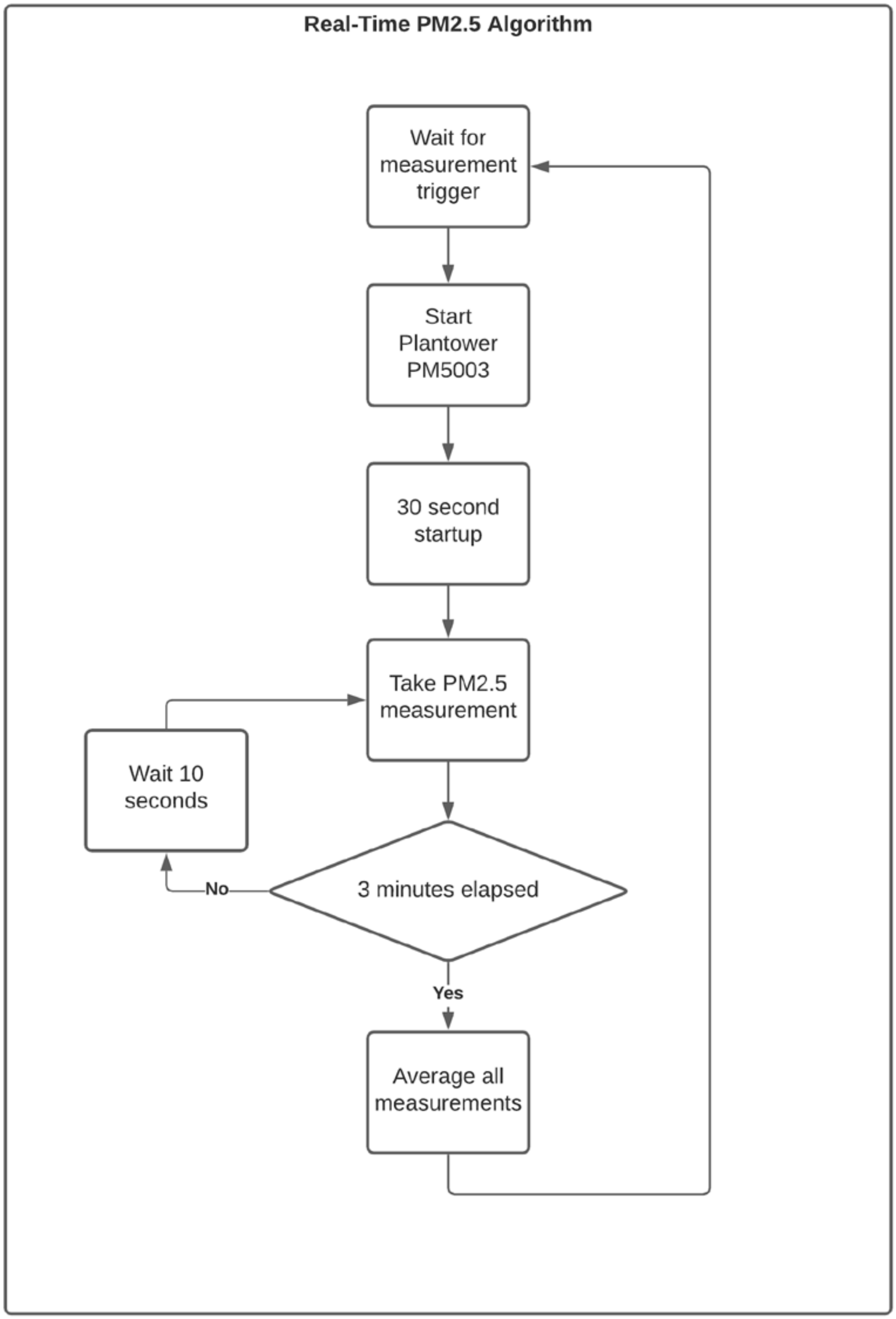

Figure S1: Overview of real-time $PM_{2.5}$ measurement protocol.

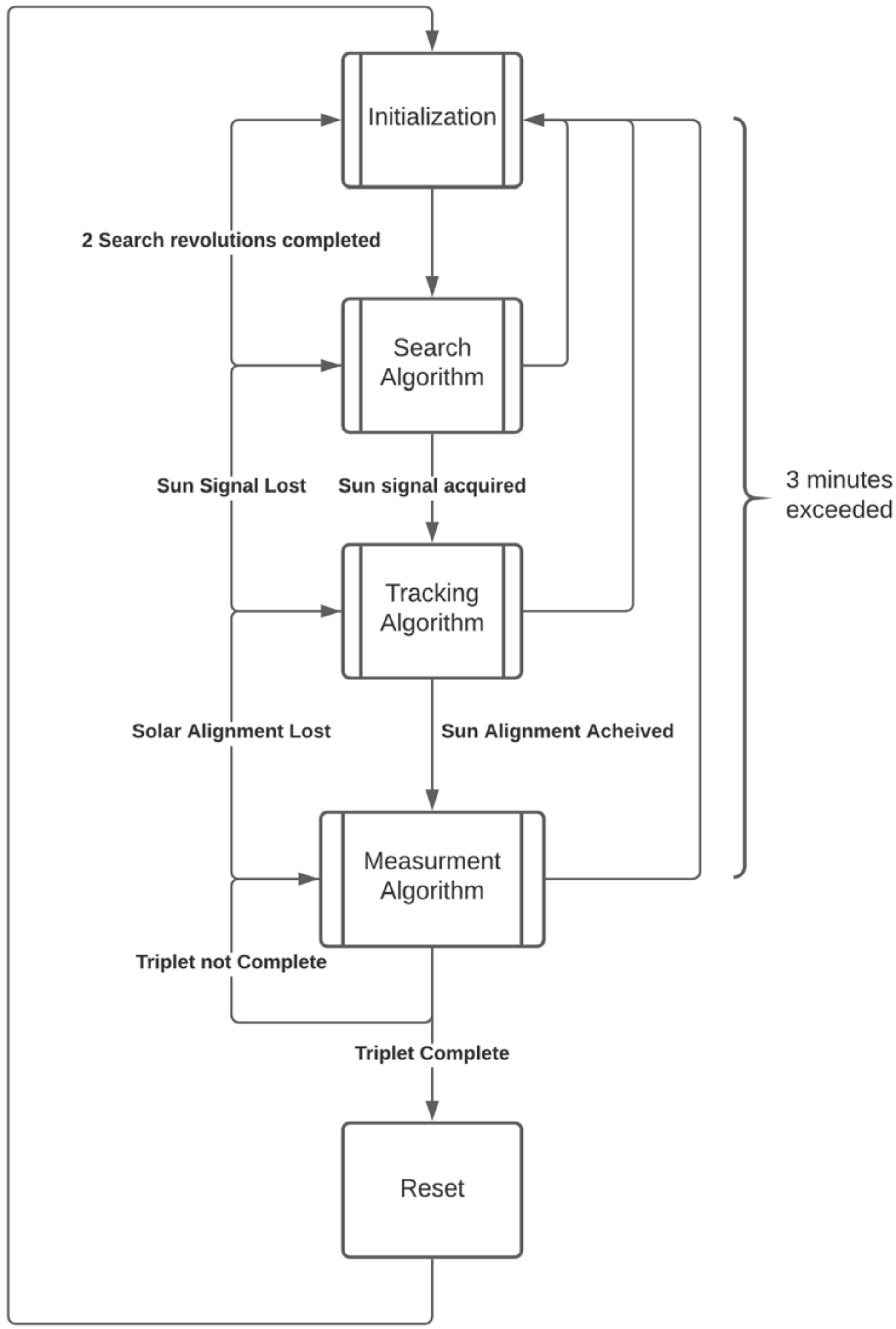

Figure S2: Overview of AOD measurement protocol. Initialization, search, tracking, and measurement algorithms are detailed in figures S2-S5.

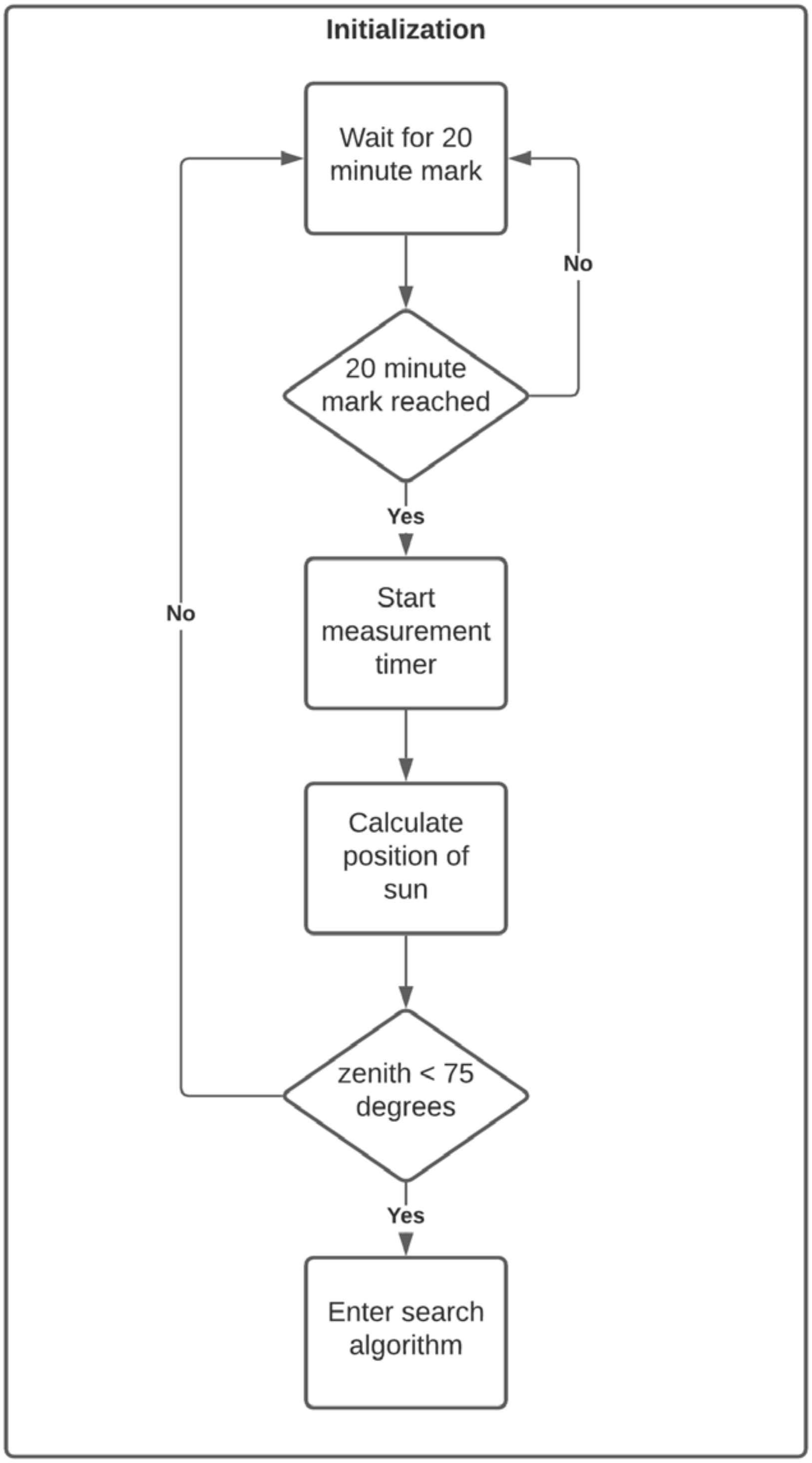

Figure S3: AOD subsystem initialization protocol.

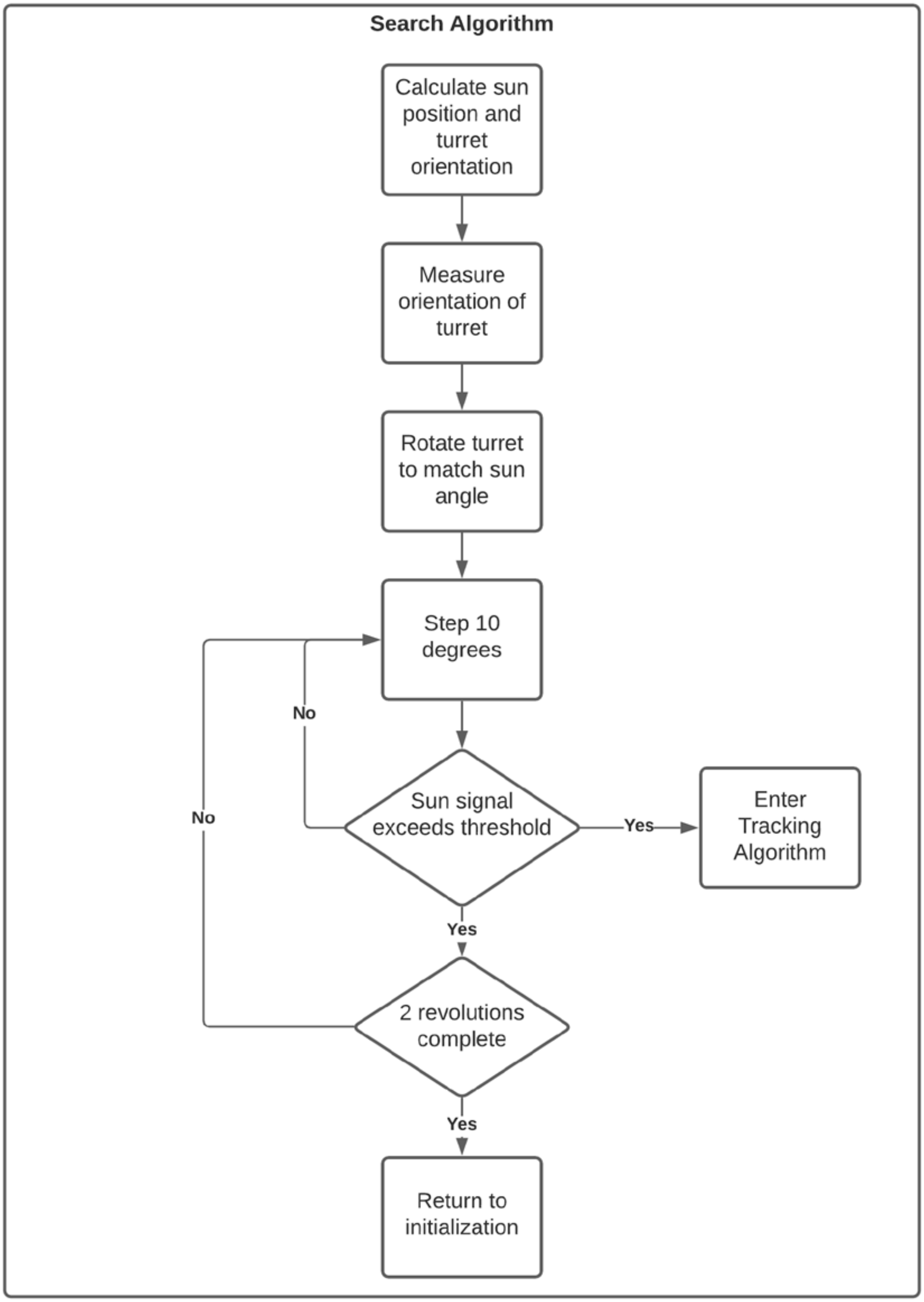

Figure S4: AOD subsystem search algorithm.

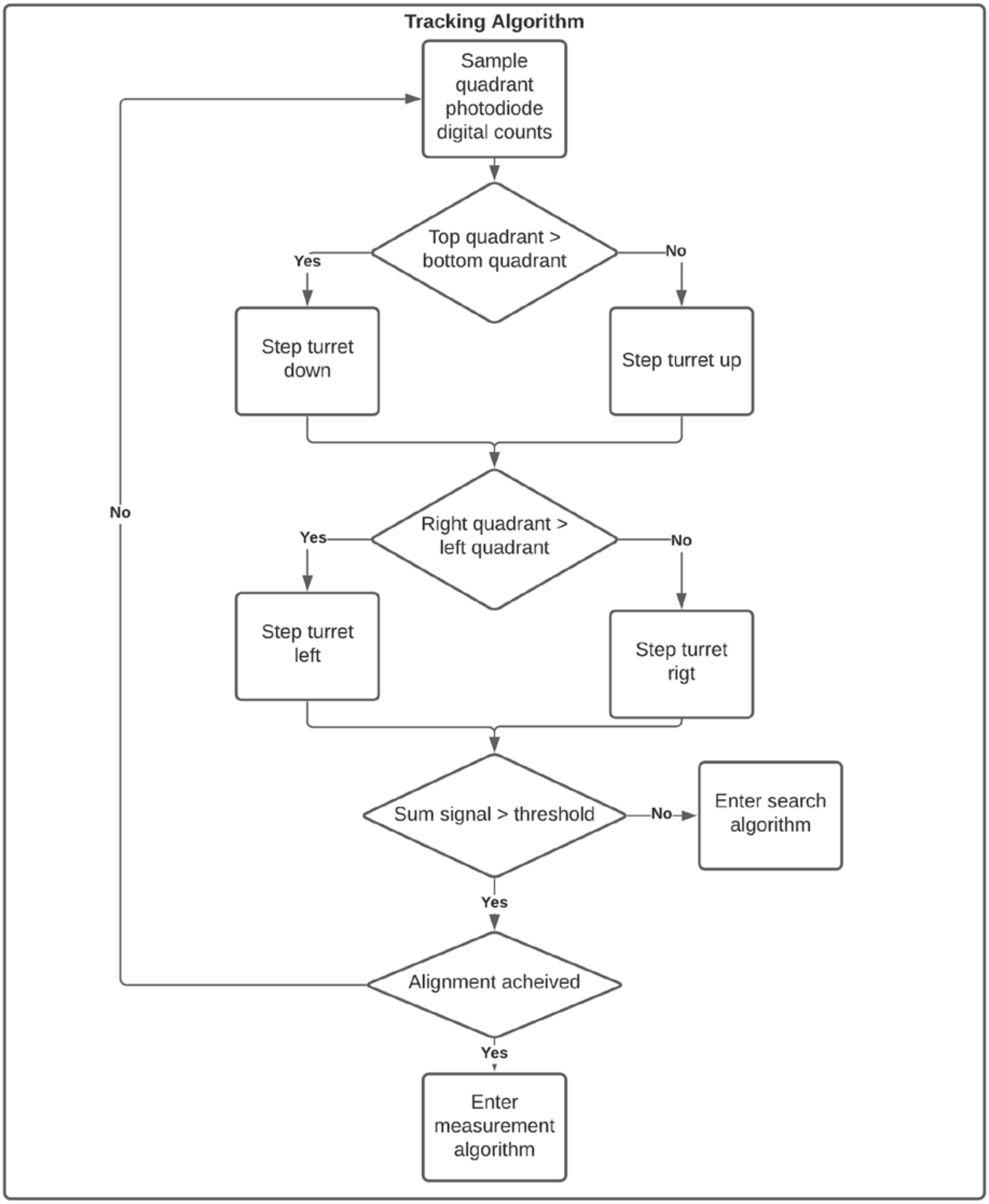

Figure S5: AOD subsystem tracking algorithm

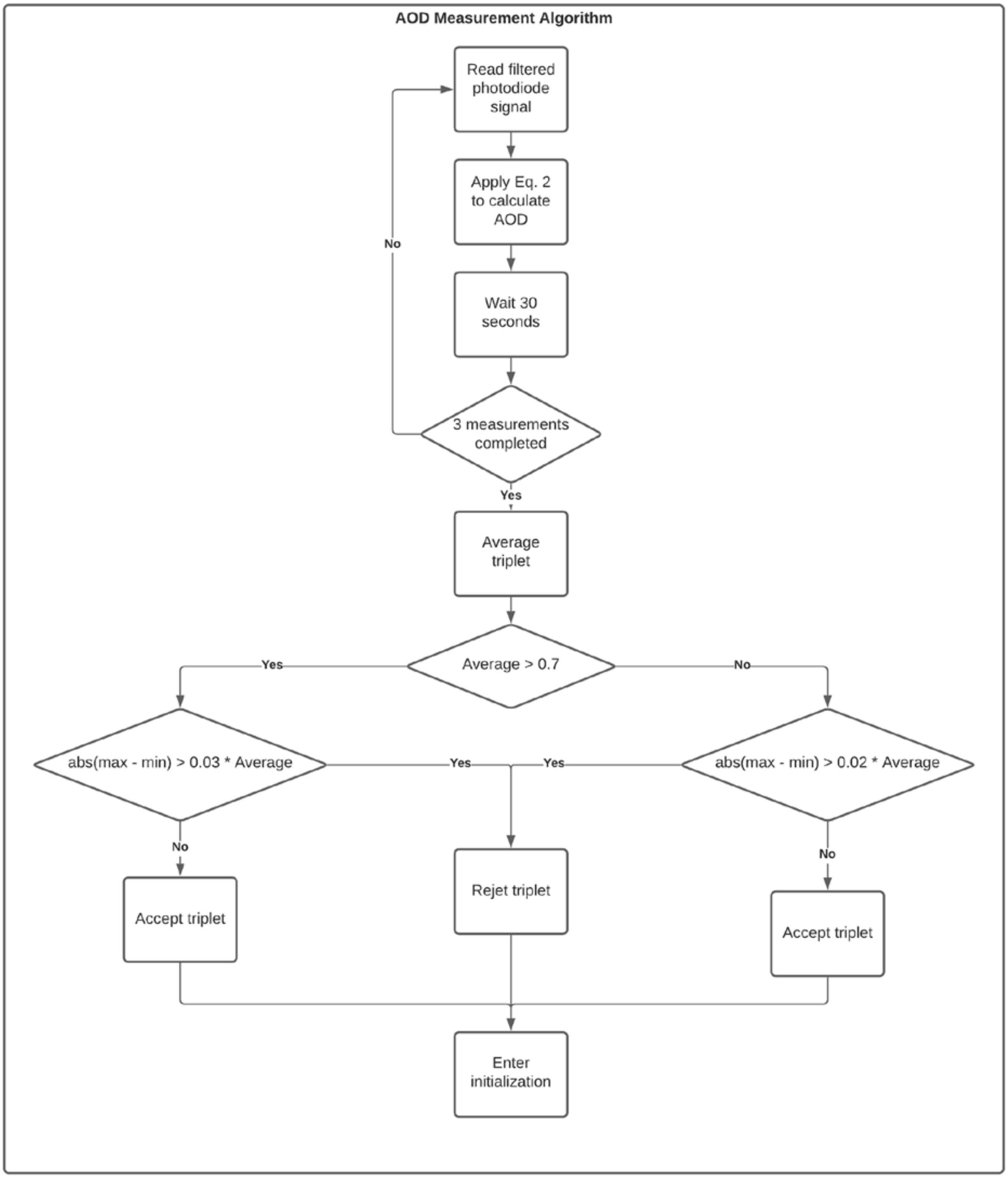

Figure S6: AOD subsystem measurement algorithm

Table S1: AMODv2 validation summary statistics calculated separately for elevated-AOD days and clear days. Elevated-AOD days were defined as days when the average AERONET AOD at 500 nm was greater than or equal to 0.15. Clear days were defined as days in which the average AOD was less than 0.15. In total, five days were identified as clear and four days were identified as elevated-AOD.

Wavelength (nm)	AERONET 500 nm AOD magnitude	Number of samples	Mean absolute error (AOD)	AOD Precision (AOD)
440	All included	426	0.04	0.02
500	All included	426	0.06	0.02
675	All included	426	0.03	0.01
870	All included	426	0.03	0.02
440	> 0.15 (elevated)	115	0.05	0.02
500	> 0.15 (elevated)	115	0.05	0.02
675	> 0.15 (elevated)	115	0.03	0.01
870	> 0.15 (elevated)	115	0.03	0.01
440	< 0.15 (clear)	311	0.04	0.02
500	< 0.15 (clear)	311	0.06	0.03
675	< 0.15 (clear)	311	0.02	0.01
870	< 0.15 (clear)	311	0.03	0.02

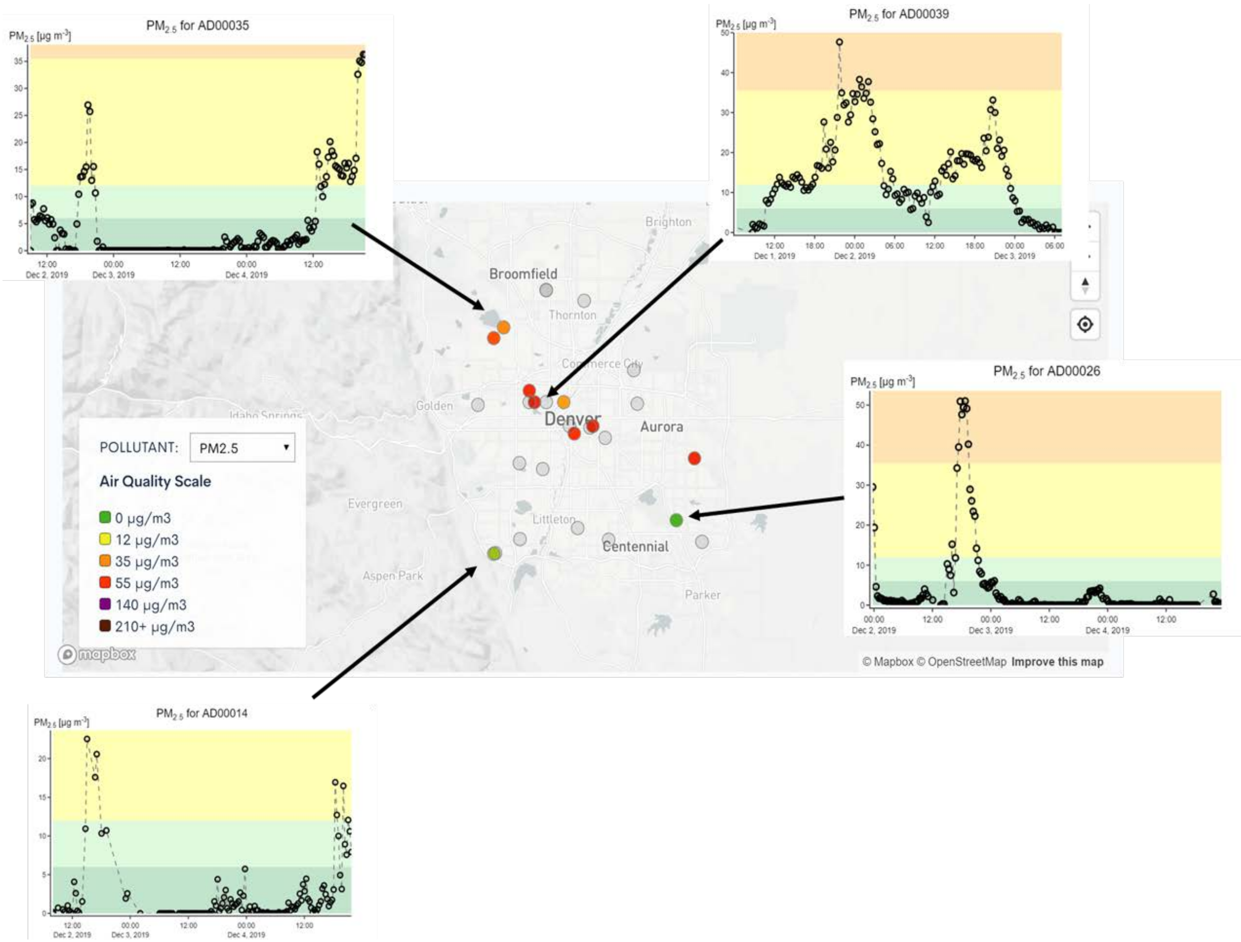

Figure S7: Example live map from project website csu-ceams.com overlaid with time series of $PM_{2.5}$ from selected units. This snapshot was taken at a time when AMODv2 units were located at different locations in Colorado for test deployments, for purposes of illustrating the web interface. Colored circles represent active AMODv2s. Grey circles represent inactive AMODv2 units. Inactive units are either charging between samples or have been sent back from the testing site. The color scale is determined by the current Air Quality Index (AQI) calculated based on the $PM_{2.5}$ measurement. The four sample $PM_{2.5}$ time series plots are linked to specific participant locations with arrows. Time series plots can be accessed by clicking on an active circle. Users may select the option to view AOD from a drop-down menu for both the map and the time series plot. Note: that this figure has been edited to show map and time series plots on the same page. On the actual website selecting a point displays only one simplified time series on the map itself. Detailed time series shown here are available on a separate page which can be accessed through selecting a unit on the map.

Here we present results from a sample deployment of 10 units. We configured the units to sample for approximately 60 hours. The 10 units were co-located and sampled simultaneously. We collected and analysed real-time PM2.5 mass concentrations, AOD, PM2.5 to AOD ratio, meteorological data, and quality control data. In Fig. S8, we provide real-time AOD at 500 nm, real-time $PM_{2.5}$, and the corresponding $PM_{2.5}$ to AOD ratios.

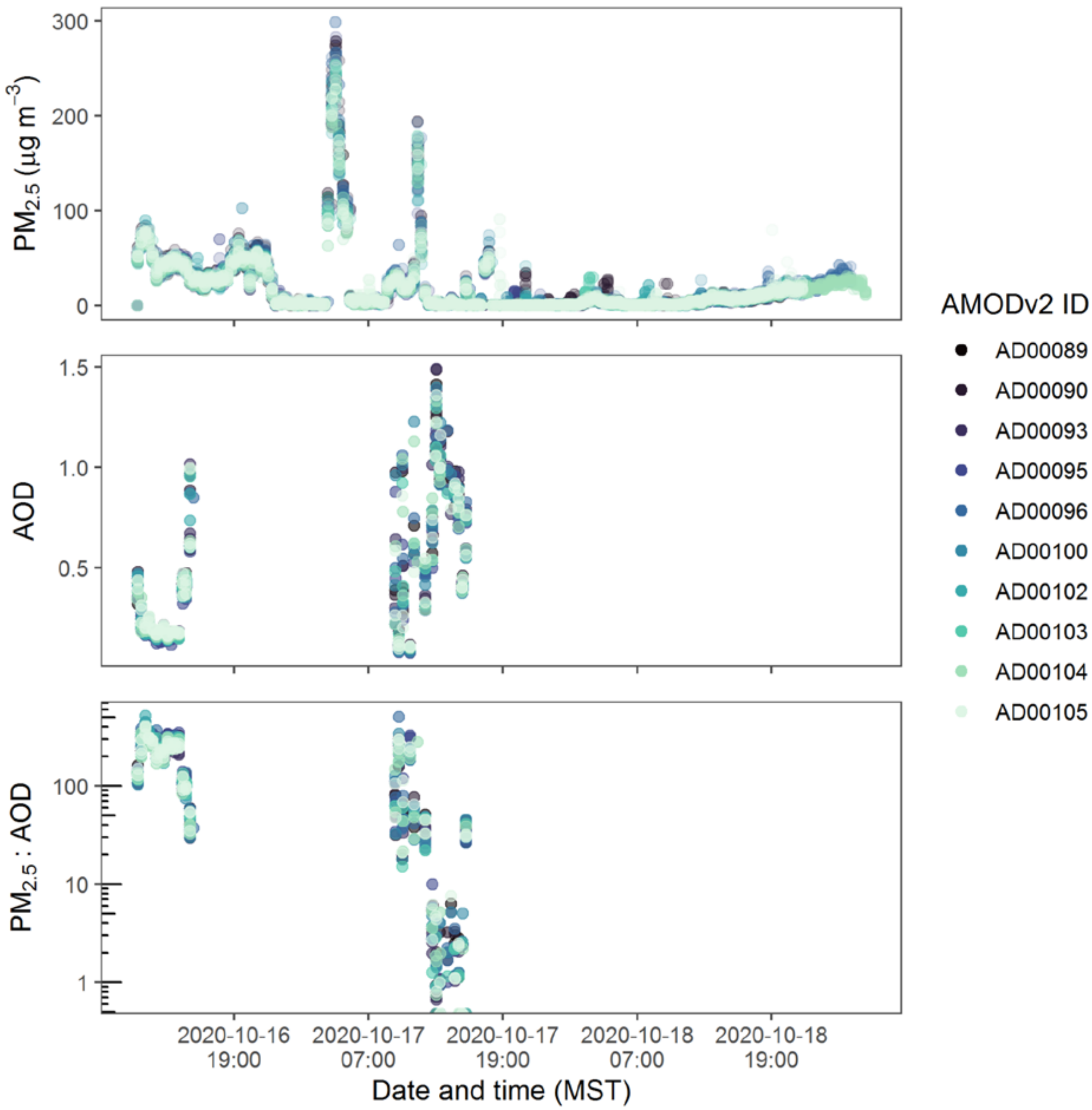

Figure S8: Time series from 10 co-located AMODv2s featuring $PM_{2.5}$ concentration, AOD at 500 nm, and $PM_{2.5}$ to AOD (at 500nm) ratio for 17-19 October 2020 in MST. $PM_{2.5}$ measurements are from the Plantower PMS5003 and are the CF = 1 values. These values have not been corrected relative to the filter mass concentrations. Points are colored according to the

AMODv2 ID. Note the vertical axis for $PM_{2.5}$:AOD is provided in a logarithmic scale to clarify lower values indicative of lofted smoke.

In Fig. S9, we provide detailed results from a single unit including 4-channel AOD, $PM_{2.5}$, and meteorological data including temperature, pressure, and relative humidity. This sample deployment highlighted several important strengths of the AMODv2 relative to AMODv1 and other prior sampling approaches. The high temporal resolution of AOD and $PM_{2.5}$ measurements facilitated a more complete understanding of the air pollution event occurring during the sample. With the AMODv2, we observed moderate air pollution at the start of the sample on the afternoon of 16 October 2020, with all units reporting consistent values for AOD (>0.30 ± 0.06) and $PM_{2.5}$ (50 ± 20.0 to 100 ± 40.0 μg m^{-3}). This was followed by increases on 17 October 2020 to severe levels (AOD up to 1.5 ± 0.06 and $PM_{2.5}$ up to 300 ± 66.2 μg m^{-3}) as wildfire smoke swept over the city in the afternoon and gradually subsided over the course of 18 October 2020. We observed reductions in $PM_{2.5}$:AOD (<10) as ground level $PM_{2.5}$ decreased to moderate and mild levels (<20 ± 2.0 μg m^{-3}), while the AOD remained elevated (>0.50 ± 0.06) due to the presence of lofted smoke. We then noted the continuation of the trend at ground level with the further reduction of ground-level $PM_{2.5}$ on 19 October 2020 (5 ± 2.0 to 15 ± 2.0 μg m^{-3}). Cloud cover prevented additional AOD measurements on 19th October, which was automatically screened for using the cloud screening algorithm. The meteorological data was also consistent with cloud cover with lower temperatures and elevated relative humidity reported on that day (Fig. S9).

Data from the sample deployment were accessed from our companion website (csu-ceams.com) in real time. With AOD, $PM_{2.5}$ and $PM_{2.5}$:AOD reported every 20 minutes throughout the sample to the website, we could assess the progress of wildfire smoke in Fort Collins remotely in real time. This was not possible with AMODv1, which lacked wireless transmission capabilities. In terms of scalability, the AMODv2 was relatively easy to deploy and maintain owing to its compact design, coupled with its automated measurement protocols. In the sample test, we were able to quickly prepare and deploy units in response to wildfire activity.

We leveraged the data accessibility features of AMODv2 for real-time quality control of incoming sample data. We monitored sample flow rate and total sampled volume to detect potential errors with the gravimetric sample collection. We monitored battery temperature to detect potential overheating of the unit, allowing proper intervention (e.g. temporarily moving the unit into shade) before the instrument reaches a shutoff threshold. We used battery voltage, battery state of charge, and current draw data to identify units unlikely to complete the intended sample duration. Current draw data was also used to identify when the tracking motors were engaged, indicating an attempted AOD measurement at the expected time. Wireless signal strength data were used to identify units with relatively poor connection and move them into areas with better signal. In the sample deployment detailed here, no interventions based on quality control data were warranted. However, in general, these data can be used to remotely identify and address malfunctioning units mid-sample. This feature represents a substantial improvement compared with AMODv1, which provided no sample quality control data in real time, requiring manual data acquisition (via micro SD card) and unit inspection following a failed sample.

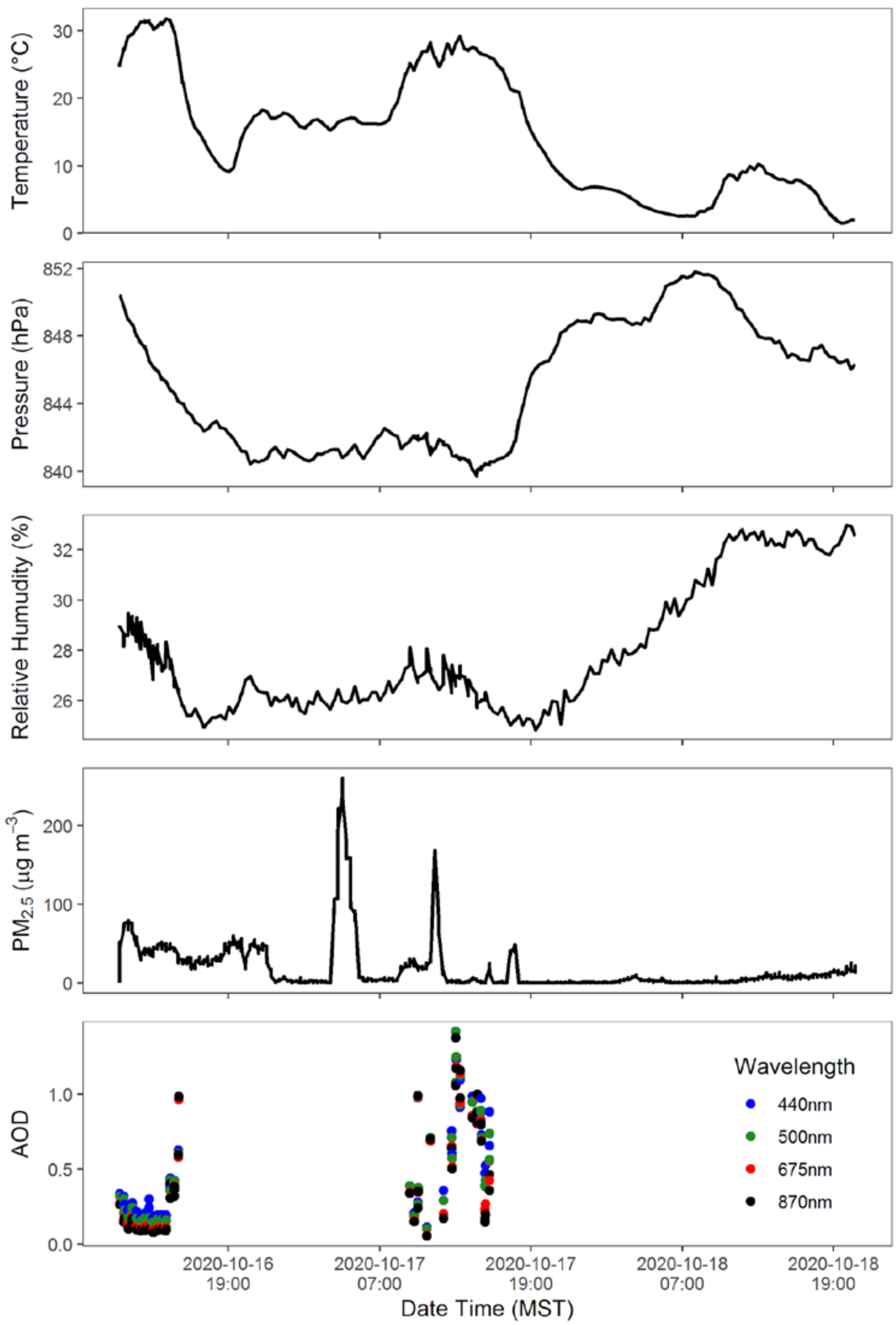

Figure S9: Sample time series from completed AMODv2 sample in MST. Temperature, pressure, relative humidity, and $PM_{2.5}$ reported at 30 second intervals are provided in the top four panels. The bottom panel gives screened AOD measurements, reported at 20 minute intervals. The presence of wildfire smoke on October 17 corresponded with increases in $PM_{2.5}$ and AOD.

Table S2: AMODv2 Cost of Goods and Assembly Summary. Costs tabulated here are for a production run of 100 units.

Component	Manufacturer	Part Number	Cost
Printed Circuit Boards	Vergent Engineering	Custom Parts	$400
440 nm Filtered Photodiode	Intor	Custom Parts	$28
520 nm Filtered Photodiode	Intor	Custom Parts	$26
680 nm Filtered Photodiode	Intor	Custom Parts	$26
870 nm Filtered Photodiode	Intor	Custom Parts	$28
Light-Scattering $PM_{2.5}$ Sensor	Plantower	PMS5003	$15
Solar Alignment Sensor	Solar MEMS	NANO-ISS5	$45
Electrical Box	Polycase	Custom Part	$55
3D Printed Fixtures	GoProto	Custom Part	$67
Cyclone and Inlet	Synergy Core	Custom Part	$74
Battery Pack	Dakota LithiumBatteries	12V 10AH LiFePO4	$63
Auxiliary Battery Pack	Battery Space	LFH4S4R1WR-C5	$68
Zenith Stepper Motor	Stepper Online	17HS10-0704S-C2	$7
Azimuth Stepper Motor	Stepper Online	17HS19-1684S-C6	$8
Misc. Housing Components	N/A	N/A	$25

Assembly Labor	N/A	N/A	$240
Total Costs			$1175