THE MARS SAMLE RETURN INTEGRATED PRODUCT TEAM ACADEMIC EXPERIMENT. M.W. Turner[1], M.P.J. Benfied[1], C.J. Runyon[2], and J. Hakkila[2], [1]The University of Alabama in Huntsville (301 Sparkman Drive, Huntsville, AL 35899), [2]College of Charleston (66 George Street Charleston, SC 29424).

Introduction: The NASA Marshall Space Flight Center (MSFC) Engineering Technical Management Office (ED10) is supporting an innovative educational experiment that seeks to train the next generation of scientists and engineers by providing the opportunity for them to plan and design future NASA missions. This experiment, Mars Sample Return (MSR) Project, begins with the assumption that the students will have a single Ares V launch vehicle at their disposal. Within this launch vehicle, the students must fit all the mission elements required to reach the Martian surface, perform their science objectives, gather samples, and return safely back to Earth.

If Mars Sample Return were a real NASA mission, it would most likely be classified as a Flagship Mission; however, for the purposes of this academic exercise, and to add structure to the class, the instructors have adopted the 2009 New Frontiers (NF) Announcement of Opportunity (AO) [1] as the guiding document for this proposal process/class. Therefore the organization of this academic experiment is divided into the traditional New Frontiers roles.

The first iteration of this project is in the Spring 2010 semester, with future iterations being in the Fall 2010 semester. During each iteration, student teams will develop their own Mars Sample Return mission – this includes all the scientific justifications and conceptual engineering design. The end product from this project will be proposals, per the 2009 NF AO, with adjustments made to the AO for the MSR mission.

There are multiple objectives to this project. First, *this is an academic exercise* – teaching the scientist and engineering students how scientists and engineers operate in the real world, and teaching them how to communicate effectively is of utmost importance. Second, using an Ares V for an MSR mission should provide for some interesting results – these results will be made public, and hopefully offer scientists, engineers, and managers useful information. Last, the complexity of an MRS mission allows the instructors of this course to experiment with techniques to mitigate the difficulties brought about by concurrent engineering design (CED) and total product lifecycle management (PLM). Furthermore, exposing the students to the complex practices of distributed concurrent engineering design and product lifecycle management will better prepare them for work in the 21st century.

Background: The capstone senior engineering design course in the Department of Mechanical and Aerospace Engineering (MAE) at The University of Alabama in Huntsville (UAH) is called the Integrated Product Team (IPT) class because the students work in interdisciplinary teams to solve common design problems. This class draws from departments from across campus, including MAE, Electrical Engineering, English, and Art. Since 1993, the IPT class has designed solutions for 25 projects, approximately half of which were from the Department of Defense and 40% from NASA. Until this project, the IPT class has always worked with an engineering customer. Drs. P.J. Benfield and Matt Turner are the instructors of this course.

In order to show versatility in the Ares V launch vehicle and to incorporate science objectives into the program, the 2010 IPT class decided that a sample return mission to Mars would be an interesting project. Moreover, the complexity of an MSR mission would allow for exploration of engineering issues such as CED and PLM. Furthermore, with this project, science and engineering issues are at of equal importance; therefore, the IPT class needs a Science Definition Team (SDT) to define the baseline and threshold science objectives for each mission. Lastly, in order to bring order to the reporting and management of this project, the IPT instructors decided to apply the basic requirements 2009 New Frontiers AO to the students' final paper process. Furthermore, since the AO deals with science and engineering issues, the instructors felt that it was a logical fit for the reporting and organizational structures of the class for this project.

MSR Organization: Because the IPT class has incorporated the NF AO, a similar organizational structure was adopted, with three main branches: (1) the Science Definition Team, (2) the Engineering Design Teams (EDT), and (3) the Education/Public Outreach (EPO) activity/experiment.

The role of the Science Definition Team will be filled by approximately 20 sophomore-through-senior level students from the College of Charleston (CoC). Drs. Cassandra J. Runyon, from the Department of Geology and Environmental Sciences, and Jon Hakkila, from the Physics and Astronomy Department, at the College of Charleston will lead their students, as they take on the responsibilities of Principal Investigator(s) (PI), Science Representatives, Instrument Leads, and Science Operations Leads. Just as a real SDT would operate, these students will define the baseline and threshold science goals, objectives, measurement requirements, and instrument functional requirements, based on the 2009 New Frontiers AO. The PI and SDT will be responsible for completing sections D and

E in the New Frontiers AO response, as well as the Science Traceability Matrix, which defines mission functional requirements for the engineering team.

The role of the EDT will be filled by the UAH IPT class, as well as senior engineering design classes from ESTACA (Ecole Supérieure des Techniques Aéronautiques et de Construction Automobile) University in Paris, France, and Southern University in Baton Rouge, LA. The EDT will be responsible for Program Management (PM), Systems Engineering (SE), Cost/Risk/Programmatics, Propulsion/Attitude Control, Command and Data Handling, Software, Power, Thermal, Structures, Telecom, and EPO management. The EDT will be responsible for completing sections F and G in the New Frontiers AO response, as well as the Mission Traceability Matrix.

In "the real world" when a team responds to a New Frontiers AO, the EPO component typically includes an effort led by university students. Since the engineering and science teams for the Academic AO Project are university students, the EPO experiment will be designed by high school students. Two high schools in the Decatur (Alabama) City School systems – Decatur and Austin High School – have been already been contacted, briefed, and given an initial design envelope for their student experiment. These two high schools are part of the Alabama Engineering Academy Initiative, and these student design experiments will be part of their Spring 2010 curriculum. The PM for each university design team will coordinate with the 30 high school students, and Drs. Benfield and Turner will aid the high school instructors in the teaching of the design process and the student experiment.

Each university partner will have three teams (A, B, and C) competitively designing a portion of the MSR mission. Collectively, all teams A (and B and C, respectively) from each university will act as a single "distributed" IPT. So, for example, students on Team A from CoC in South Carolina will be the SDT for students on Team A (designing the Martian lander) at UAH in Alabama, while they work with students on Team A (designing the Mars orbiter) at ESCTAC in Paris, who are also working with students on Team A (designing the Mars ascent vehicle) from Southern University in Louisiana. Everyone has to work together – they must solve their team's design issues, while working toward a collective common goal. Just like the current organizational structure of the current design of the Constellation Program, this project highlights concurrent engineering and "distributed" IPTs. PLM issues include sample handling – Earth landing operations, surface transportation, and the sample receiving facility impact the design of the sample canister, which impacts the Mars lander, orbiter, etc.

Approach: As outlined, an MSR mission is very complex. The IPT instructors have divided the MSR mission into four basic mission elements (assuming that the Ares V provide trans-Mars injection delta-V): (1) the Mars Orbiter, (2) the Martian Surface Elements, (3) the Mars Ascent Vehicle, and (4) the Earth Return Vehicle. Furthermore, because of the large throw mass of the Ares V, the instructors have imposed two ground rules on the teams – the MSR architecture must be end-to-end (cannot rely on any existing space vehicles at Mars), and sample return must occur at two or more locations (which have yet to be defined).

AO Modifications. Obviously, some modifications to the NF AO were required. First and foremost, the 2009 NF AO has no science objectives for an MSR mission. Therefore, the IPT instructors have incorporated the white paper from Borg, et al. [2]. Second, as an MRS mission would be a Flagship, and not a NF class mission, the NF $650M cost-cap was eliminated. Other minor changes to the NF AO were also made.

Pre-Planning. In order to enable the students to complete their designs in the Spring 2010 semester, some engineering and science students started planning the mission in the Fall 2009 semester. Students and instructors from UAH visited CofC, ESTACA, and video teleconferenced with Southern University. Furthermore, during the Fall 2009 semester, systems engineering and mission design and analysis graduate students have prepared systems engineering reports and trajectory analyses, respectively, for the MSR project.

Total Disclosure. All of the results from the MRS mission will be posted on the IPT website, at UAH once completed and defended during an oral presentation in front of a review board of professional scientists and engineers.

Summary: The University of Alabama in Huntsville and the College of Charleston have embarked on an educational experiment, supported by the NASA Marshall Space Flight Center (MSFC) Engineering Technical Management Office, called the Mars Sample Return Mission. This project seeks to simulate real-world engineering and science design and collaboration in the classroom. The goal of this project is to teach scientists and engineers how to communicate properly and work through complex problems as a team to accomplish a common goal.

References: [1] NASA (Release Date: April 20, 2009) *Announcement of Opportunity: New Frontiers 2009*. NNH09ZDA007O. Proposal Due Date: July 31, 2009. [2] Borg, L., et al.(2009). A Consensus Vision for Mars Sample Return, 7p. white paper posted September 2009 by the Mars Exploration Program Analysis Group: http://mepag.jpl.nasa.gov/reports/index.html