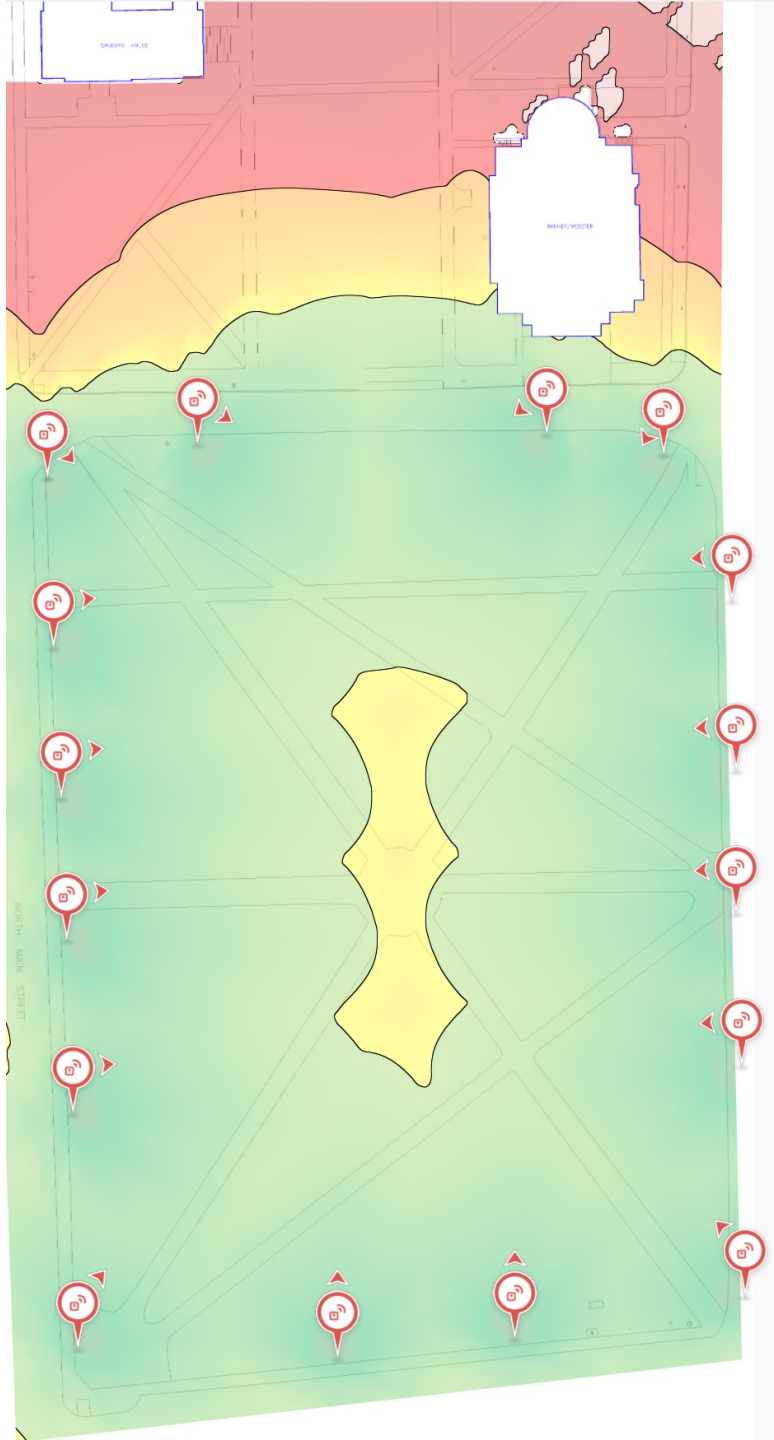
- 1600+ simultaneous users on homecoming night





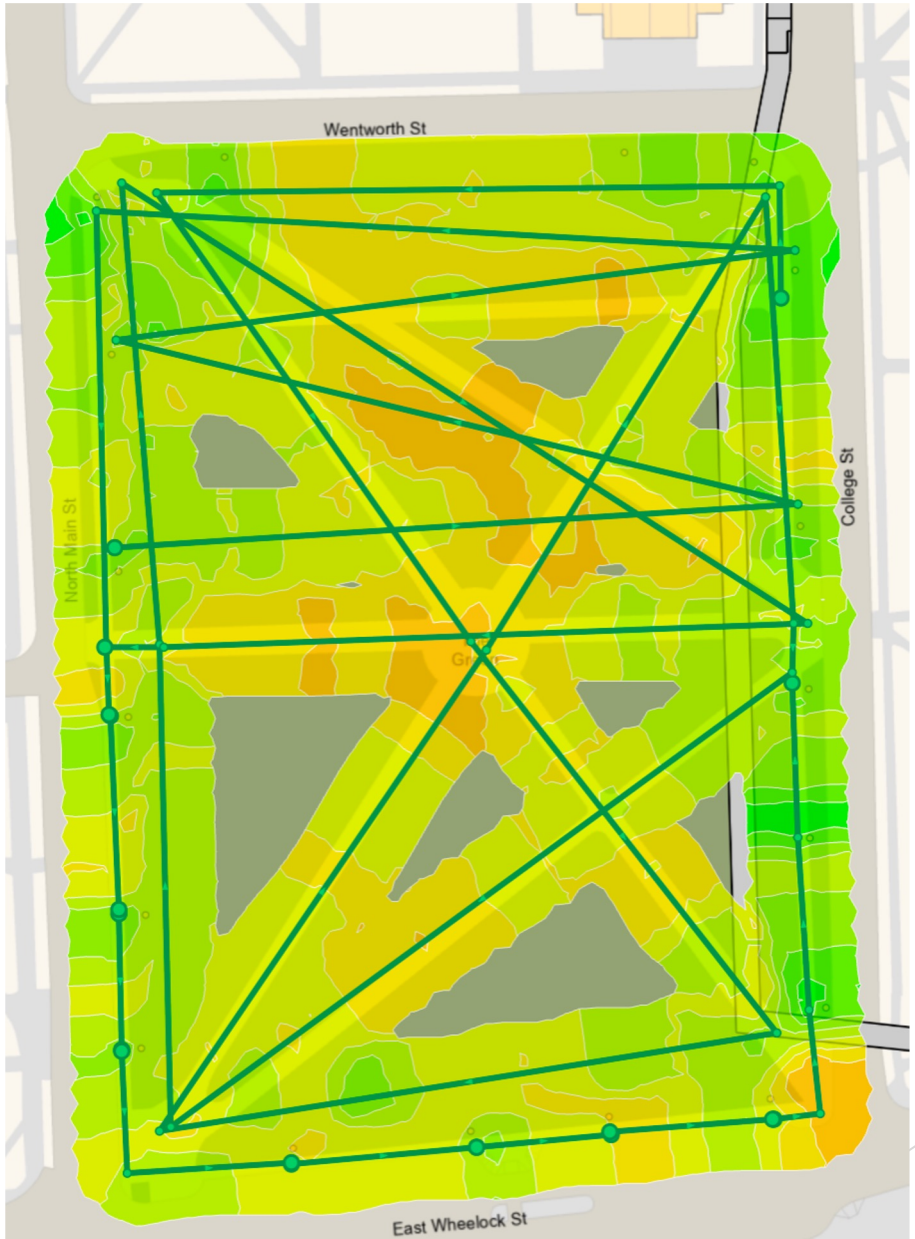
Hamina

Predictive Design



Hamina

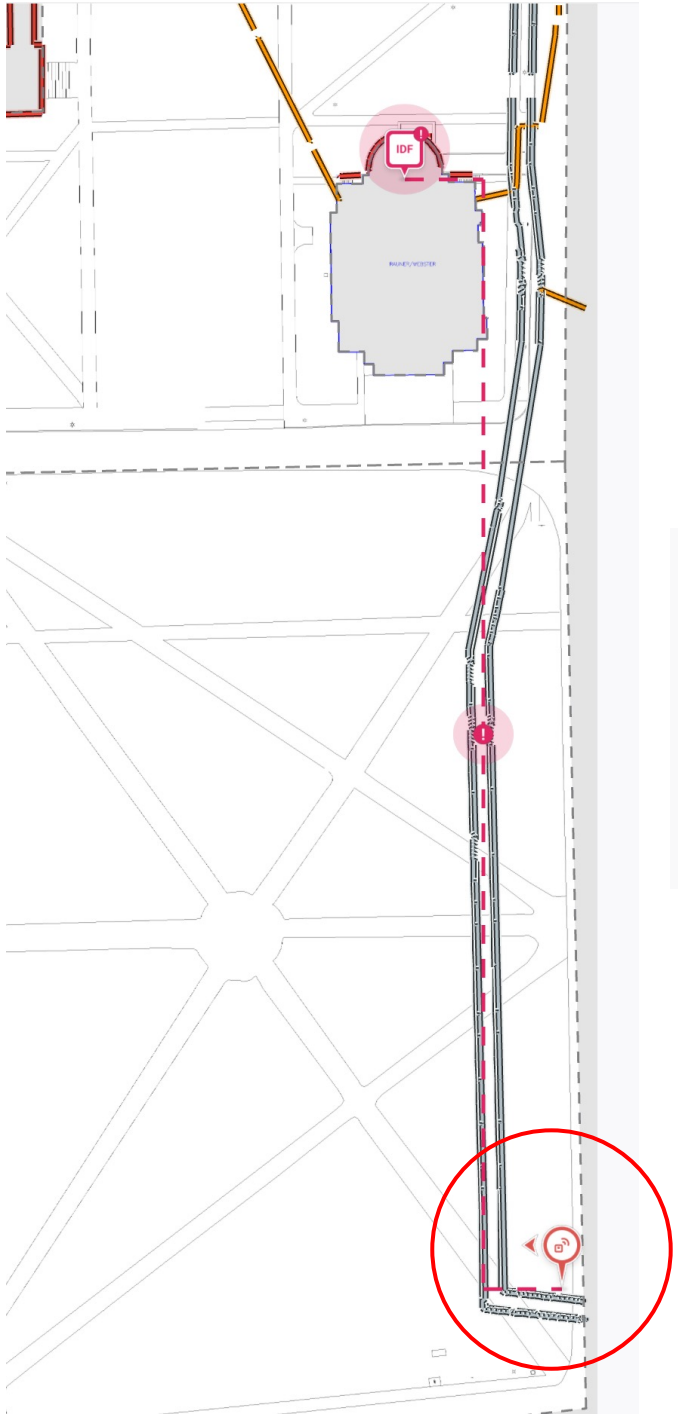
Validation Survey



ekahau

Outdoor Wi-Fi

Hybrid
Power + Fiber
Cabling



Name	APs	Wired clients	Consumed / Ports total	Power / APs	Power / clients	Consumed / Power total
IDF 1	1	0	**1 / -**	25.5	0	**25.50 / -**

Devices connected to "IDF 1":

Device Name	Make	Model	Power	Cable Length
Green 25	Juniper	AP63	25.50 W	907.26 ft

Hamina

How long can a twisted-pair Ethernet cable be?

Cat6A, 23AWG Solid, 1000Base-T, 30W PoE

- 100m (328 ft)
  - At 20 deg C (68 deg F)
- 90m (295ft) – BICSI TDMM 14 Chapter 5-17
  - 5m (16ft) patch cord allowance on each end
- 84m (275ft)
  - 3m (10ft) service loops on each end
- 75m (250ft)
  - Because nothing is ever a perfectly straight line

How long can a fiber optic cable be?

2009 Alcatel-Lucent

100Gbps over 7000km

Typical Enterprise:

OS2 SMF, 1000Base-LX, 1310nm

- 10km

But what about power?

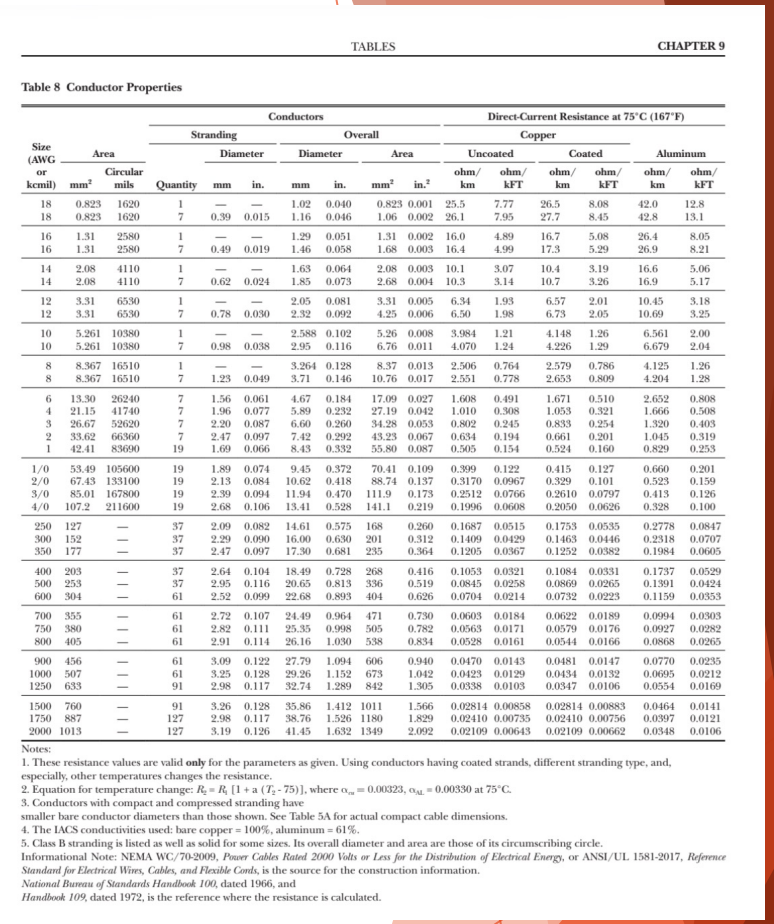
DISCLAIMER

I AM NOT A LICENSED ELECTRICIAN NOR A LICENSED PROFESSIONAL ELECTRICAL ENGINEER

NONE OF THE CONTENT IN THIS PRESENTATION IS INTENDED TO BE USED FOR CONSTRUCTION WITHOUT PROPER REVIEW BY A PROFESSIONAL ENGINEER

National Electrical Code

- Chapter 9, Table 8 “Conductor Properties”
- It’s as complicated as the MCS Index tables…
- Need to know
  - Wire size (in AWG or mm^2)
  - Solid or Stranded
    - If Stranded, how many strands?
  - Copper or Aluminum (Hint: you should use copper)
  - Insulated (Coated or Uncoated)



TABLES CHAPTER 9

Table 8 Conductor Properties

Size (AWG or kcmil)	Conductors: Area mm²	Area Circular mils	Stranding: Quantity	Stranding: Diameter mm	Stranding: Diameter in.	Overall: Diameter mm	Overall: Diameter in.	Overall: Area mm²	Overall: Area in.²	Direct-Current Resistance at 75°C (167°F): Copper Uncoated ohm/km	Copper Uncoated ohm/kFT	Copper Coated ohm/km	Copper Coated ohm/kFT	Aluminum ohm/km	Aluminum ohm/kFT
18	0.823	1620	1	—	—	1.02	0.040	0.823	0.001	25.5	7.77	26.5	8.08	42.0	12.8
18	0.823	1620	7	0.39	0.015	1.16	0.046	1.06	0.002	26.1	7.95	27.7	8.45	42.8	13.1
16	1.31	2580	1	—	—	1.29	0.051	1.31	0.002	16.0	4.89	16.7	5.08	26.4	8.05
16	1.31	2580	7	0.49	0.019	1.46	0.058	1.68	0.003	16.4	4.99	17.3	5.29	26.9	8.21
14	2.08	4110	1	—	—	1.63	0.064	2.08	0.003	10.1	3.07	10.4	3.19	16.6	5.06
14	2.08	4110	7	0.62	0.024	1.85	0.073	2.68	0.004	10.3	3.14	10.7	3.26	16.9	5.17
12	3.31	6530	1	—	—	2.05	0.081	3.31	0.005	6.34	1.93	6.57	2.01	10.45	3.18
12	3.31	6530	7	0.78	0.030	2.32	0.092	4.25	0.006	6.50	1.98	6.73	2.05	10.69	3.25
10	5.261	10380	1	—	—	2.588	0.102	5.26	0.008	3.984	1.21	4.148	1.26	6.561	2.00
10	5.261	10380	7	0.98	0.038	2.95	0.116	6.76	0.011	4.070	1.24	4.226	1.29	6.679	2.04
8	8.367	16510	1	—	—	3.264	0.128	8.37	0.013	2.506	0.764	2.579	0.786	4.125	1.26
8	8.367	16510	7	1.23	0.049	3.71	0.146	10.76	0.017	2.551	0.778	2.653	0.809	4.204	1.28
6	13.30	26240	7	1.56	0.061	4.67	0.184	17.09	0.027	1.608	0.491	1.671	0.510	2.652	0.808
4	21.15	41740	7	1.96	0.077	5.89	0.232	27.19	0.042	1.010	0.308	1.053	0.321	1.666	0.508
3	26.67	52620	7	2.20	0.087	6.60	0.260	34.28	0.053	0.802	0.245	0.833	0.254	1.320	0.403
2	33.62	66360	7	2.47	0.097	7.42	0.292	43.23	0.067	0.634	0.194	0.661	0.201	1.045	0.319
1	42.41	83690	19	1.69	0.066	8.43	0.332	55.80	0.087	0.505	0.154	0.524	0.160	0.829	0.253
1/0	53.49	105600	19	1.89	0.074	9.45	0.372	70.41	0.109	0.399	0.122	0.415	0.127	0.660	0.201
2/0	67.43	133100	19	2.13	0.084	10.62	0.418	88.74	0.137	0.3170	0.0967	0.329	0.101	0.523	0.159
3/0	85.01	167800	19	2.39	0.094	11.94	0.470	111.9	0.173	0.2512	0.0766	0.2610	0.0797	0.413	0.126
4/0	107.2	211600	19	2.68	0.106	13.41	0.528	141.1	0.219	0.1996	0.0608	0.2050	0.0626	0.328	0.100
250	127	—	37	2.09	0.082	14.61	0.575	168	0.260	0.1687	0.0515	0.1753	0.0535	0.2778	0.0847
300	152	—	37	2.29	0.090	16.00	0.630	201	0.312	0.1409	0.0429	0.1463	0.0446	0.2318	0.0707
350	177	—	37	2.47	0.097	17.30	0.681	235	0.364	0.1205	0.0367	0.1252	0.0382	0.1984	0.0605
400	203	—	37	2.64	0.104	18.49	0.728	268	0.416	0.1053	0.0321	0.1084	0.0331	0.1737	0.0529
500	253	—	37	2.95	0.116	20.65	0.813	336	0.519	0.0845	0.0258	0.0869	0.0265	0.1391	0.0424
600	304	—	61	2.52	0.099	22.68	0.893	404	0.626	0.0704	0.0214	0.0732	0.0223	0.1159	0.0353
700	355	—	61	2.72	0.107	24.49	0.964	471	0.730	0.0603	0.0184	0.0622	0.0189	0.0994	0.0303
750	380	—	61	2.82	0.111	25.35	0.998	505	0.782	0.0563	0.0171	0.0579	0.0176	0.0927	0.0282
800	405	—	61	2.91	0.114	26.16	1.030	538	0.834	0.0528	0.0161	0.0544	0.0166	0.0868	0.0265
900	456	—	61	3.09	0.122	27.79	1.094	606	0.940	0.0470	0.0143	0.0481	0.0147	0.0770	0.0235
1000	507	—	61	3.25	0.128	29.26	1.152	673	1.042	0.0423	0.0129	0.0434	0.0132	0.0695	0.0212
1250	633	—	91	2.98	0.117	32.74	1.289	842	1.305	0.0338	0.0103	0.0347	0.0106	0.0554	0.0169
1500	760	—	91	3.26	0.128	35.86	1.412	1011	1.566	0.02814	0.00858	0.02814	0.00883	0.0464	0.0141
1750	887	—	127	2.98	0.117	38.76	1.526	1180	1.829	0.02410	0.00735	0.02410	0.00756	0.0397	0.0121
2000	1013	—	127	3.19	0.126	41.45	1.632	1349	2.092	0.02109	0.00643	0.02109	0.00662	0.0348	0.0106

Notes:
1. These resistance values are valid **only** for the parameters as given. Using conductors having coated strands, different stranding type, and, especially, other temperatures changes the resistance.
2. Equation for temperature change: $R_2 = R_1 [1 + a (T_2 - 75)]$, where $\alpha_{Cu} = 0.00323$, $\alpha_{AL} = 0.00330$ at 75°C.
3. Conductors with compact and compressed stranding have smaller bare conductor diameters than those shown. See Table 5A for actual compact cable dimensions.
4. The IACS conductivities used: bare copper = 100%, aluminum = 61%.
5. Class B stranding is listed as well as solid for some sizes. Its overall diameter and area are those of its circumscribing circle.
Informational Note: NEMA WC/70-2009, *Power Cables Rated 2000 Volts or Less for the Distribution of Electrical Energy*, or ANSI/UL 1581-2017, *Reference Standard for Electrical Wires, Cables, and Flexible Cords*, is the source for the construction information. *National Bureau of Standards Handbook 100*, dated 1966, and *Handbook 109*, dated 1972, is the reference where the resistance is calculated.

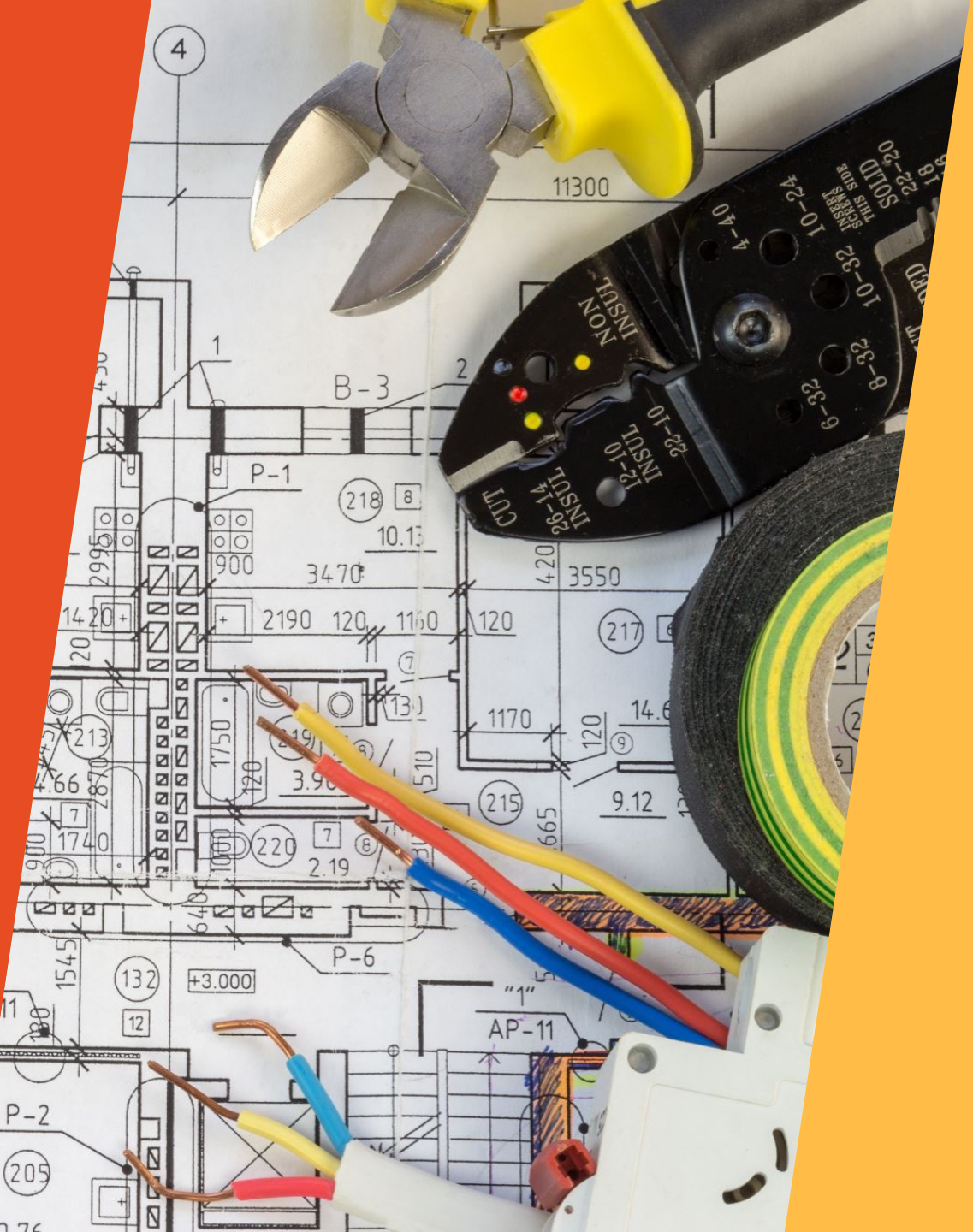
Voltage Drop

- That gives you resistance in Ohms per foot of wire
  - At 75 degrees C (167 degrees F)
- You then need to do math to determine length of wire
  - Based on Voltage
  - Amperage (Current Drawn)
  - And the resistance per foot value
- This gives you Voltage Drop
  - How much voltage loss is acceptable in your applications

Calculators Exist

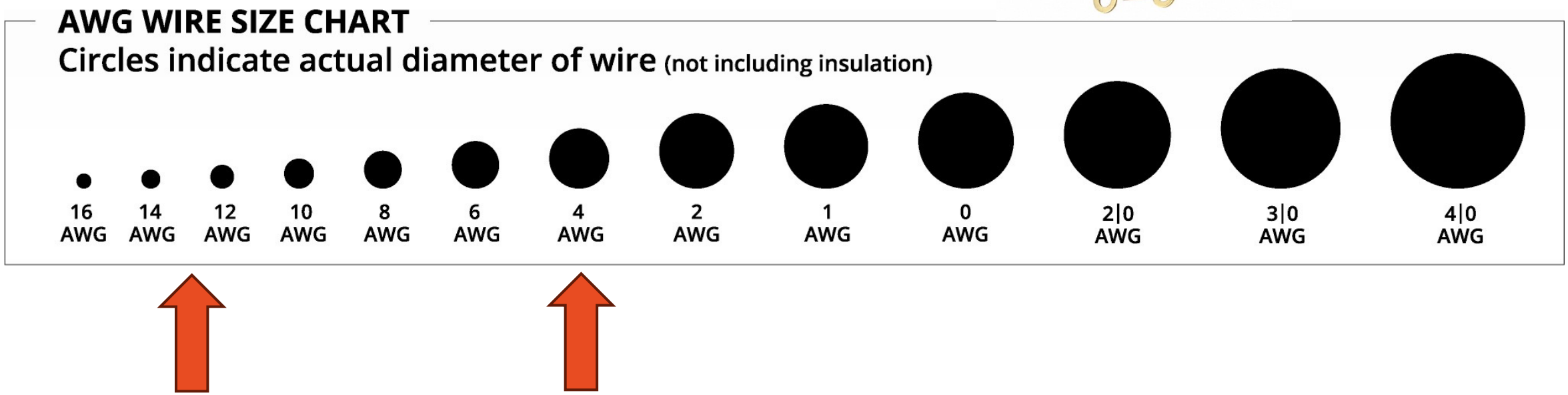
PoE Voltage Drop

- 802.3af, 15.4W (802.3 Clause 33 Table 33-18)
  - Type 1 Devices 37V to 57V
- 802.3at, 30W (802.3 Clause 33 Table 33-18)
  - Type 2 Devices 42.5V to 57V
- 802.3bt, 99.9W (802.3 Clause 145 Table 145-29)
  - Depends on the specific PoE Device class
  - 44.3V to 57V
- Design for nominal range 48V DC to 56V DC




LAN
POE

120V, 15A



$3.50 per foot

Cat6A: 87¢ per foot

https://www.bluesea.com/products/20010/Wire_Fuse_and_Fuse_Holder_Selection_Chart

Other Considerations

- Waterproof
- Underground Rated
- Sunlight/UV
- Rodent-Proof
- Flexibility & Bend Radius
- Temperature
- Ease of Install
- Practicality

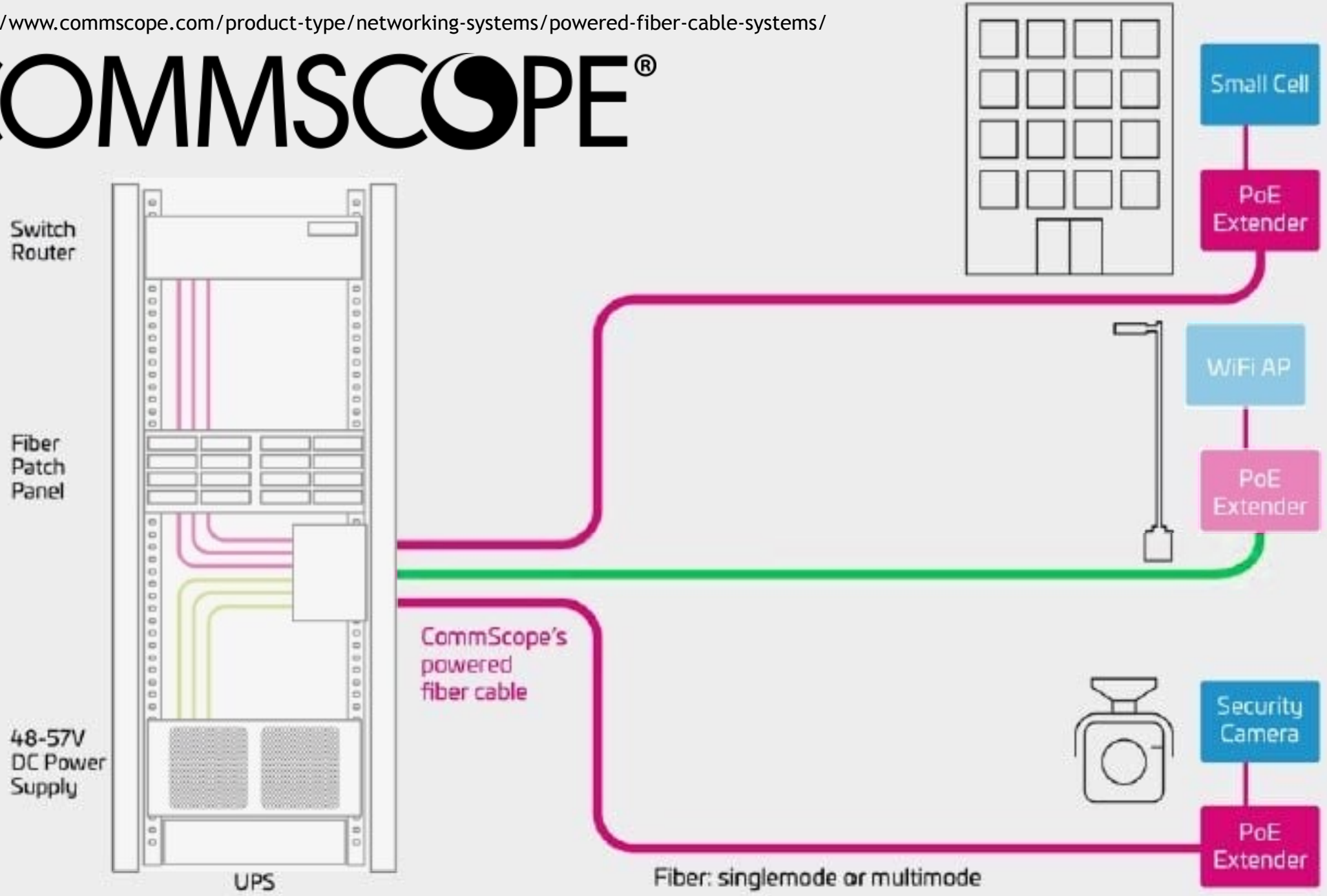
Registered Communications Distribution Designer
BICSI CERTIFIED RCDD

What if we could run the **power** as far as the **data**?

Powered Fiber

https://www.commscope.com/product-type/networking-systems/powered-fiber-cable-systems/

COMMSCOPE®



Commscope Powered Fiber Cable

2, 4, or 12 strands
SMF or MMF

Indoor/Outdoor and
Direct Burial Rated

12AWG or 16AWG
Copper Conductors

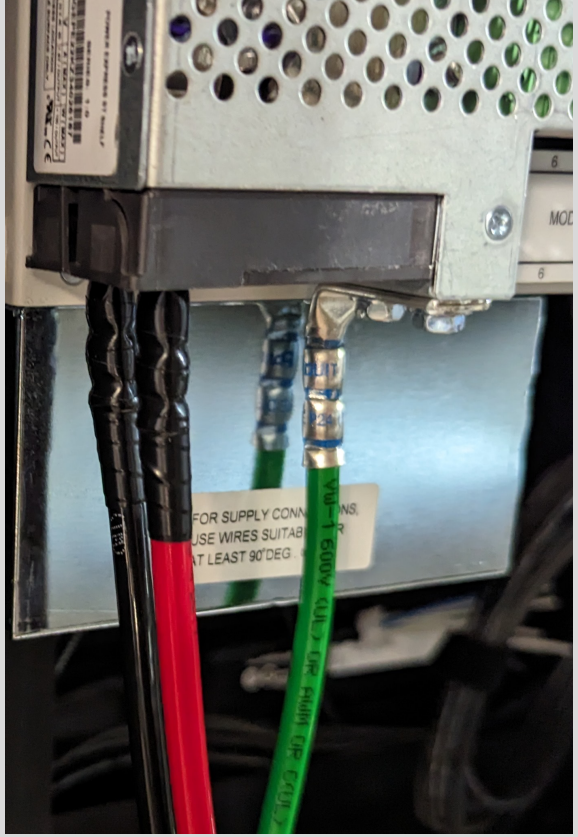
Commscope PoE Extender (Media Converter + PoE Injector)

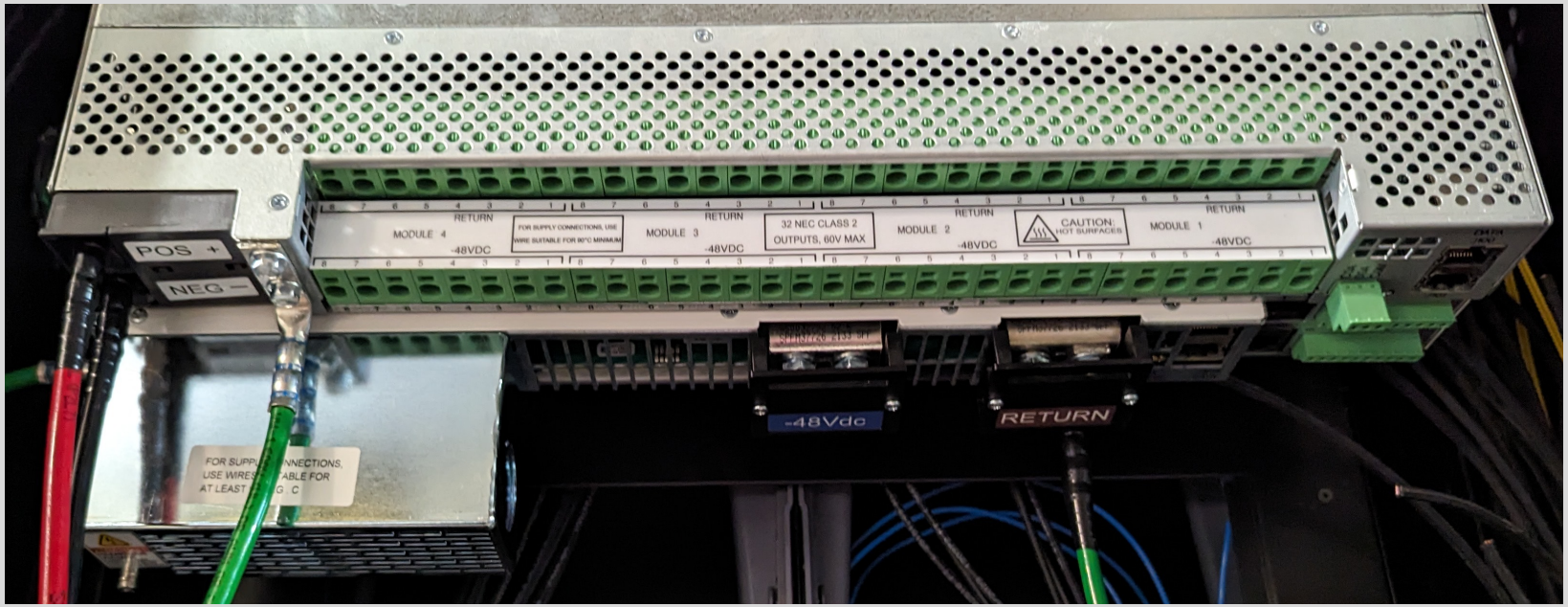
1x or 2x
1Gbps, 30W PoE
Ethernet Out
802.3af/at compliant

Powered Fiber In

IP68 Dust/Water Rated
Pole Mount in Sunlight OK
NOT Direct-Burial Rated
NOT REMOTE MONITORABLE


-52.0V-


FOR SUPPLY CONN NS,
USE WIRES SUITAB
AT LEAST 90°DEG.


POS +
NEG –
MODULE 4
RETURN
-48VDC
MODULE 3
RETURN
-48VDC
32 NEC CLASS 2
OUTPUTS, 60V MAX
MODULE 2
RETURN
-48VDC
CAUTION:
HOT SURFACES
MODULE 1
RETURN
-48VDC
-48Vdc
RETURN


POS +
NEG –
-48Vdc
RETURN
DATA
J100
J101
J2 ALARMS
J3/J4
DATA

SPS841A_0I6R_DS_DAS (1.3.1, 4.8.43, 4.8.43)

Site: GREEN-TUNNEL

Description: Steam Tunnel under the Green near the North-East hatch

	Volts	Amps	Watts
Primary Bus: (rectifiers)	-57.01 V	3.7 A	212 W
Secondary Bus: (converters)	0.0 V	0.0 A	
Input:	120 V	2.3 A	

State: FLOAT
Plant Type: -48V
Serial #:
Date: 02/14/2024
Time: 10:19PM
Highest Ambient Temp.: 47 C
Next Highest Ambient Temp.: 0
Lowest Ambient Temp.: 47 C
Number of Ambient Probes: 0

Batteries

Installed Capacity:	0 Ah
Online Capacity:	0 Ah
State of Charge:	0.0%
Total Current:	0.0 A
On Discharge:	NO
Model:	VALVE-REG
Number of Strings:	0
Reserve Time:	NO BATTERY CONFIG
Highest Temperature:	*n/a*
Lowest Temperature:	*n/a*
Number of Temperature Probes:	0
Boost State:	OFF
Number of Voltage Probes:	0

Plant

Status Legend: (on), (off), (standby), (missing), (fail)

Installed Rectifier Capacity: 44.0 A
Online Rectifier Capacity: 44.0 A
Total Rectifier Drain: 3.5 A

Alarms

Severity	Event	Date	Time
MAJ	PE Load Dropped	02/14/2024	06:41PM
-	no warnings	-	-

Show: ☑ Alarms ☑ Warnings ☐ Record Only

Distribution Current Monitor

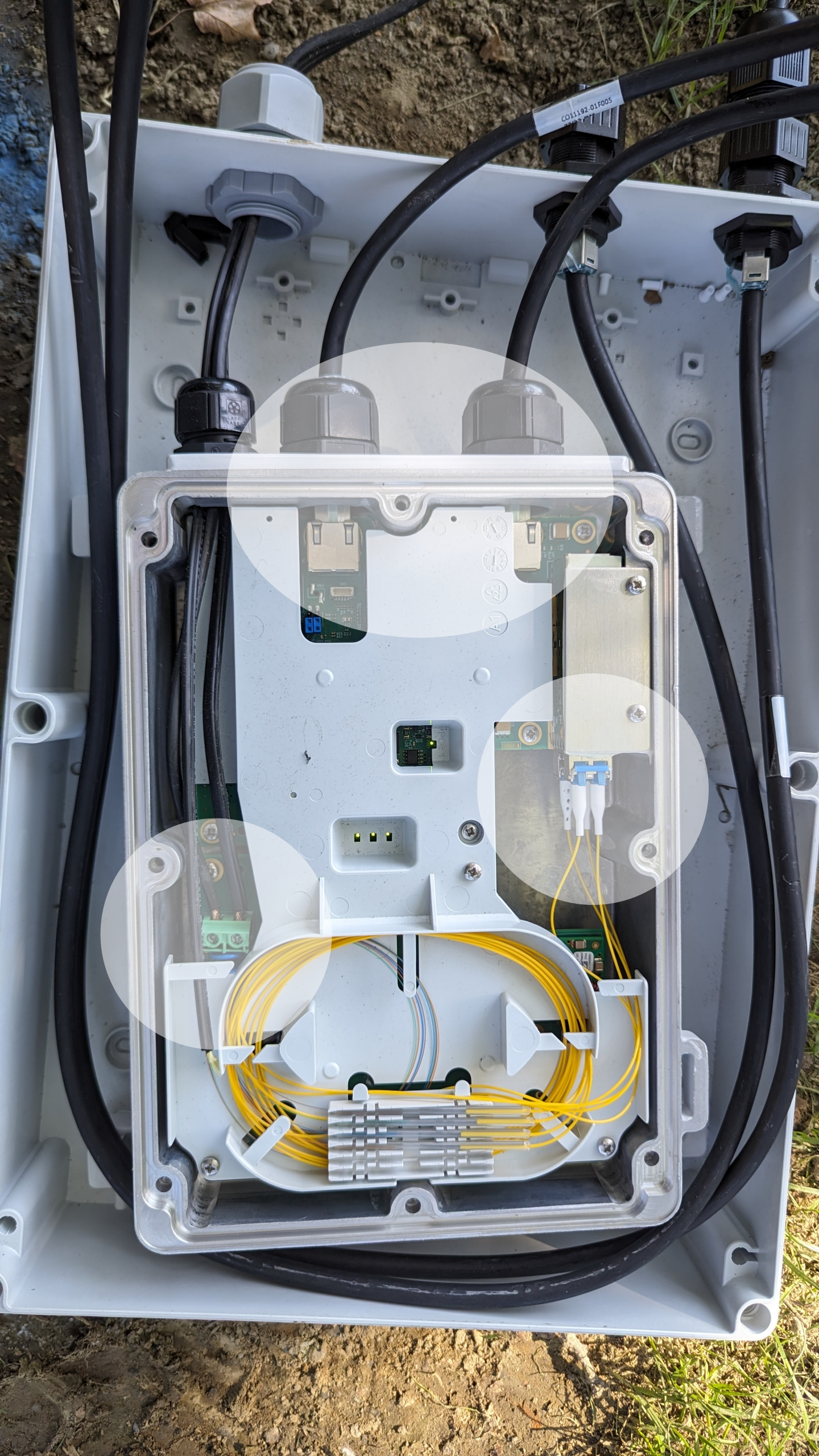
Description	Type	Current
Plant Current	BATTERY	0.0 A
Distribution Current 1	BATTERY	0.0 A

Contactor Interface

Description	Type	State
Ctlr Contactor Interface	LVBD	NONE
Contactor Interface 1	LVBD	NONE
Contactor Interface 2	LVLD1	NONE
Contactor Interface 3	LVLD2	NONE
Contactor Interface 4	LVLD3	NONE

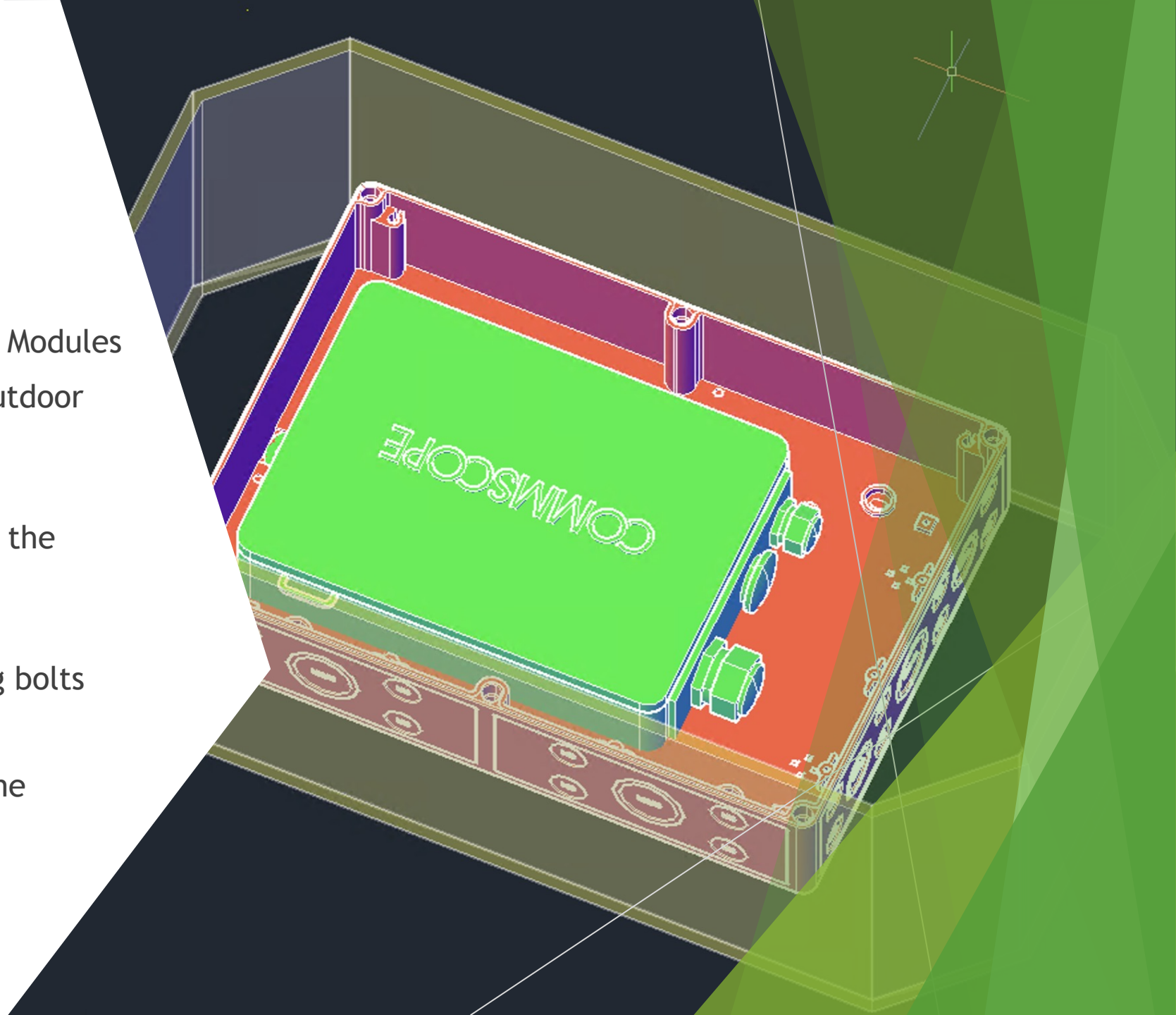

Excellence at
DARTMOUTH


COMMSCOPE®



Environmental Considerations

- Temperature-Rated (Industrial) SFP Modules
  - Converters are “exposed” to outdoor temperatures
- Drainage
  - IP68 = Waterproof only to what the manufacturer states
- Accessibility vs Security
  - Special wrench, can get locking bolts
- Traffic Resistant
- Bigger than you think, long lead time

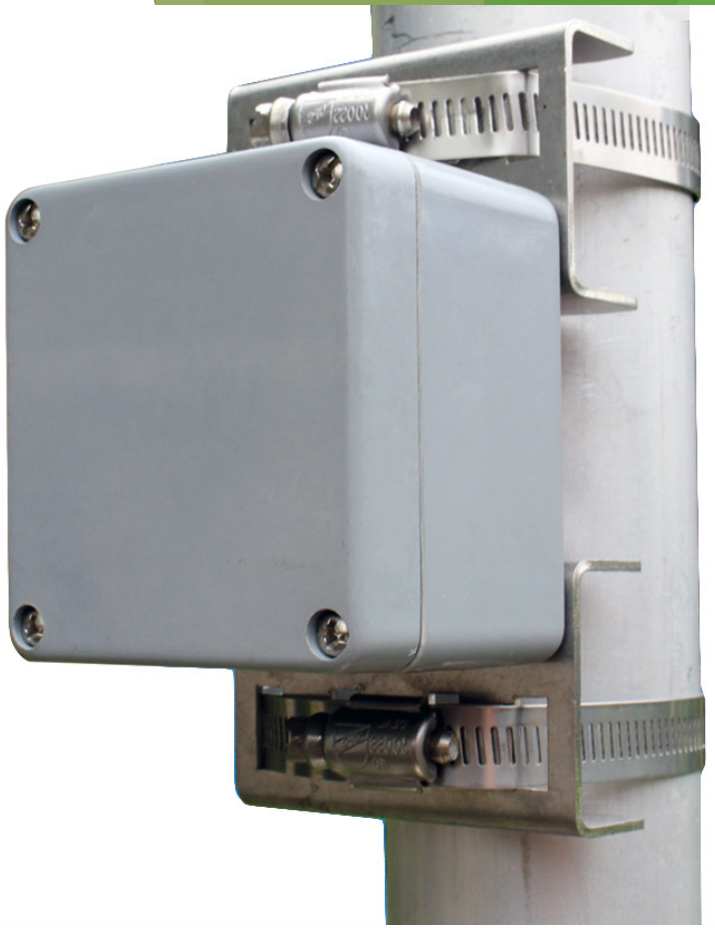


Cable from Extender to AP

- Outdoor rated
  - Waterproof
  - Sunlight/UV Resistant
  - 300V insulation or better
  - Approved by local inspector to coexist with power wiring inside the lamp post
- NO BOOTS

Pole Mount APs

- Permaband
  - Used for Traffic Signals
- Unistrut
- Pole Mount Kits
- **Duct Seal is your New Friend**



Yes, But How Long?

- My Farthest AP: 1,200ft
- PFC: 12AWG, 4 Strand SMF
- 1Gbps, Class 3 30W PoE
- **6,443.57 ft – OVER A MILE**
- **Nearly 20x Copper Ethernet**

- Class 0 PoE (15.4W)
  - **10,442.91 ft**
- Class 6 PoE (60W), or 2x 30W
  - **3,215 ft**

PFCS Calculator Ver. 6 (6-Apr-2021)

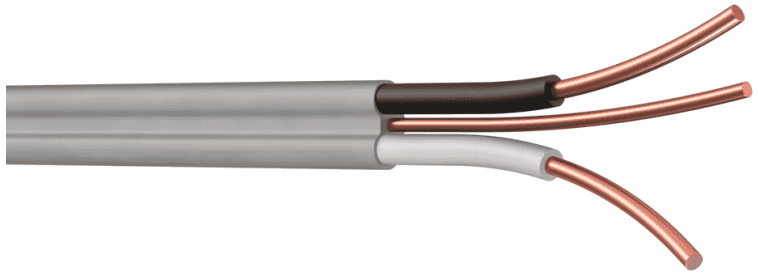
Power Supply	
Output Voltage (V)	57
Output Power (W)	100
Powered Fiber Cable	
Conductor Gauge (AWG)	12 AWG
Ambient Temp (C)	20C (Underground/Ducted)
Extender	1-port 1Gb PoE PFU-P-C-O-060-01
Cable Length Units	Meters
Powered Device #1	
PoE Device Class	Class 4
Max Input Power (W)	25.5
Min Input Voltage (V)	42.5
Max Input Voltage (V)	57
Cable Type	CS Cat6a F/UTP Outdoor Patch Cord (Recommended)
Cable Ambient Temp	20C (Underground/Ducted)
Cable Length (m)	8
Result	
Powered Fiber Cable max length (m)	1964
Additional Information	
Worst case supply output current (A)	1.1
Worst case supply output power (W)	61.6

Could you DIY?

Do it Yourself

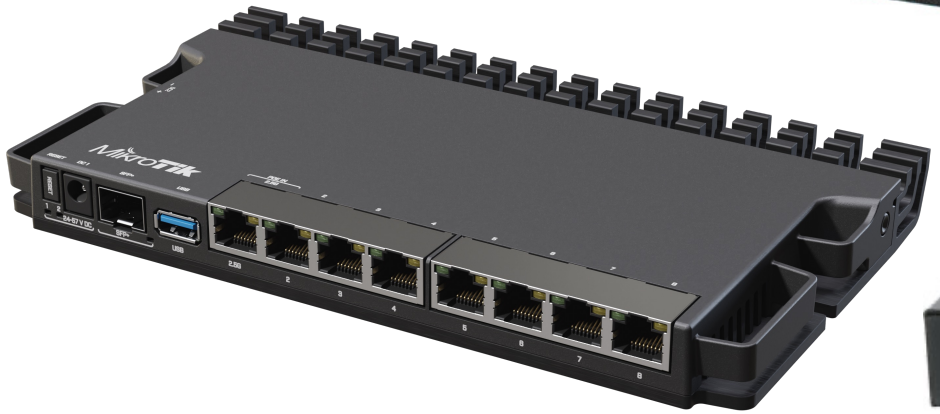
- Power Supply
  - Mean Well DHP-1U
  - Unipower Aspiro 1U M35

- Can run separate fiber optic cable and 2x 12AWG wire in conduit
  - Or run direct burial rated fiber and UF rated power cable without conduit



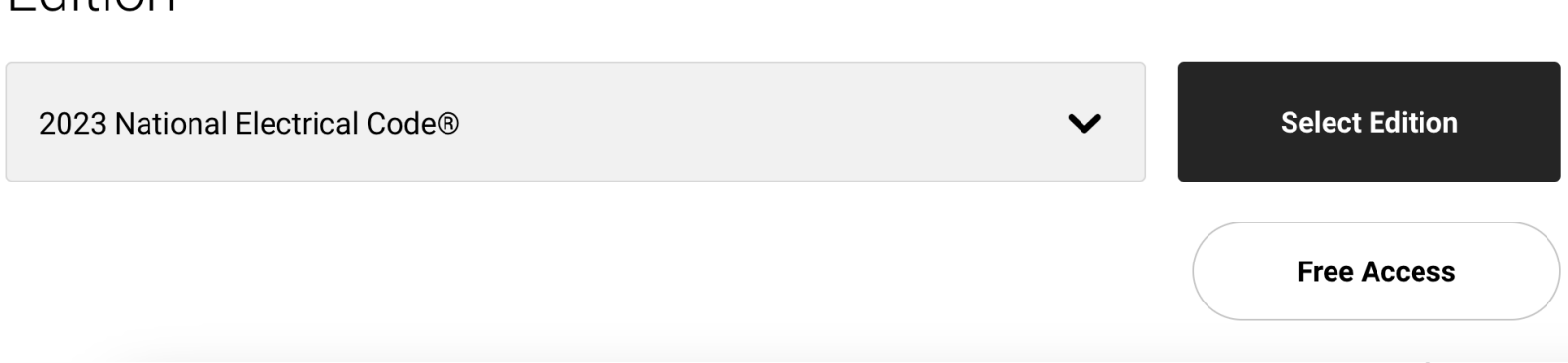
Do it Yourself

- Use any remote-side media PoE converter
  - **Lantronix SISPM1040**
  - TrendNet TI-PF11SFP
  - Mikrotik RB5009UG
  - Perle S-110HP 802.3bt 100W PoE



Free Standards!

- National Electrical Code (NFPA 70)
  - Create a free, personal account and sign in.
  - https://www.nfpa.org/codes-and-standards/7/0/nfpa-70
  - Then scroll down and click the Free Access button
- **Most local laws refer to OLDER editions of the NEC.** Make sure you are using the correct one for your area!



Free Standards!

- IEEE 802
  - 802.3, 802.11, etc.
  - Available via IEEE GET. Create a free, personal account and sign in.
  - https://ieeexplore.ieee.org/browse/standards/get-program/page/series?id=68
  - Click on the standard you want to read, then click the PDF button
  - Higher Ed? You often have access to ALL IEEE Standards thru your library! Look for the Institutional Sign In button

Free Standards?

- BICSI Telecommunications Distribution Methods Manual
  - BICSI standards are usually not required by law
  - They are industry best-practices
  - You need to pay for the document… It's worth it!
  - 15th Edition just came out. 14th edition came out in 2020.
  - You can hire a Registered Communications Distribution Designer (RCDD) who is certified in these design practices
  - Hire BICSI Certified Installers to do the installation work

Commscope Powered Fiber Cable Solution

https://www.commscope.com/product-type/networking-systems/powered-fiber-cable-systems/

Thank You!

- Thank You!