earlier in this proposal in order to measure the absorbtance and reflectance of the MCA materials produced during this project. Additional facilities for the measurement of longer IR wavelength emission would be helpful, if available at NASA-JSC. Potential collaboration with Marshall Flight Center has been discussed with the JCS Project Manager.

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Thrust Measurement and Plasma Detachment Characterization in a Magnetic Nozzle

UH faculty have formed a team with investigators from NASA-JSC on the Variable Specific Impulse Magnetoplasma Rocket (VASIMR) in the Advanced Space Propulsion Laboratory. The opportunity exists for a Post-Doctoral Aerospace Fellow (PDAF) to join the project. The post-doctoral fellow will be responsible for two major tasks. First, the PDAF will begin the process of making force measurements with the recently installed Marshall Space Flight Center (MSFC) momentum flux probe. In this process, efforts will characterize and understand plasma and facility effects on the momentum flux probe. Second, the fellow will be expected to take the lead in designing and conducting a series of experiments to demonstrate the occurrence of plasma detachment in the VASIMR prototype.

A fundamental problem in human and robotic planetary exploration is the intrinsic limitation of today's chemical rocket. Developing a high power electric propulsion system suitable for use as the sustainer engines for manned missions beyond Earth orbit is directly relevant to JSC's mission to enable human space flight. One candidate system, the plasma rocket, opens up new and imaginative possibilities for fast space transportation. Utilizing ionized gases accelerated by electric and magnetic fields, these devices expand the performance envelope of rocket propulsion far beyond the limits of the chemical rocket. With a properly shaped magnetic duct, the internal energy of plasma could be extracted in the form of rocket thrust. The duct becomes a magnetic nozzle, the magnetic equivalent of a conventional nozzle.

At present, the VX-10 experimental device at the NASA Johnson Space Center in Houston is exploring the physics and engineering of the VASIMR. The VASIMR consists of three main sections: a helicon plasma source, a radio frequency (RF) power booster, and a magnetic nozzle. One key aspect of this concept is its electrode-less design, which makes it suitable for high power density and long component life by reducing plasma erosion and other materials complications. The magnetic field ties the three stages together and, through the magnet assemblies, transmits the exhaust reaction forces that ultimately propel the ship.

In many respects, the magnetic nozzle is the most controversial and speculative aspect of the VASIMR concept. If one considers only first order plasma physics, one naively expects the plasma produced in a magnetic bottle configuration to remain in a magnetic flux tube attached to the rocket, thus producing no thrust. In fact, detailed consideration of the expected plasma dynamics indicates that one should expect the exhaust plasma to detach from the engine magnetic field and become a true exhaust plume when one reaches an axial distance where the plasma pressure exceeds the effective pressure of the magnetic field. The principal goal of this project is to demonstrate that plasma detachment is occurring in the VASIMR engine.

The next two years will provide an ideal opportunity to show that plasma detachment occurs. Three recent or planned improvements to the laboratory version of the VASIMR engine will facilitate this research. First, the power level in the system is being increased from the present 10 kW to 50 kW. This increase will be completed by the end of the summer of 2004. Second, a powered axial translation stage for diagnostic instruments has been built and installed in the large exhaust chamber. This translation stage will enable VASIMR experimenters to scan along the axis of the exhaust plume with a variety of diagnostic instruments designed to measure the properties of the exhaust plasma. The first instrument intended for use on this translation stage is a momentum flux probe developed by Dr. Greg Chavers of the NASA Marshall Space Flight Center. Third, a substantial increase in the pumping capacity of the exhaust chamber is being designed. At present, the build-up of neutral backpressure owing to recombination of the exhaust plume outrunning the capacity of the available vacuum pumps limits the ability of the system to simulate plasma detachment meaningfully. The increased pumping capacity will significantly reduce this problem.

The VASIMIR project will entail two complementary sets of activities. First, the existing set of diagnostics that are or can be installed on the translation stage in the exhaust bell will be operated during all appropriate VASIMR runs to investigate the plasma dynamics of the extended exhaust plume. These diagnostics include a momentum flux probe, plasma probes, and gridded energy analyzers, also known as retarding potential analyzers (RPAs). There is considerable controversy regarding the validity of momentum flux probe data in electric propulsion applications. Careful and detailed study of the validity of the data is central to the success of the project. Much attention will be paid to identifying and characterizing plasma and facility effects on the momentum flux probe. These instruments will allow us to determine if the exhaust plume is expanding entirely along the lines of the vacuum field or if, as expected, it is pulling the field out into an extended configuration. The most critical data will be the radial profiles of plasma density and directed ion energy as a function of axial distance. This activity will dominate the first year of research with routine operations continuing throughout the fellowship.

Second, additional instruments will be procured or developed for use on the translation stage. (UH and other VASIMR collaborators have already been awarded funding for this purpose.) These additional instruments include dc magnetometers for mapping the magnetic field configuration to look for evidence of stretching and induction magnetometers (B-dot) probes to look for evidence of reconnection. Further, an additional transverse degree of freedom will be added to the translation stage to facilitate taking radial profiles. This horizontal profile bar will be developed so as to mount multiple probes, including Langmuir probes to determine electron temperature and assess energy balance, a steerable collimated RPA, neutral pressure gauges, and induction magnetometer (B-dot) probes to look for impulsive, time varying reconnection. All magnetic probes are meant for dynamic measurements of reconnecting structures. At this point, we cannot say if the detachment will occur as a single coherent "blob" or rather as a collection of scattered, smaller "islands." Design, procurement, and fabrication will take place during the first year, with detailed exhaust studies commencing as the new instruments come on line. Major study with the new instruments is expected during the second year of the project.

Post-Doctoral Fellow's Role

All of the instruments mentioned above are in plan or on order. Some have been procured by out-of-town collaborators or "belong" to students not yet able to spend full-time at ASPL. The most important of these is the MSFC momentum flux probe. The critical functions that the post-doc will fulfill include operating and validating the momentum flux probe and making sure that none of the instruments from our external collaborators become "orphans." They also include design and construction of the horizontal profile bar and welding all of the available downstream diagnostics together into a coherent, focused investigation of detachment.

NASA-JSC Resources

The post-doctoral fellow will have access to the VX-50 prototype, associated diagnostic equipment, the new axial diagnostic translation stage, the MSFC momentum flux probe, UH and UT diagnostic probes installed on the VX-50, digital data acquisition system and the rest of the panoply of associated hardware as needed.

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