This thesis represents a broad study to characterize the heavy-particle structure of the exhaust plume produced from a 1.5-kW-class Hall thruster. The goal of this study was to provide an extensive data base of plasmadynamic quantities to be used as an input to plasma-surface interaction models. Additionally, conclusions drawn from analysis of these quantities yielded insight regarding basic thruster performance mechanisms.

The plume characterization study employed the use of a variety of classic plasma diagnostic techniques including Langmuir probes, retarding potential analyzers (RPAs), and Faraday probes. Novel probes were also conceived of and tested to evaluate previously un-obtained information regarding the plasma components. These techniques included the development of a neutral particle flux probe (NPF) to quantify the existence of high-energy neutral atoms and the application of a heat-flux probe technique in the determination of ion and neutral densities.

To complement the in-situ probe data, a unique molecular beam mass spectrometer (MBMS) was designed and used to provide great insight into the plasma species and energy structure of the Hall thruster plume. This system provided simultaneous mass and energy measurement through the use of an electrostatic energy analyzer in a time-of-flight mode. The MBMS data enabled
the measurement of propellant ionization states and the construction of species-dependent ion energy distribution functions useful for evaluation of basic thruster acceleration mechanisms.

Through an evaluation of the probe-based data in addition to the MBMS results a collisional analysis of the ionic portion of the plasma plume was performed. Through models and concepts developed in this thesis the products of both elastic momentum transfer and inelastic charge-exchange collisions were directly identified within the measured ion energy distributions. These results confirmed the existence of both single- and multiple-electron transfers between plume ions and parasitic neutral gas due to ground-test facility interactions in addition to momentum transfer collisions between propellant ionic species.