THE 2015-2016 SEPMAP PROGRAM AT NASA JSC: SCIENCE, ENGINEERING, AND PROGRAM MANAGEMENT TRAINING. L. Graham[1], D. Archer[2], J. Bakalyar[1], E. Berger[3], E. Blome[1], R. Brown[1], S. Cox[1], P. Curiel[1], R. Eid[1], D. Eppler, M. Fries[1], J. Gruener[1], M. Haddock[1], K. Harder[1], T. Hong[1], C. McCann[1], K. Neiss[1], D. Newswander[1], J. Odina[1], A. Peslier[2], Z. Quadri[1] S. Ross[1], M. Rutovic[1], R. Schulte[1], R. Thomas[1], J. Vos[1], M. Waid[1], L. Welzenbach[3], B. Willman[1], [1]NASA Johnson Space Center, Houston, TX, [2]Jacobs [3]Planetary Science Institute, Tucson, AZ. [3]GCS-Jacobs-NASA Johnson Space Center, Houston, TX.

Introduction: The Systems Engineering Project Management Advancement Program (SEPMAP) at NASA Johnson Space Center (JSC) is an employee development program designed to provide graduate level training in project management and systems engineering. The program includes an applied learning project with engineering and integrated science goals requirements. The teams were presented with a task: Collect a representative sample set from a field site using a hexacopter platform, as if performing a scientific reconnaissance to assess whether the site is of sufficient scientific interest to justify exploration by astronauts. Four teams worked through the eighteen-month course to design customized sampling payloads integrated with the hexacopter, and then operate the aircraft to meet sampling requirements of number (≥5) and mass (≥5g each). The "Mars Yard" at JSC was utilized for this purpose. This project activity closely parallels NASA plans for the future exploration of Mars, where remote sites will be reconnoitered ahead of crewed exploration.

Project Description: SEPMAP is a technical development program aimed to give mid-career engineers at JSC the opportunity to develop advanced skills in project management and systems engineering. The 18-month class that ran from May 2015-November 2016 was the third offering of the program. This class had 19 participants from 6 different units across JSC. The program included training courses in project management, systems engineering, and leadership as well as a book club, mentoring, and the applied learning project. Each project team included a volunteer team scientist from the Astromaterials Research and Exploration Science (ARES) division at JSC.

For the actual hexacopter sampling component, the teams performed a required site assessment flight, followed by sample collection flights on a separate day. The teams were limited in the number of flights by battery life with a NASA Unmanned Aerial Vehicle (UAV) pilot provided for all flights. The assessment flight required imaging of the entire field site with sufficient altitude and resolution to identify targets for sampling. Each team then reviewed their imagery with their scientist and devised a sampling plan to collect a suite of samples that represented the geological diversity of the site as well as being targets of high scientific interest. Mission requirements included prevention of cross-contamination between samples and sample collection hardware be visibly clean before each sample collection sortie. This did not preclude re-use of equipment, however. Materials of elevated astrobiological interest were placed to mimic natural geological features. Sample types included rock salt (to simulate an evaporite site), crushed charcoal (to mimic biological fossil material), and perlite (to mimic a low-density evaporite). The teams were provided a basic description of the exposure size of materials at the site, but the particle size distribution, density, and appearance were not provided since these would not be known with certainty during an actual reconnaissance mission.

Figure 1: *Upper Left:* The Team Hexplorers hexacopter performing a sample collection sortie. *Upper Right:* Google Earth view of the JSC "Mars Yard" showing sites suitable for collecting representative samples from each "geological unit" present (red), simulated evaporite (white), and kerogen deposits (black). *Lower Left:* Team Ripsaw servicing their hexacopter between sampling sorties, showing the clean landing pad with single-use plastic liners for contamination control. *Lower Right:* Team RASCALS preparing for a sampling

Sampling Design and Operations Approach:

Team Hexplorers: The Hexplorers used 3 identical sample collection devices suspended side by side underneath the hexacopter to collect multiple samples during each flight. Each collection device consisted of a linear actuator, a force pressure sensor, and a "Geckskin" adhesive pad covering a morphable pouch, all housed in a containment box for contamination control. The team went through studies to assess different options weighed against target design criteria. The Geckskin adhesive pouch design was chosen as it could handle varying terrain conditions, provided minimal disruption to the natural environment, and did not contaminate the samples.

After landing at the chosen sample location, the operator initiated the collection sequence for the desired collection device. The sequence opened the housing door, deployed the actuator until the pressure sensor read a minimum of 2 pounds of force, retracted the actuator (with samples attached to the Geckskin adhesive pad), and closed the door. The operations team had a valuable real-time video/telemetry feed to make decisions, along with a recorded High Definition (HD) camera feed for post-mission analysis.

Team Ripsaw: Team Ripsaw designed a payload that consisted of four small plastic scoops attached to each corner of the hexacopter landing gear, such that the hexacopter used the scoops as landing gear. The scoops were spring loaded and locked with a pin in the open position prior to takeoff. The pins were connected with fishing line through a support structure made of PVC tubing to a single linear actuator. The fishing line was tied such that only one pin was pulled at a time to increase margin between required actuation force and linear actuator applied force. The actuator pulled the pins from all four scoops after landing, allowing them to close around the sample. The scoops were covered with a plastic bag that was replaced between each sortie to prevent cross-contamination. The plastic bag was secured to the scoop with a binder clip and zip tie to allow for fast replacement between sorties. The hexacopter landed on a clean landing pad with single-use layers of plastic sheets replaced after each sortie, for cross-contamination prevention at the launch/landing site. The team chose this design due to its simplicity. The weight of the hexacopter alone provided the down force needed to push samples up into the scoops. Also, the pin-pull release mechanism is highly reliable. The pin-pull mechanism and protective bags were reset quickly enough that the mission objectives were achieved within the time available.

Team Hitchhikers: The Hitchhiker payload collection system was modeled after a self-inking stamp. An adhesive pad was attached to a rotating plate using Velcro and the plate was extended/rotated via remote control of linear actuators. When the stamp was 'retracted', the pad was completely enclosed in the stamp housing to preclude contamination during transport. When the stamp was 'deployed' the pad was rotated and extended down to press the adhesive media against the ground. This solution required one sortie for each sample collected. On return to the service base, the ground crew manually actuated the stamp to retrieve the pad with the sample attached and then attached a new pad for the next sortie. This design and operational concept approach was chosen to simplify the mechanical design of the collection mechanism in order to reduce the overall cost and meet schedule requirements.

Team RASCALS: Team RASCALS (Remote Aerial Sample Collection and Location System) designed a payload that collected samples by scooping the terrain with nets. The payload used seven "fine filter" nets which were independently actuated. This design allowed flexibility in operations and provided the ability to collect samples from different sites in the same sortie. Net liners provided individual sample containment and contamination control as well as the opportunity to revisit sites. The structure of the payload was primarily wood to simplify fabrication, and more complex parts were directly fabricated using additive manufacturing. On mission day, the payload operated as designed and samples were collected from a total of 10 sites. At each site all seven nets were actuated to increase the volume and likelihood of sample collection.

Results:

Charlie the Biosignature: As a "bonus" target, "Charlie", the skull of a *Bos taurus* was placed in the field site. No previous notification and therefore no specific requirements had been levied to search for such an obvious target. The point was to encourage the teams to be flexible in their search approach and be open to noting unexpected observations. Only one out of four teams noted Charlie and adapted their plan to collect images.

Overall: All teams met and exceeded mission requirements in terms of both number of samples and total mass collected. In a more qualitative sense, both the development program participants and scientist volunteers gained valuable experience in solving the sampling problem as a team. This experience gave all involved firsthand experience working across traditional scientist/engineer cultural divisions. The SEPMAP class of 2016 has graduated and are now working on projects across JSC.

Future SEPMAP programs may expand on this experience by testing notional mission concepts. Results will include a peer-reviewed publication, which serves the dual purposes of reporting rigorous, repeated tests of a mission concept and providing SEPMAP participants first-hand experience with the peer-review publication process.