

Theoretical Analysis of the Electron Spiral Toroid Concept: an Update June, 2002

NASA published a report in December 2000 analyzing the Electron Spiral Toroid (EST) titled "Theoretical Analysis of the Electron Spiral Toroid Concept" (NASA/CR-2000-210654). Since that report was published, EPS and MIT scientists have added to the technology to answer the questions raised [Seward 2001], [Chen 2001], [Guss 2002].

EPS has discovered a self-confined plasma toroid that remains stable in atmosphere with no external magnetic fields. EPS claims the self-confined plasma toroid has potential for major advances in propulsion and energy applications as reported at www.electronpowersystems.com. As part of a recent contract from the BMDO, MIT Plasma Science and Fusion Center confirmed, "It is found that a class of self-organized EST equilibria exists with or without an externally applied toroidal magnetic field. It is shown that in the absence of any applied toroidal magnetic field, the EST equilibria are stable at high electron densities." [Chen 2001].

NASA reported a different conclusion. NASA reported, "... there is undeniable evidence of plasma [toroid] structures ..." as seen at EPS, and as reported. NASA raised the question of how the ions movement could be accounted for. EPS provided a derivation with this answer, to which the NASA reviewer agreed in an email "It is absolutely correct that if an external confining force can be applied to the ions, then [the ion stability condition is satisfied]." However, this agreement was reached after the report was published, and so was not included.

The NASA report includes in its Section 5 the ion stability condition needed for equilibrium of the plasma toroid, as provided by EPS. We now know that the experimental data provided by EPS, and included below, meets this condition [Seward 2001]. It shows that pressure provides the ion stability, demonstrating that the self-confined plasma toroid is possible in atmosphere.

The NASA report concludes that the EST cannot be scaled up to the extent that EPS claimed in its NIAC report [Seward 1999], and on this point EPS agrees. The NASA report correctly shows that the ion stability condition cannot be practically satisfied at that high level of energy. EPS agrees it overlooked the implications of the ion stability condition in that analysis.

EPS claims the self-confined plasma toroid will potentially provide breakthrough capabilities in the areas of propulsion and energy generation, both areas presently limiting NASA's future missions. These are discussed on the ESP website.

Stability, Data, and Balance of forces: The NASA report provides a derivation of the EST equations in Section 5. EPS provided a derivation of the confining force to ensure equilibrium, and NASA added this to Section 5 of the report. For one ion:

$$\frac{e^2}{\epsilon_0 k_0 (d_i)^2} = F_{\text{Containment}} \quad (1)$$

Experimental EST's are produced using atmospheric pressure to provide the restoring force. The pressure of containment for the experimental EST is measured as 0.001315 atmospheres, or 133.2 Newton/m². The area of the EST is 5.21E-05 m² ($r_T = 0.002\text{m}$, $r_0 = 6.6\text{E-}04\text{m}$), with volume of 1.72E-08 m³. Total confinement force is 6.93E-03 N.

The number of particles is calculated from (1) above to ensure ion stability. The ions form a surface that is a single ion thick due to their electrostatic forces. In addition, the ion surface will be close to the electron surface, so the radius of the ion surface is essentially that of the electron surface. By corollary, the electrons also form a surface a single electron thick. From (1) above, the containment force required for each ion is 6.6E-13 N. Dividing the force per ion into the total containment force calculated above yields $N_i = 1.05\text{E}+10$. To fit these into a single shell the ion distance is 7.1E-08m.

Using the equations in Section 5 of the NASA report, the balance of forces on the electrons is demonstrated. The initial energy of the electrons and ions is 10 eV, based on the experimental values, and consistent with the typical measurements as reported in the "Handbook of Vacuum Arc Science and Technology," (Boxman, 1995 by Noyes Publications). The balance of forces will occur with an ion fraction of 1.0019. The balance of force calculations is shown in [Seward 2001]. At EST initiation, an internal magnetic field is established. This is calculated to be 3.78E-05 Tesla.

References:

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* Available at www.electronpowersystems.com