Summary: The topic of this presentation was the development of Pegasus-III and solenoid-free startup for nuclear fusion reactors. This presentation was given by Professor Stephanie Diem of the University of Wisconsin-Madison. Before Professor Diem became a professor at the University of Wisconsin-Madison, she worked as a scientist at Oak Ridge National where she joined the Pegasus-III project. To begin, Pegasus-III is a nuclear fusion reactor in the form of a spherical TOKAMAK. Nuclear fusion reactors attempt to heat and confine deuterium and tritium plasma to mirror the reaction occurring in all stars, which is known as fusion. Fusing atoms together has not been difficult, but maintaining the requisite density, temperature, and confinement time to produce energy has been extremely difficult. A challenging aspect of operating a fusion reactor is obtaining the required plasma temperature to facilitate fusion. To obtain the plasma temperatures required for fusion, the gas inside the reactor needs to be externally heated. Traditionally, this external heating has been supplied with neutral beams, ohmic heating, or radio frequency (RF) power. Neutral beams shoot a beam of superheated particles into the plasma. However, neutral beams do not work for large reactors as their surface area to volume ratio is too low. Ohmic heating leverages the charged nature of the plasma to generative resistive heating throughout the plasma. RF heating uses radio waves tuned to the natural frequency of the plasma, which transfers energy into the system. However, the Pegasus-III team uses injectors. Injectors generate a current through the center of the reactor ripping magnetic field lines and imparting the energy stored in these field lines into the plasma. Not only do injectors take up far less space than previous heating methods, but they can also be used to fix instabilities in the plasma. After the reactor has been started, superconducting magnets are used to generate magnetic fields to contain the plasma. However, instabilities arise when trying to confine the plasma. This process has been described as “trying to contain Jell-O with rubber bands.” The Pegasus-III team believes injectors can solve the wobbles that occur in the plasma by ripping the magnetic field lines in a controlled manner.

Response: The concept of injectors are new to me, but I think they are a great idea. The instabilities that occur in fusion plasmas occur when the plasma lashes out in a manner like a solar flare. These miniature solar flares Injectors, however, are extremely unpredictable. I believe Professor Diem mentioned they are almost entirely unpredictable except for a brief instant before the event occurs. These mini-solar flares fling plasma hotter than 100e6 K against the wall of the reactor. When the plasma hits the wall, it ejects material into the plasma and causes impurities. However, injectors may be able to rectify these extremely violent events. By breaking the field lines in a controlled manner, the unpredictable nature of these events disappears. Additionally, when the magnetic field lines are constantly being broken and reconnected, not as much energy can be stored in each field line. With less energetic magnetic fields, there is less of a chance for these field lines to undergo an unexpected outbreak. I think it is very clever to use injectors to simultaneously reduce instabilities and heat the plasma – these two issues are some of the biggest challenges with fusion energy. I agree with most of the information presented and agree that injectors could be the future of fusion energy. However, I disagreed with her assertion that the energy stored in the capacitors for RF power can power the entire city of Madison. I do not think this is false, however, any amount of energy can be used to power an entire city. The issue I have is that the energy stored in these capacitors could power the entire city for a second, week, year, or century. The quantity we are concerned with is the work the stored energy is capable of. Aside from this pedantic grievance, I thought this presentation was pretty good. I am interested in what this group will accomplish with injectors and will follow their publications for more information.