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Miniaturized Scanning Electrical Mobility Sizer (mSEMS) Instrument Handbook – Airborne Version

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Acronyms and Abbreviations

aMCPC	advanced mixing condensation particle counter
CPC	condensation particle counter
DMA	differential mobility analyzer
mSEMS	miniaturized scanning electrical mobility sizer
SMPS	scanning mobility particle sizer
UAV	unmanned aerial vehicle

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1.0 Instrument Description

The miniaturized scanning electrical mobility sizer (mSEMS), as shown in Figure 1, represents an advancement in particle size measurement technology. Designed for portability, this compact instrument is engineered to deliver precise and accurate assessments of particle size distributions. The mSEMS uses scanning electrical mobility sizing technology to analyze aerosol particles within a specified size range. Its miniaturized design does not compromise on performance, making it ideal for a myriad of applications across laboratory research, environmental monitoring, and industrial settings. The user friendly interface simplifies operation, while the instrument's robust construction ensures reliability in various conditions. Researchers and professionals can rely on the mSEMS to provide invaluable insights into aerosol dynamics, contributing to advancements in aerosol science. (McMurry 2000)

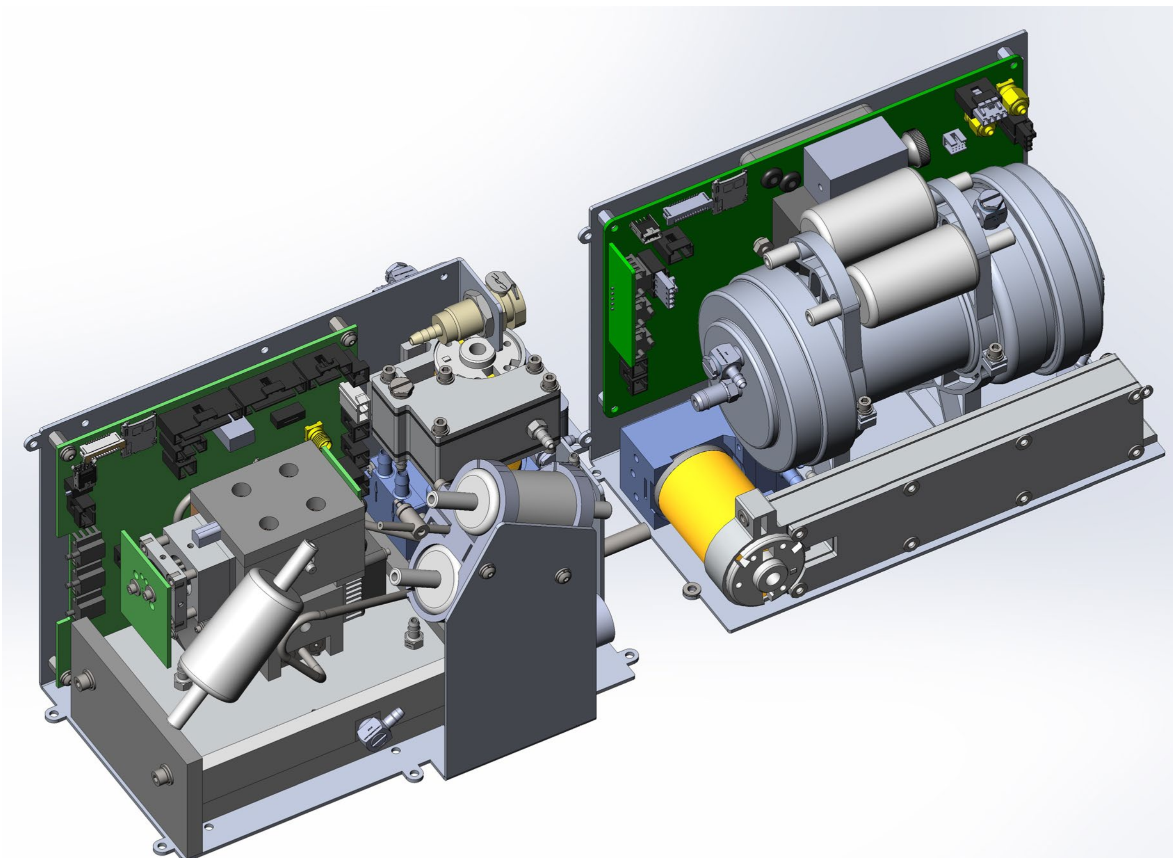

Figure 1. mSEMS instrument inline arrangement. Image from mSEMS Manual, ver. 83-00031-01.

1.1 Technical Specification

An instrument specification from the manufacturer, Brechtel, is listed as below (accessed on 2/23/2024).

Table 1. mSEMS technical specification.

Parameter	Value
Selectable particle diameter size range	5-375 nm
Size resolution (set by Qaer/Qsheath)	Variable (10:1 typical)
Scan time range	5 secs to several mins
Sheath flow range	2-3 lpm
Aerosol sample flow range	0.1-0.76 lpm
Particle concentration range with aMCPC	1- 10^7 /cc
Range of high voltage	0-3,000 Volts
Communications	RS-232
aMCPC butanol use	1.9 ml/hr
Operating temperature	-20-35°C
Operating Pressure (unpressurized cabin)	300-1,000 mb
Physical size mSEMS Sizer	18x13x10 cm
Physical size aMCPC	18x12x13 cm
Weight mSEMS Sizer	1.55 kg
Weight aMCPC	1.80 kg
Power usage mSEMS Sizer	9 Watts avg; 13 Watts peak
Power usage aMCPC	40 Watts avg; 90 Watts peak (at startup)
Voltage input range	10-14 VDC

1.2 Instrument/Measurement Theory

The mSEMS operates on the principle of using electrical mobility to measure and characterize aerosol particles. Beginning with the generation of a monodisperse aerosol through a differential mobility analyzer (DMA, right top in Figure 1), charged particles are introduced into an electric field within the mSEMS cylindrical chamber. This electric field induces characteristic velocities, known as electrical mobility, causing particles to separate based on size. The DMA systematically varies voltage, scanning through different particle sizes and measuring their corresponding electrical mobility. Subsequently, a particle counter (an advanced mixing condensation particle counter (aMCPC), left side in Figure 1) detects and counts the separated particles, enabling the construction of a detailed particle size distribution. The collected data is then analyzed to provide insights into the aerosol's concentration at various size ranges. In essence, the mSEMS excels in delivering high-resolution measurements of particle size distribution, making it a crucial instrument in fields such as atmospheric science, environmental monitoring, and nanotechnology research. (Stolzenburg and McMurry 2008, Wiedensohler 1998, Wang et al. 2002)

To control the mSEMS, you will need to use a computer running the "unmanned aerial vehicle (UAV) reader" program, as shown in Figure 2.

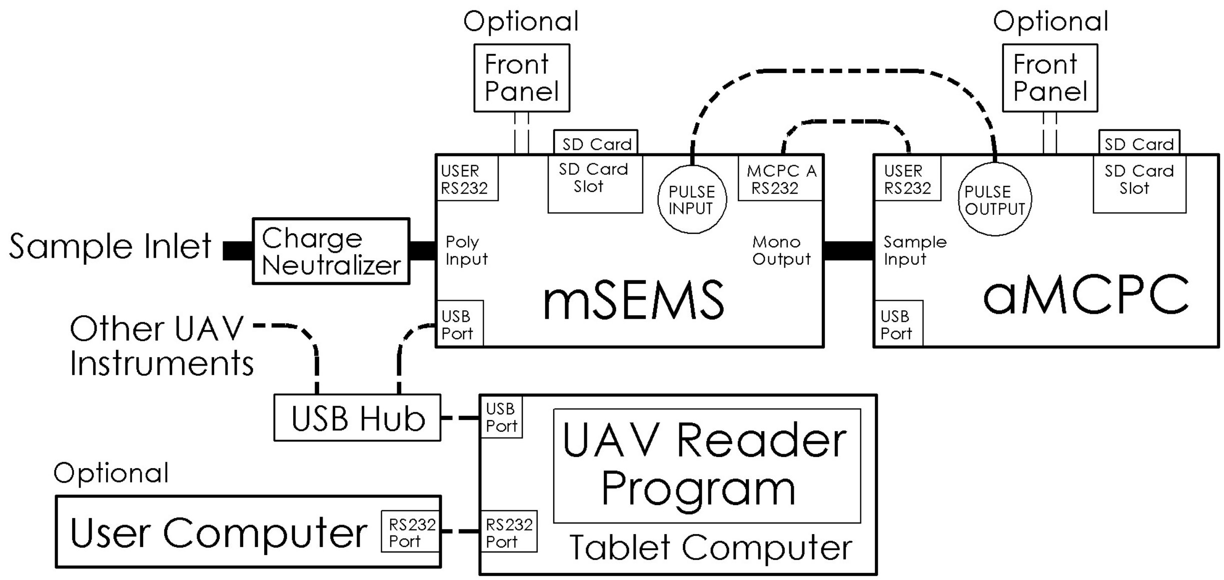

Figure 2. Schematic diagram – controlling the mSEMS with tablet computer. Image from mSEMS Manual, ver. 83-00031-01.

2.0 Data

Two data file types are generated by the mSEMS operation, a READINGS file and a SCAN results file. The READINGS file records all of the settings and readings every second. Data is written to the READINGS file while the mSEMS Mode is either "Mono" or "Scanning". Nothing is written to the READINGS file when the Mode is "Off". The SCAN results file is written at the end of each scan.

2.1 Data Description

Both data file types are generated by both the mSEMS hardware (saved on the SD memory card) and the UAV Reader Software (saved on the tablet computer). The SCAN results file contains the biggest difference between the mSEMS hardware and the UAV Reader SCAN files. The mSEMS hardware SCAN file contains only the raw scan results. The UAV Reader SCAN file has the raw scan results plus the "post-processed" final scan concentration results. The final scan concentration results are written right after the raw scan results in the UAV Reader SCAN file.

For both the mSEMS hardware and the UAV Reader data files, the file naming is done using a combination of the instrument serial number, the date, and the time as shown below:

”mSEMS ” + mSEMS serial number + + YYMMDD + + HHMMSS + ”READINGS.txt”

”mSEMS ” + mSEMS serial number + + YYMMDD + + HHMMSS + ”SCAN.txt”

e.g., ”mSEMS_106_240220_183828_SCAN.txt” and ”mSEMS_106_240220_183828_REASINGS.txt”

2.2 Data Quality and Uncertainty

The data quality of SMPS measurements is generally high due to its ability to provide high-resolution information about particle size distribution. However, like any measurement technique, various factors can contribute to uncertainties in the data. Some considerations for data quality and uncertainties in SMPS measurements include (Ku and Kulkarni 2012, Park et al. 2004):

1. Instrument calibration: Accurate calibration of the instrument is essential to ensure precise sizing and counting of particles. Maintaining stable flow rates in both the sheath and sample flows is critical for accurate measurements. We recommend calibrating the DMA flow and aMCPC flow before each field campaign, and performing a regular checking during the deployment.
2. Particle Charging Efficiency: The charging efficiency of particles in the DMA can affect the accuracy of size measurements. Variations in charging efficiency may introduce uncertainties, and efforts to control and monitor charging conditions are essential. We recommend routinely comparing the charger performance with a standard instrument to minimize the impact.
3. Particle Shape: SMPS assumes spherical particle shape for size calculations. For non-spherical particles, uncertainties may arise, and additional characterization techniques may be needed to account for irregular shapes. We will file a data quality report when we expect the spherical particle shape assumption is invalid.

3.0 Historical Background

mSEMS is a miniaturized version of the SMPS. The SMPS has evolved through the history of aerosol research, emerging from a need for more sophisticated particle-sizing techniques in the mid-20th Century. Initial investigations into airborne particles prompted the development of the DMA in the 1960s, a pivotal advancement that allowed for precise classification based on electrical mobility. Over subsequent decades, the integration of the DMA with a condensation particle counter (CPC) in a scanning mode led to the establishment of the SMPS configuration. Commercialization by companies like TSI Incorporated in the late 20th Century made SMPS systems widely available, marking a transformative period for aerosol research. Continuous advancements in instrumentation and software have solidified the SMPS as a key tool, offering high-resolution data for understanding particle size distributions in diverse applications, thus emphasizing its significant historical and contemporary contributions to aerosol science. (McMurry 2000)

4.0 Maintenance Plan

The mSEMS column can be disassembled for cleaning, as follows:

1. Unscrew the bottom cap and remove it.

2. Unscrew the top cap and remove it.
3. Lift out the upper collet.
4. Disassemble each piece for cleaning as shown in Figure 3.

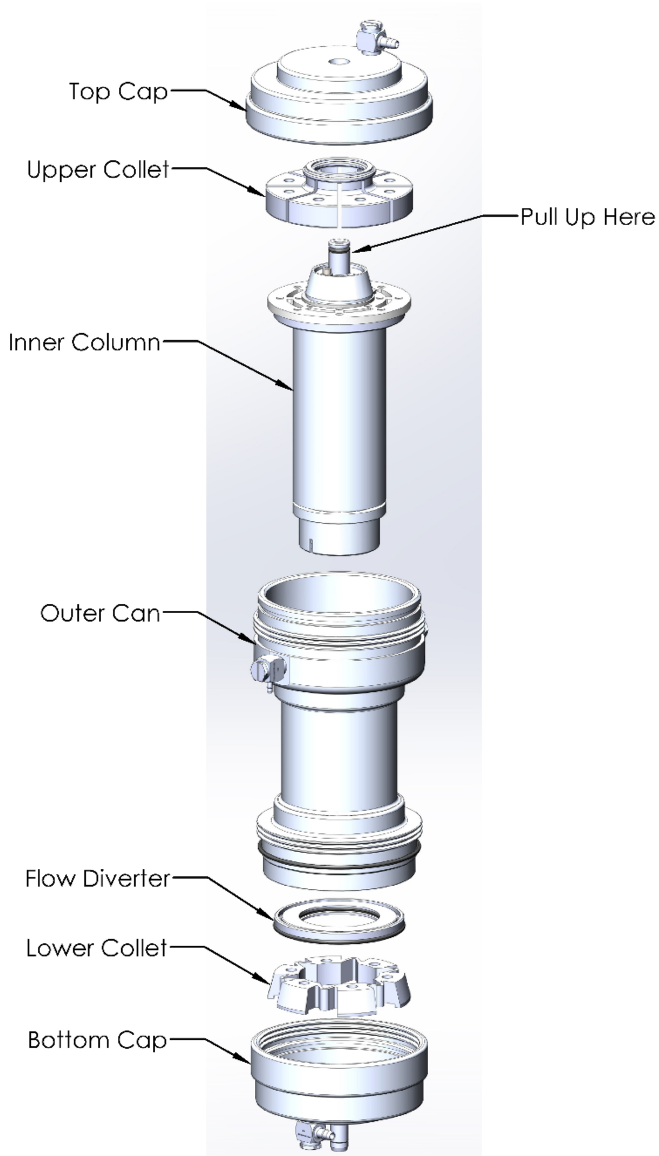

Figure 3. DMS column disassembly. Image from mSEMS Manual, ver. 83-00031-01.

5.0 User Notes and Know Issues

Data Inversion Algorithms: The process of converting raw data into a particle size distribution involves inversion algorithms. The choice and accuracy of these algorithms can influence the final results, and researchers must be mindful of their impact on data quality.

6.0 Citable References

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