ELECTROMAGNETIC SPACECRAFT USED FOR MAGNETIC NAVIGATION WITHIN ASTEROID BELT, MINING CONCEPTS AND ASTEROID MAGNETIC CLASSIFICATION G. Kletetschka [1,2,3], T. Adachi[1,2], and V. Mikula[1,2], [1]Department of Physics, Catholic University of America, Washington DC, USA, [2]NASA Goddard Space Flight Center, Greenbelt, MD, USA, [3]Institute of Geology, Academy of Sciences of the Czech Republic, Prague, Czech Republic.

Introduction: The objective of asteroid investigation is an establishment of the remote data acquisition system allowing sufficient characterization and classification of asteroids. It is generally accepted that asteroids are the parent bodies for most meteorites reaching the Earth [1]. Magnetic classification of meteorites indicates that the amount of iron in asteroids within asteroid belt is efficiently detected by measurement of magnetic susceptibility of asteroidal material [2, 3]. Presence of nearby magnetic source is enhanced by any soft magnetic component, which in asteroidal material is mostly iron and nickel compounds. Such material reaches magnetic susceptibility of 1 e-3 m^3/kg. Even if diluted within the asteroid, the presence of such material creates a potential for magnetic force interaction between rock rich in Fe-Ni bearing minerals and nearby localized magnetic source carried by an orbiting spacecraft. This magnetic interaction can become a dominant force acting either on the spacecraft or magnetic rock fragments due to lack of significant gravity sources of low mass asteroidal bodies.

Methods: We tried to identify the importance of magnetic remanence within three meteorites (Bjurbole – L4, Plainview – H5, and ALH769 – L6) for which we had various sizes available, from gram size to (ALH76009 – 23.7 kg, Allende – 17.2 kg, and Canyon Diablo – 454 kg). The samples were assigned a coordinate system and placed at the center of the 40 foot "Helmholtz" coil array housed at NASA GSFC Magnetic test facility, fully within the region where intensity and gradient of the magnetic field can be fully controlled. Two three-axis fluxgate magnetometers record the field intensity of the fixed x, y, and z meteorite coordinate system as it is rotated through 360 degrees. Magnetic remanence was measured in pristine state (NRM) and also after demagnetization by a 5 mT alternating magnetic field. Resulting remanence was a strong function of the grain size [4] and indicates that large asteroids in general may lack magnetic remanence. However, meteorites and therefore asteroids are known to have large magnetic susceptibilities, so large, that the household magnet is attracted to most of the meteorites and that meteorite collectors can easily identify meteorite from the terrestrial rock. We took advantage of this property and propose to use "the household magnet" feature for collection of rock fragments from asteroidal bodies, using them to adjust the speed and direction of the spacecraft and finally use magnetic attraction for magnetic classification of asteroids. We modeled magnetic field generated by electromagnets containing high permeability cores and connected with high permeability tubes. We use Finite Element Method Magnetics software written by David Meeker, 2004.

Magnetic navigation: Let us assume that a spacecraft is located within the asteroid belt. Asteroids have gravitational interactions orders of magnitude smaller than planet Earth. Any orbiting spacecraft has very low speed on its orbit allowing precise navigation and maneuvering. We propose that part of such spacecraft contains an electromagnet and call this magnetic spacecraft. This spacecraft is composed of a system of two coils connected with the high permeability expandable/collapsible tube where each coil (~1000 turns) has 0.2m internal diameter and 0.6m outer diameter. The core of each coil is made of high permeability material (See Figure 1)

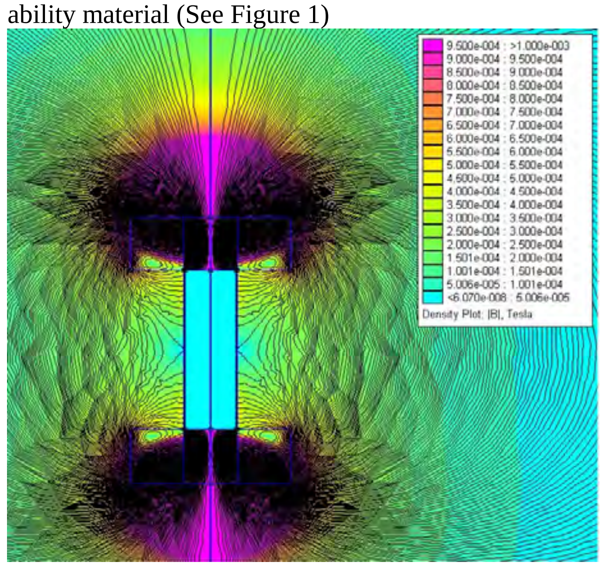

Figure 1a: Dipole arrangement of two electromagnets connected with magnetically permeable collapsible/retractable tube. Outer coil diameter is 0.6m. Inner coil diameter is 0.2m. Coils have approximately 1000 turns of high conductivity wire.

The presence of collapsible high permeability tube allows the magnet to expand/collapse and can modify the magnetic anisotropy of the magnetic spacecraft.

The electromagnet will self expand when it is in its tripole magnetic arrangement (Figure 1b). The central plane forms a third planar pole of one polarity and is repelling the opposite polarity of the poles near the electromagnets causing the magnetic spacecraft to expand. In its expanded form, magnetically active spacecraft will have high affinity to point one of its poles towards the asteroid body. It will also have tendency to collapse by pressing on the high permeability tube. If magnetic collapse is not allowed such elongated electromagnet will generate a magnetic pull (in vicinity of the asteroid) towards the asteroid surface due to induced magnetic carriers within the asteroid (the pole of the magnet will act like a magnet attracted by meteorite). If such pull is generated while the magnetic spacecraft is approaching /leaving along non-collision course, the gravity and magnetic combination of forces will result in overall spacecraft velocity increase/decrease, respectively. This velocity increase can be used in principle for orbital maneuvering without use of the chemical propellant.

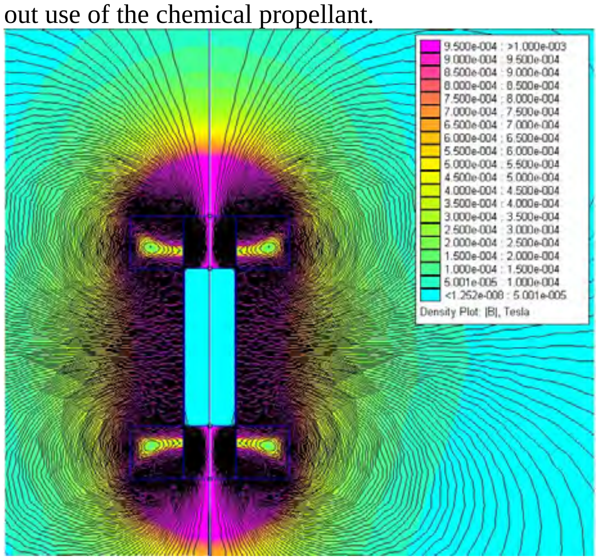

Figure 1b: Tripole arrangement of two electromagnets connected with magnetically permeable collapsible/retractable tube. Outer coil diameter is 0.6m. Inner coil diameter is 0.2m. Coils have approximately 1000 turns of high conductivity wire.

Magnetic mining: Due to low gravity of the near Earth asteroids some of the asteroids may be composed of "rubble pile" where individual grains are not bound together by any significant force. Such situation allows for very small force to lift up a sample from the asteroidal surface. The magnetic coil, described above in its dipole form, will have ability to magnetically lift up asteroid fragments that are rich in magnetically permeable material without landing on asteroid surface. Magnetic lift can be made by just controlling the current inside the electromagnet.

Asteroid classification: When magnetically active, coil on orbit around the asteroid in its expanded form, can monitor the perturbations to the orbital motions and use them for estimates of the induced component within the asteroid. Knowledge of the magnetic susceptibility of the asteroidal surface would allow classification of the asteroid based on multiple meteorite studies [2, 3].

Concluding remarks: Application of expandable/collapsible magnetic coil can open the way towards an effective spacecraft velocity increase/decrease without using chemical propellants. The same concept of magnetic attraction can open the way for effective magnetic mining of asteroids. Magnetic interaction between magnetic spacecraft and the asteroid surface can be used for the first order classification of the asteroids.

References: [1] Wasson, J. T. and Wetherill, G. W. in Asteroids, eds. T. Gehrels and M.S. Matthews (1979), U of Arizona Press, 926-974. [2] Rochette P. et al., (2003) MAPS38, 251-268 [3] Rochette P. et al, (2004) LPS XXXV, Abstract # 1132 [4] Wasilewski et al., (2002) MAPS37, 937-950.