5. Conclusions

- A theory has been developed for a propulsion technique which allows direct conversion from electrical energy at microwave frequencies to thrust.

- An expression has been developed to enable the thrust from such a system to be calculated.

- An experimental thruster was designed using a mathematical model to establish the basic dimensions and electrical characteristics.

- An experimental 850W thruster operating in S band was manufactured and resonant operation at microwave frequencies was tested using low power sources.

- The tuning dimensions for resonance at the nominal operating frequency of 2541 MHz and at the lower frequency limit of 2432 MHz were measured. These dimensions agreed closely with the tuning positions predicted by the model.

- A further test, short circuiting the dielectric section resulted in no resonance being detected, proving that propagation was taking place as designed.

- The experimental thruster was successfully powered from an 850W magnetron approximately 450 times over periods of up to 50 secs. A full range of thrust, power and temperature measurements were recorded. During the programme a total of 5 different magnetrons were used.

- The test programme included tests in both a nominal and an inverted position on three different balances. In all tests, when correctly tuned, the thruster gave an upward force in the nominal position and a downward force in the inverted position, in accordance with the design.

- Peak thrusts measured were comparable to those predicted from the theoretical expression.

- When not correctly tuned the thruster gave reduced thrust or no measurable thrust. Results over a range of input and resonance tuning adjustments gave good correlation between power and thrust measurements.

- The sequence in which test runs were carried out was shown to have no influence on the thrust measured.

- The operation of the cooling fan was shown to have no influence on the thrust measured.

- The direction of the outgassing of cooling air from the thruster was shown to have no influence on the thrust measured.

- The orientation with respect to the Earth's magnetic field was shown to have no influence on the thrust measured.

- Operation within a hermetic enclosure clearly demonstrated the reduction of the buoyancy offset due to the outgassing of cooling air.

- Expressions were derived for the thrust/time profile, to predict the pulsed thrust output, due to a half wave rectified voltage input to the magnetron.

- These expressions were used to predict the thrust/time profiles expected when the thruster was tested on two balances with widely different spring constants.

- The thrust/time profiles measured agreed closely with those predicted for both balances.

- Force/time profiles were predicted for assumed spurious forces due to mass change, thermal slopes and electromagnetic pulse forces. In each case the change in profile with the different balance configurations was opposite to the profile change actually measured. This finding totally confirms the earlier tests that eliminated these spurious forces.

- The thrust/time profile equations predicted a stepped thrust output when viewed over a number of pulse cycles. This stepped thrust output was measured using the processed output of an oscilloscope.

- The pulsed thrust output correlated closely with the predicted output in both nominal and inverted configurations.

- It is concluded that the test data presented verifies the theory of operation of the microwave thruster and thus, for the first time, a method of propulsion that does not rely on propellant has been demonstrated.