# High Performance Rare Earth Permanent Magnets for Advanced Motors and Alternative Energy Applications

White Paper for TIP

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## Background

Worldwide permanent magnet sales topped $9 billion before the last recession, with U.S. manufacturing capacity representing only an insignificant portion of the total market. This market is predicted to reach $14 billion by 2020 driven by automotive, electronics, and alternative energy applications, such as hybrid vehicles, computers, and wind turbines.

China now dominates the permanent magnet market, producing over 75% of Nd-Fe-B magnets, over 85% of hard ferrite and 65% of Alnico and Sm-Co magnet materials.

United States used to be the leader in this market with all three generations of rare earth magnets discovered in this country. $SmCo_5$ was discovered by Dr. Karl Strnat in the late 1960's while conducting research at the Wright Patterson U.S. Air Force Research Lab. Nd-Fe-B was invented in part by engineers and scientists in 1980's at Magnequench, a division of General Motors. But now all U.S. magnet producers were closed and moved offshore with only one Sm-Co magnet producer remaining in the United States.

Magnet materials are the backbone of manufacturing technologies that support U.S. energy and defense markets. The loss of production capabilities has also resulted in a brain drain of engineers with background in permanent magnet materials.

## Critical National Need

President Obama has been pushing for the development of alternative energy sources, one of which being wind energy. Wind turbines use significant amount of permanent magnets, which has to be procured from countries like China.

Permanent magnets are also critical components for hybrid vehicles, computers, appliances, motors, generators and office automation equipment.

Permanent magnet assemblies are critical components for almost all major military platforms, such as missile systems (Trident, Minuteman IV, Patriot, PAC III, AMRAAM), Navy ships (Aegis Radar, Virginia Submarines, Motors, Generators), Army tanks (M1A1 tanks, AH-64 Apache, Striker Humvee), and Air Force fighter jets (F-15, F-16, F-18, B-52, Towed Decoys, Joint Strike Fighter, Predator, and unmanned aerial vehicles).

The market dominance of Chinese producers poses a significant risk to our national defense as well as U.S. economy as a whole. In order to reverse the trends of U.S. supply chain vulnerabilities in permanent magnets, there should be some concerted effort to re-build the U.S. manufacturing base in magnet manufacturing and continue to lead in innovation in this industry.

**Societal Challenge**

Significant investment is needed in order to develop next generation permanent magnets, which is the key to re-build U.S. manufacturing base. With intellectual property in future generation magnets, U.S. manufacturing will be able to lead again.

Although theoretical predictions suggest new discoveries are on the horizon, there is so far no breakthroughs. Significant effort should be focused on process development in the following technologies:

(1) High performance high electrical resistivity rare earth permanent magnets, which would help reduce eddy current losses in motors and generators. This is going to be enabling technology for hybrid vehicles, wind turbines and other rotating permanent magnet machines. Recent studies at Electron Energy Corporation suggest that this is feasible.

(2) High energy product permanent magnets, which will further improve our weapon systems as well as industrial and commercial systems.

Electron Energy Corporation is interested in the development of large scale, low cost, manufacturing processes and facilities for high energy, high electrical resistivity rare earth permanent magnets with the help from Technology Innovation Program (TIP). It is a high risk program due to the fact that the development work is still at a very early stage and the current performance data is still far below the theoretical predictions. The reward of this high energy high electrical resistivity magnet technology will have a great impact on many industries as well as military / aerospace market. If it is successful, it will open up a new window for innovation in magnetic devices, from computer hard disk drives, motors, generators to wind turbines.

Private sector needs help for the development due to the significant uncertainty involved**. If the next generation permanent magnets were developed in China or other countries, it would be another blow to U.S. economy and manufacturing base. It would also increase significantly the supply-chain risk in magnetic systems, especially for military applications.**

## Transformational Result

High electrical resistivity high performance magnets will increase the efficiency of motors and generators and reduce the size of these systems. The maximum energy products could be doubled according to theoretical predictions and the electrical resistivity could be doubled or tripled based on preliminary data at Electron Energy Corporation. This could become a disruptive technology, which will affect many markets including but not limited to alternative energy, automotives, consumer electronics, nuclear reactors, inertial guidance, electronic warfare, space propulsion, and microwave communications.

## Research Team

***Electron Energy Corporation*** (EEC) has 4 scientists with PhDs and a dozen of other engineers. EEC will focus on manufacturing process and facilities development.

The Magnetics Lab at ***University of Delaware*** led by Prof. George Hadjipanayis will focus on microstructure and compositional analysis.

***Oakridge National Lab*** will focus on laboratory scale process development and characterization.

Resources at NIST are also available in magnetic materials research, microstructure analysis, and theoretical simulations, which will be beneficial for this effort. The Magnetic Materials Group at NIST led by Dr. Robert D. Shull is one of the leaders in this field.

## References

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