2PA.1 Abstract # 265

Advance Aerosol Separator for Planetary Exploration

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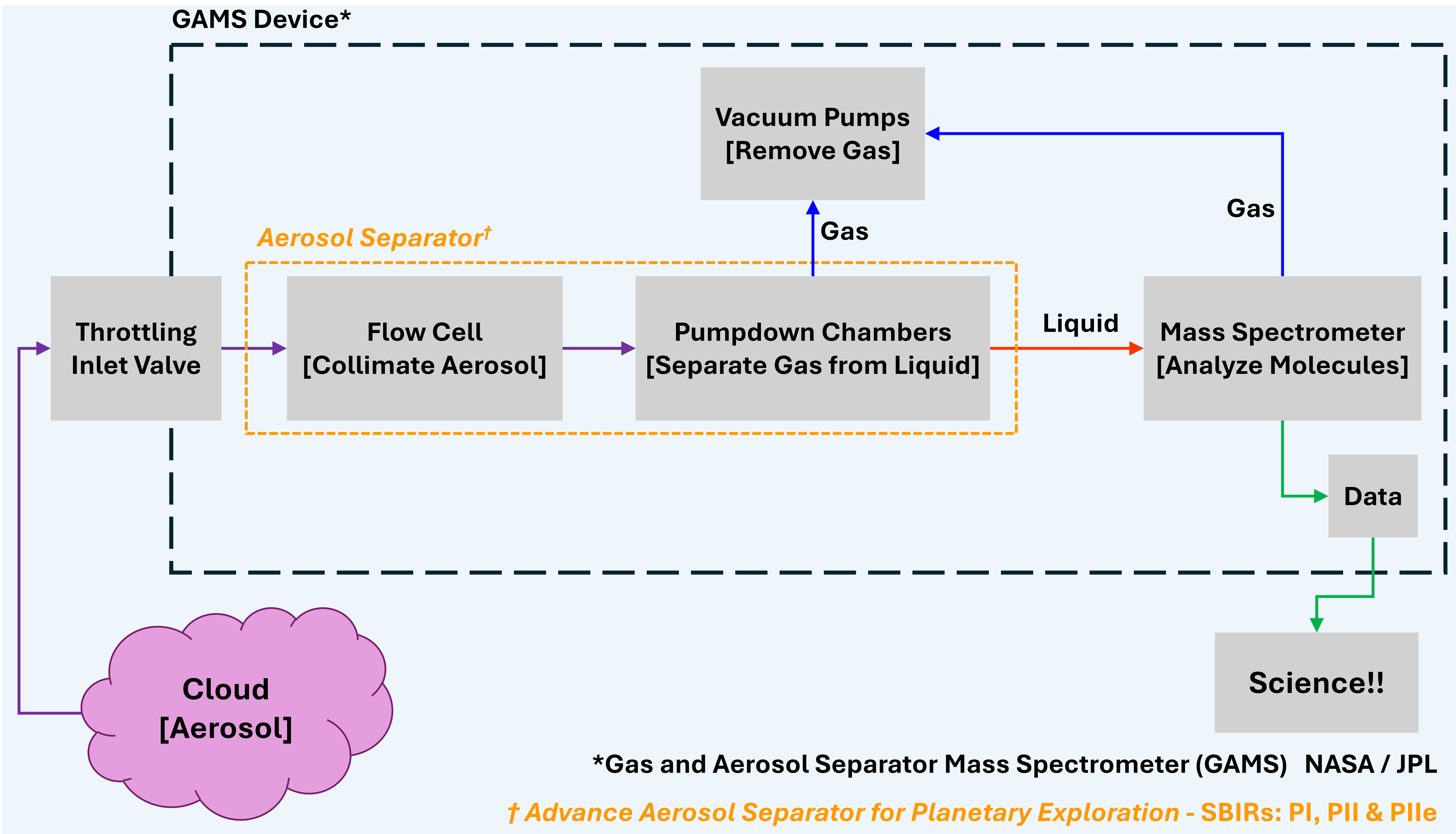
JPL approached Integrated Deposition Solutions Inc. (IDS) to provide an aerosol-separating device that could be integrated into an aerosol analyzing instrument. This device would allow the instrument to analyze a continuous flow of aerosol by removing the gas in real-time as the aerosol enters the mass spectrometer. IDS was awarded Phase 1 and Phase 2 SBIR grants to develop an aerosol separator (AS) for the Jet Propulsion Laboratory (JPL) for use with an aerosol mass spectrometer to investigate the chemistry of planetary atmospheres.

"The determination of the composition and size distribution of Venusian hazes and clouds is a prime objective of Venus exploration, as consistently promoted by the Venus Exploration and Analysis Group (VEXAG)." - Dr. Dragan Nikolic (GAMS PI)

Project Goal:

We developed a robust particle-separating apparatus that could survive launch from Earth, entry into the Venusian atmosphere, and operation with the caustic atmospheric aerosol; the device would need to continuously sample the atmosphere surrounding Venus for at least 12 months.

While initially developed as a key instrumentation component for planetary atmospheric research, many potential commercial, industrial, regulatory, and other scientific applications exist for the IDS Aerosol Separator technology.

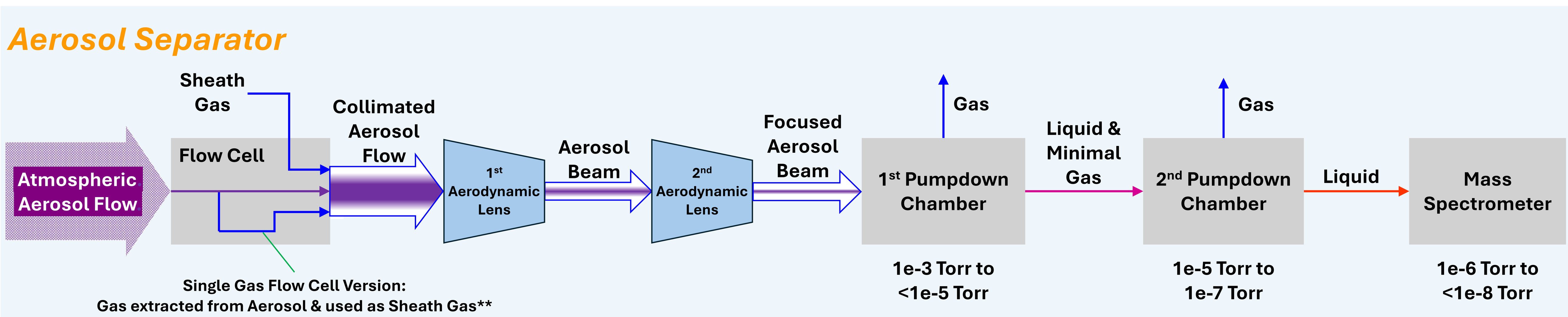


*Gas and Aerosol Separator Mass Spectrometer (GAMS) NASA / JPL

† Advance Aerosol Separator for Planetary Exploration - SBIRs: PI, PII & PIIe

Aerosol Separator Gas Removal

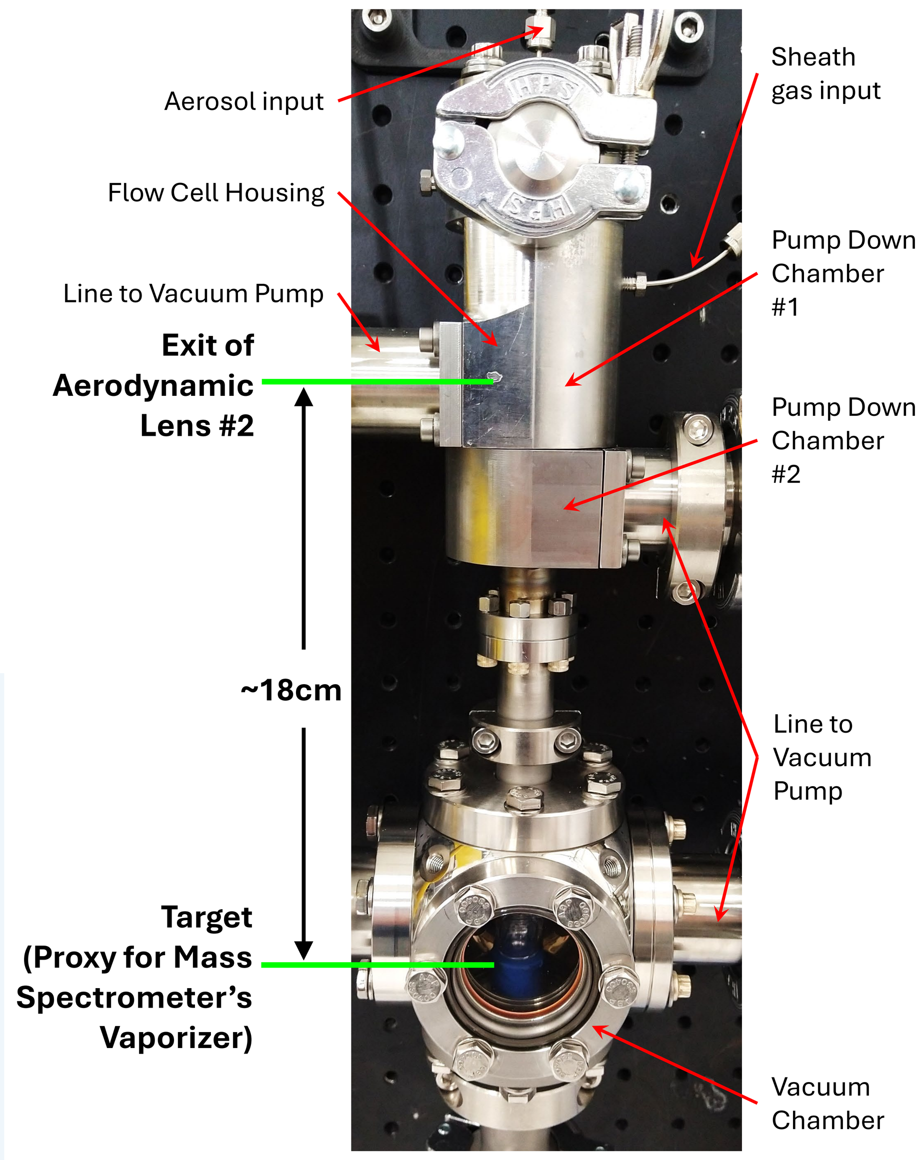
Numerous pump-down and flow tests have been performed to evaluate the pressure levels within the system using several different configurations and vacuum pumping systems. Tests have shown that the aerosol's gas constituent can be effectively removed in real time as the aerosol's liquid particles travel into the mass spectrometer's vacuum chamber for analysis. Testing also shows that the AS design can achieve downstream pressure levels that are low enough to operate a mass spectrometer properly and that provide a high-quality signal-to-noise ratio.



Single Gas Flow Cell

IDS has designed a prototype flow cell that extracts gas from the incoming aerosol flow and then uses it as a sheath gas to collimate the aerosol downstream flow. CFD analysis has shown negligible low-mass particles travel with the extracted gas and that a very high percent of the liquid particles from the incoming aerosol would be transported further into the aerosol separator. Because of this high transmission efficiency, the extracted gas is considered suitable for a sheath. Lab testing with a resin 3D printed version of the single gas prototype flow cell with aerosolized Test Ink has confirmed a well-collimated aerosol flow exits the flow cell.

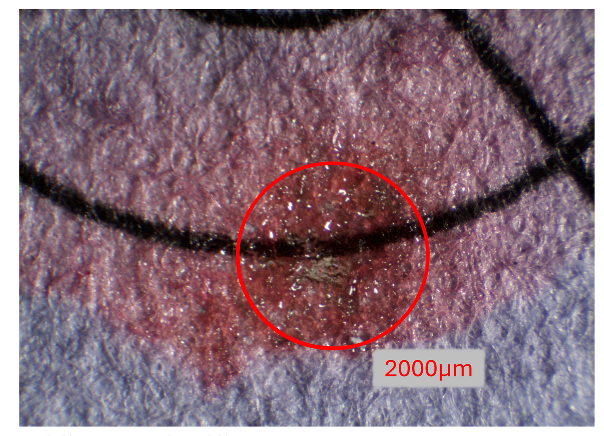
**The single gas flow cell, as depicted in the Aerosol Separator flow chart above, offers a significant advantage in space exploration. In the context of aerosol sampling, the need for a secondary clean gas supply for the sheath gas flow in the aerosol separator can add to the system payload and limit operational time. However, this prototype flow cell not only enhances the efficiency of the aerosol sampler but also presents a potential for cost savings by eliminating the need for the secondary clean gas supply.



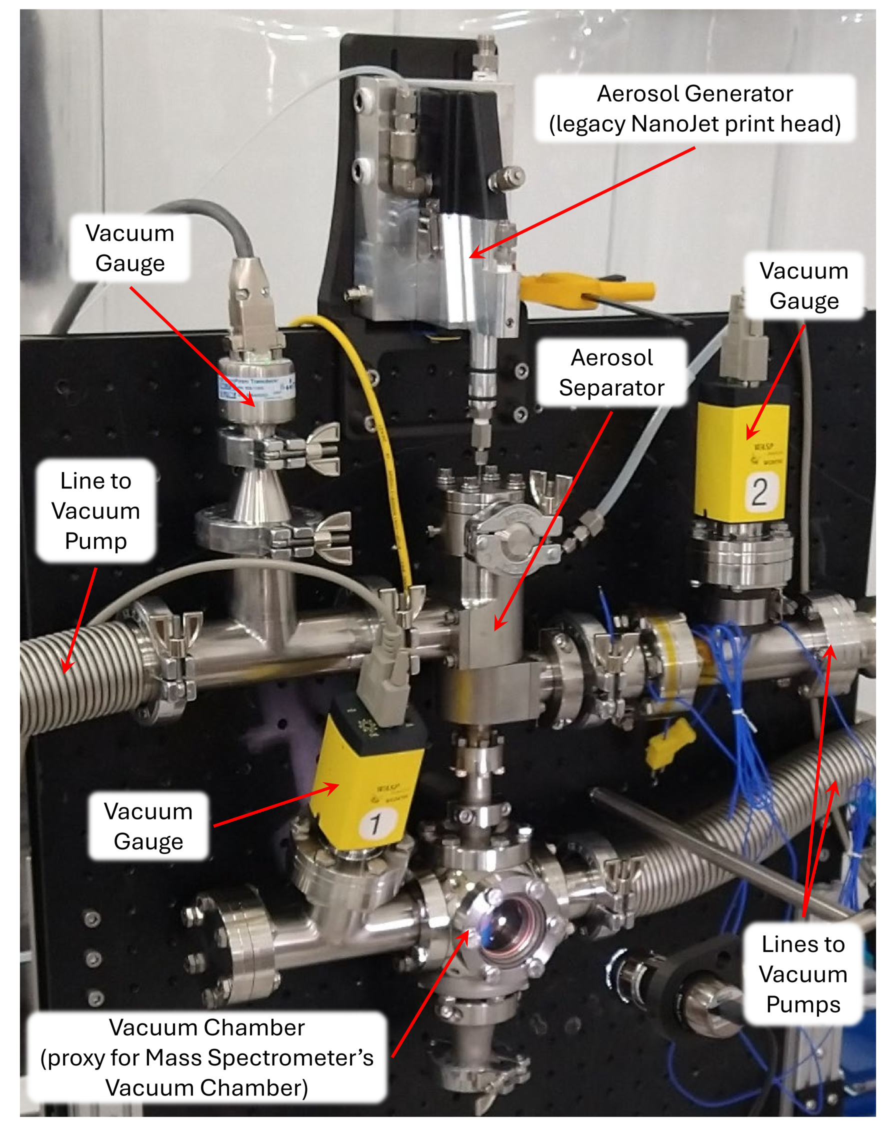
Aerosol Separator (AS) V1 Prototype

Device Overview

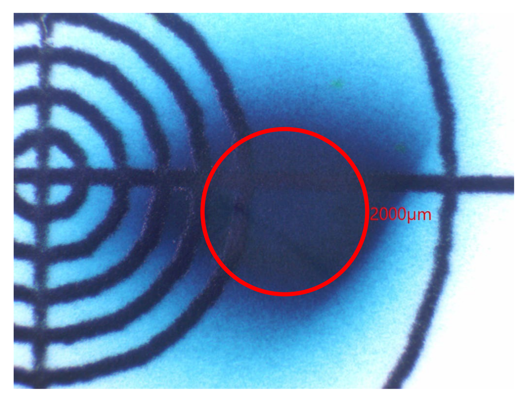
The function of this device is to separate the atmospheric aerosol's gas and liquid constituents, concentrate and collimate the extracted liquid into a narrow particle beam that can traverse several centimeters within a vacuum, and maintain a high transmission efficiency. IDS leveraged the technology within the NanoJet print head to develop a flow cell that focuses the incoming stream of highly corrosive aerosol into a particle beam approximately 2mm in diameter while removing the atmospheric gas. Test results have shown this particle beam can travel over 20cm in a high vacuum and impact a target in an adjacent vacuum chamber. The vacuum chamber adjacent to the AS on the testing setup was analogous to the mass spectrometer vaporizer chamber.



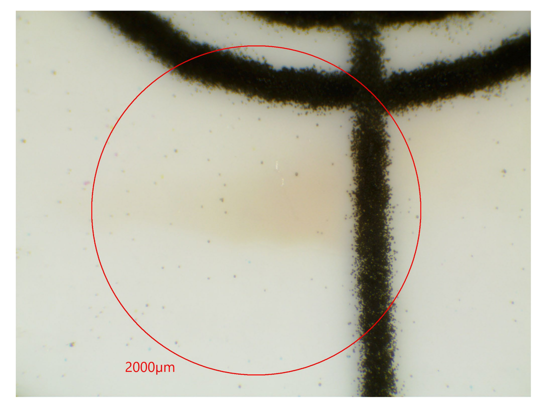
Micrograph of litmus paper target post-test with ~2mm liquid dot that has reacted with the litmus paper.



Aerosol Separator (AS) V1 Prototype Under Test



Micrograph of the deposition of aerosolized Test Ink on photo paper target after passing through the aerosol separator under vacuum.



Micrograph of the deposition of aerosolized H_2SO_4 on photo paper target after passing through the aerosol separator under vacuum.

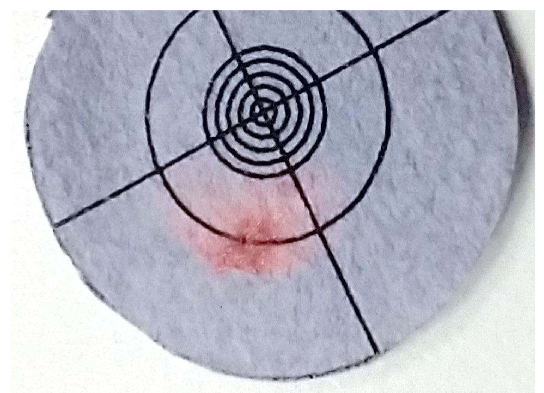


Photo of a litmus paper target post-test. The liquid deposited from the AS has changed color indicating it is acidic.

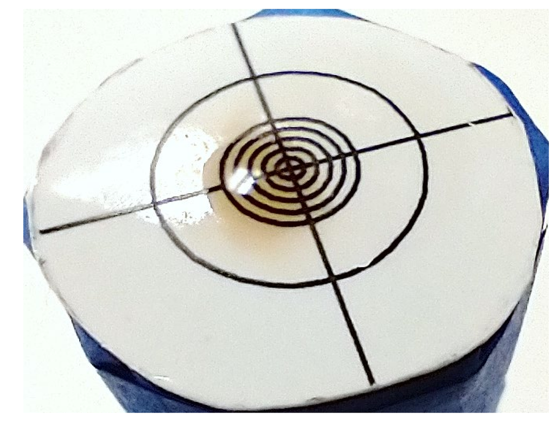


Photo of a paper target post-test. Target has liquid acid deposited from the AS.

Testing with Concentrated H_2SO_4 Aerosol

After several tests that used IDS Test Ink aerosol to analyze the AS's ability to function properly, similar testing was performed with sulfuric acid of different concentrations. Aerosolized sulfuric acid, in concentrations as high as 95% ($^{w}/_{w}$), was tested several times in the AS and it was shown to perform similar to that of the IDS Test Ink. Acid-indicating litmus paper targets were used to review the liquid spot size and shape that was deposited on the target. Acid was deposited well within the target area with a generally tight distribution. The targets were a proxy for the mass spectrometer vaporizer, and the target pattern was included to help show the size of the acidic dots, not the accuracy of deposition.

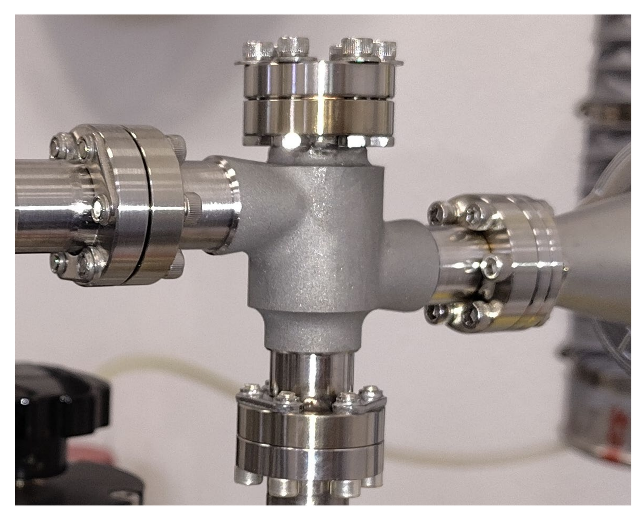
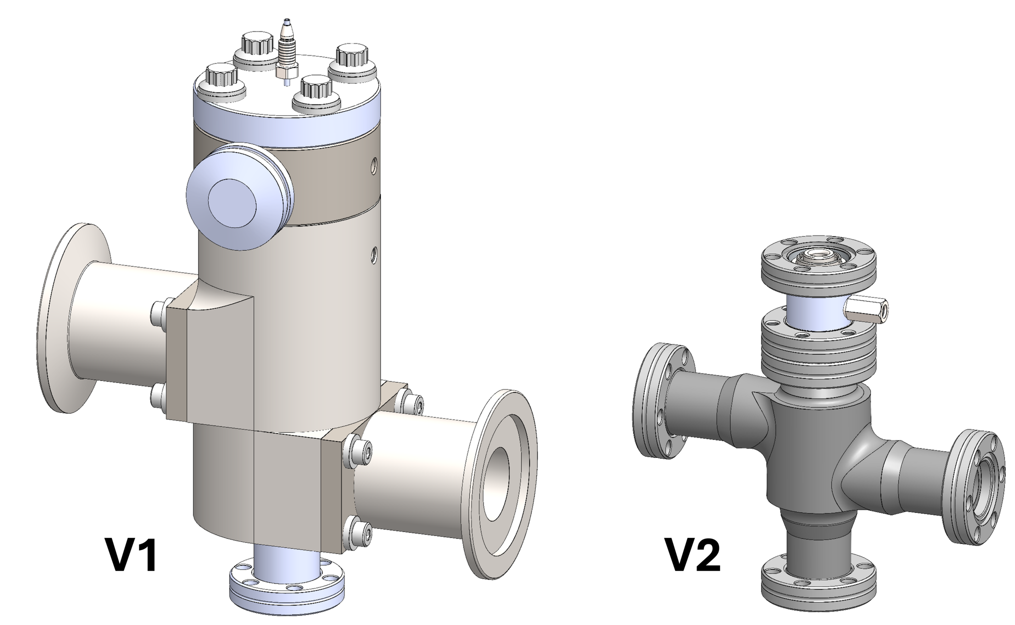


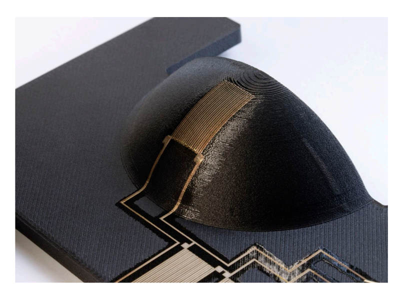
Photo of the AS V2 chamber stack (pumpdown chambers 1 & 2) under test prior to attaching the flow cell. The AS chamber stack has the inlet capped.



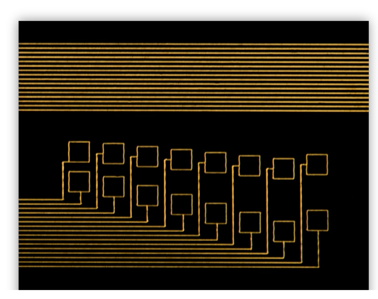
Rendering of the AS versions 1 & 2 next to each other. Both AS are drawn at the same scale to illustrate the reduction in size and mass of v2. Left AS V1 & Right AS V2

Who is IDS?

IDS, Inc. (Integrated Deposition Solutions) is the premier supplier of aerosol printing technology. IDS offers a patented direct-write technology for printed electronics, including electronic and microelectronic circuit fabrication. Applications range from flat panel display metallization to the production of high-density interconnect circuits for implantable devices. IDS was established in 2013 and has developed its technology position from original patents licensed from Sandia National Laboratories. Located in Albuquerque, New Mexico, IDS is rapidly growing in serving the microelectronics, bio-medical, and industrial segments. The IDS products, marketed as NanoJet, are ideally suited for integration with various motion platforms.

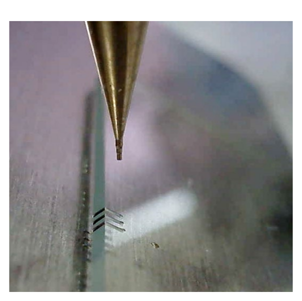


Multi-Layer Deposition on 3D Surfaces

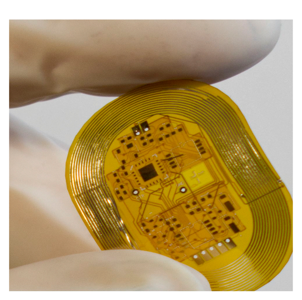


20μm Aerosol Printed Au Lines

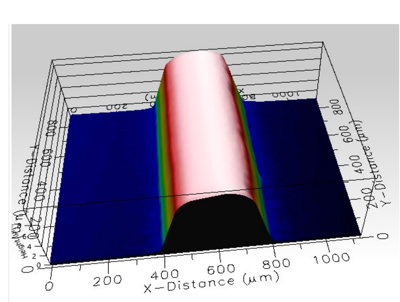
Optical Coatings



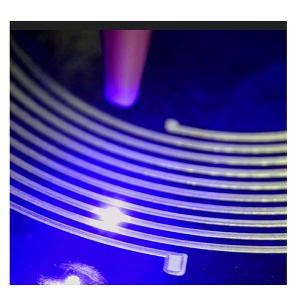
Precision Circuit Repair



Bioelectronics

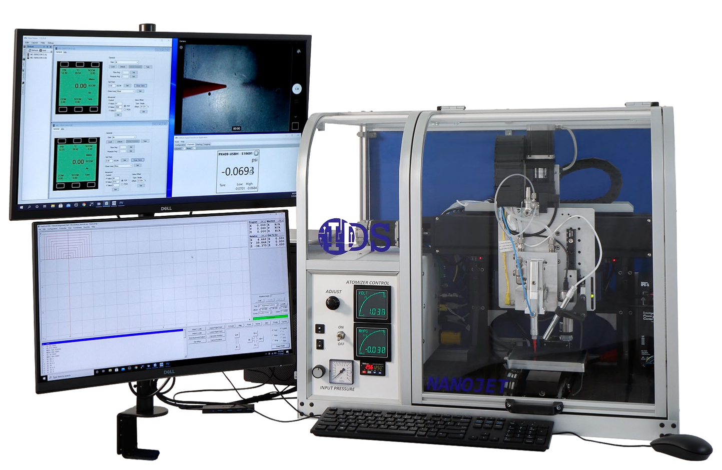


Wide-Area Deposition



Low-Temperature Substrates

NanoJet Free Standing System



NanoJet Desktop

NanoJet Gen2 Subsystems

What are NanoJet printers?

The NanoJet print technology uses multiple aerodynamic lenses to collimate a broad distribution of particle sizes to produce high-resolution printed lines. Each of the aerodynamic lenses collimates sequentially smaller particles within the jet to produce exceptional printed line edge quality. Technology licensed from Sandia National Laboratories along with other IDS patented innovations enable reliable aerosol-based printing. The NanoJet print technology is able to print features to approximately 20 μm. Printed line density with a pitch twice that of the printed line width has been demonstrated.

Revision of the Aerosol Separator Pump Down Chambers

A second version of the AS was designed to reduce the pump-down, chambers' overall size, mass, construction complexity, and number of seals while improving the component's gas extraction efficiency. The core of the new chamber stack is made from 3D-printed stainless steel. Extensive testing was performed on 3D-printed stainless steel structures to help determine optimal manufacturing and design parameters. Manufacturing the AS via 3D printing allows for rapid production, minimal complex machining, and flexible design for several critical features.

Acknowledgements

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