A Summary of the NASA Fusion Propulsion Workshop 2000

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A NASA Fusion Propulsion Workshop was held on Nov 8 and 9, 2000 at Marshall Space Flight Center (MSFC) in Huntsville, Alabama. A total of forty three papers were presented at the Workshop orally or by posters, covering a broad spectrum of issues related to applying fusion to propulsion. The Workshop was opened by Dr. Row Rogacki, Director of the Space Transportation Directorate at MSFC, and Garry Lyles, Manager of the NASA Advanced Space Transportation Program. The need to take into account the practical constraints on the propulsion system mass and the R&D cost is emphasized by Garry Lyles at the outset. The status of fusion research was reported at the Workshop showing the outstanding scientific research that has been accomplished worldwide in the fusion energy research program. The international fusion research community has demonstrated the scientific principles of fusion creating plasmas with conditions for fusion burn with a gain of order unity: 0.25 in Princeton TFTR (1994), 0.65 in the Joint European Torus (1996), and a Q-equivalent of 1.25 in Japan's JT-60 (1998). This research has developed an impressive range of physics and technological capabilities that may be applied effectively to the research of possibly new, propulsion-oriented fusion schemes. The pertinent physics capabilities include the plasma computational tools, the experimental plasma facilities, the diagnostics techniques, and the theoretical understanding. The enabling technologies include the various plasma heating, acceleration and the pulsed power technologies. This circumstance makes it compelling for NASA to take a serious look at the subject – how a research program may be pursued to realize the potential of fusion for propulsion? Mission studies presented at the Workshop make it clear that for the serious exploration and development of space, even for the inner solar system, propulsion systems with the simultaneous attainment of high specific impulse (> 10,000 seconds), high vehicle specific power (> 10 kW/kg) and high jet power (> 10's MW) are required. Significant increase in system safety and reliability is also required or highly desirable. These improvements over current chemical propulsion systems and future fission propelled systems are needed in order to drastically reduce the mission time and cost for piloted travel to the outer planets. Theoretical studies and concepts presented at the Workshop indicate that fusion propulsion has the potential of delivering the necessary propulsion performance. Fusion produces a high-temperature plasma, ideal for producing thrust directly, without the need for an intermediate mass-intensive step of producing electricity and applying the electricity in turn in a plasma or ion thruster to create thrust. The high temperature fusion plasma is highly conductive, and can be used to create thrust directly by pushing against a magnetic field. Being electrodeless and involving no moving parts, fusion propulsion systems potential enjoy a high degree of engineering simplicity and thus reliability. Substantial R&D is required, however, to substantiate these claims. It was pointed out at the Workshop that, although there is considerable overlap in the underlying science and technology in the research and development of fusion for propulsion and for terrestrial electrical power generation, there are fundamental technical and programmatic differences in the two applications as follows: In propulsion, the primary concern is harnessing the fusion energy to produce thrust versus producing electricity. The fusion process can be operated in an open cycle for propulsion versus close cycle for terrestrial power generation. Mass per unit jet power is the concept and design driver in propulsion, whereas cost per unit electrical energy is the concept and design driver in the terrestrial application. The convenient availability of vacuum in space encourages fusion concepts that can take advantage of its easy availability, whereas vacuum is a design and conceptual burden in terrestrial application. If fusion propulsion were available now, it would meet the immediate needs for several applications in space, whereas the time table for the use of the terrestrial fusion power depends on competing terrestrial energy technologies and environmental consideration. For these reasons, fusion approaches which are attractive for propulsion may not be necessarily attractive for terrestrial power generation and vice versa, though the plasma science and technologies that underpin both applications would enjoy much overlay and synergism. There is a need thus to pursue research to address the scientific and technological issues of using fusion reactions for propulsion, in parallel to and independent from the research that addresses the application for terrestrial power generation. A total of seventeen fusion concepts were discussed for potential application to propulsion. Out of these, at least three concepts lead to fusion propulsion systems with a dry mass of less than 80 metric tons including the radiation cooling panels, delivering specific power exceeding 30 kW/kg and specific impulse in excess of 50,000 seconds. (80 metric tons is the lift capability of the Magnum Lifter).