Concept Generation:

Ideas for the project were developed during a group brainstorming session and with the assistance of concept generation tools. During the brainstorming session 30 minutes was allotted for individual brainstorming. Ideas were developed in subsections of the project: onboarding, orienting, and storage. Once the individual brainstorming session was complete, the group discussed the ideas generated and continued researching related projects.
At the completion of the group brainstorming session, concept generation tools, such as a morphological chart, biomimicry, and forced analogy, were utilized to generate additional concepts. The morphological chart is used to generate new, complete concepts by combining separate subproblem solution concepts. Using one concept from each column resulted in 462 (11*7*6) complete concepts. The morphological chart can be seen below Figure 2.

Figure 2

Subproblem Solution Concepts		
On-Boarding	**Orientation**	**Storage**
Robotic arm	Rubik's cube solver	Moon rock storage
Claw Machine	Gryoscope mount/ concentric circles	Revolver style
Shovel/Rake	Rotating pedestal	Bin/Bucket
Ramp	2 C-clamps	Modular storage (boxes on tracks)
Microscopic Grippers	Electromagnets	Saran wrap box
4-bar Curve	4-prong claw/platform	Diaper pail
Lacrosse-net with slider	Pinscreen/Pintoy	
C-clamp		
Vacuum/Suction		
Light-bulb changer		
Marshall Picker (ATV rock picker)		

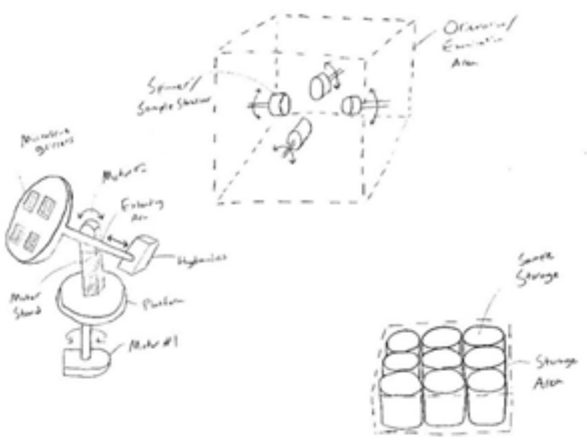
Medium Fidelity Concepts

The group selected five concepts generated during brainstorming and with concept generation tools to further develop and assess. Drawings and brief descriptions of the five medium fidelity concepts are detailed below.

Concept 1

To collect the sample from the surrounding environment, the end effector attached to the moving device will incorporate microspine grippers. Microspine grippers are bio-inspired, by geckos, and are currently being developed and researched at NASA’s Jet Propulsion Laboratory as well at the FAMU-FSU College of Engineering STRIDe Lab by Dr. Jonathan Clark. The microspine end effector is attached to an arm capable of reaching nearby samples. 3 DoF of the arm are produced by two stepper motors and a set of hydraulics. Once a sample is collected, samples are deposited within the examination area. The orientation area utilizes four spinners with semi-moldable heads to reorient and stabilize the sample. If the sample is deemed acceptable, the sample is placed within the sample storage area. The storage area has multiple cylindrical containers that both secure and seal individual samples onboard the device.

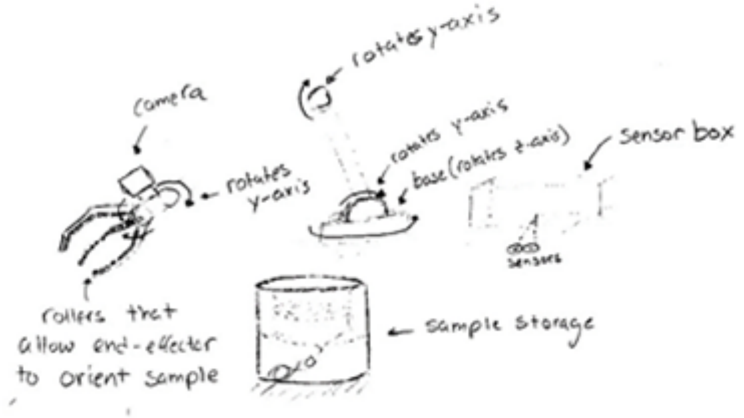
Figure 3



Concept 2

There are small wheels located on the fingers of the end-effector which can be controlled to spin, rotating the sample while it is grasped. By doing so, the arm can hold the sample over the sensor box and rotate the sample as needed without the need for a separate subsystem. The concept also features a camera on the arm to assist in sample location and positioning. If the sample is deemed undesirable, it will be dropped off to the ground by the manipulator. If instead the sample is desirable, the manipulator will bring it to the storage container. When the sample is dropped in the storage container, the sample will be wrapped in a plastic or material to keep it contained and to prevent damage.

Figure 4



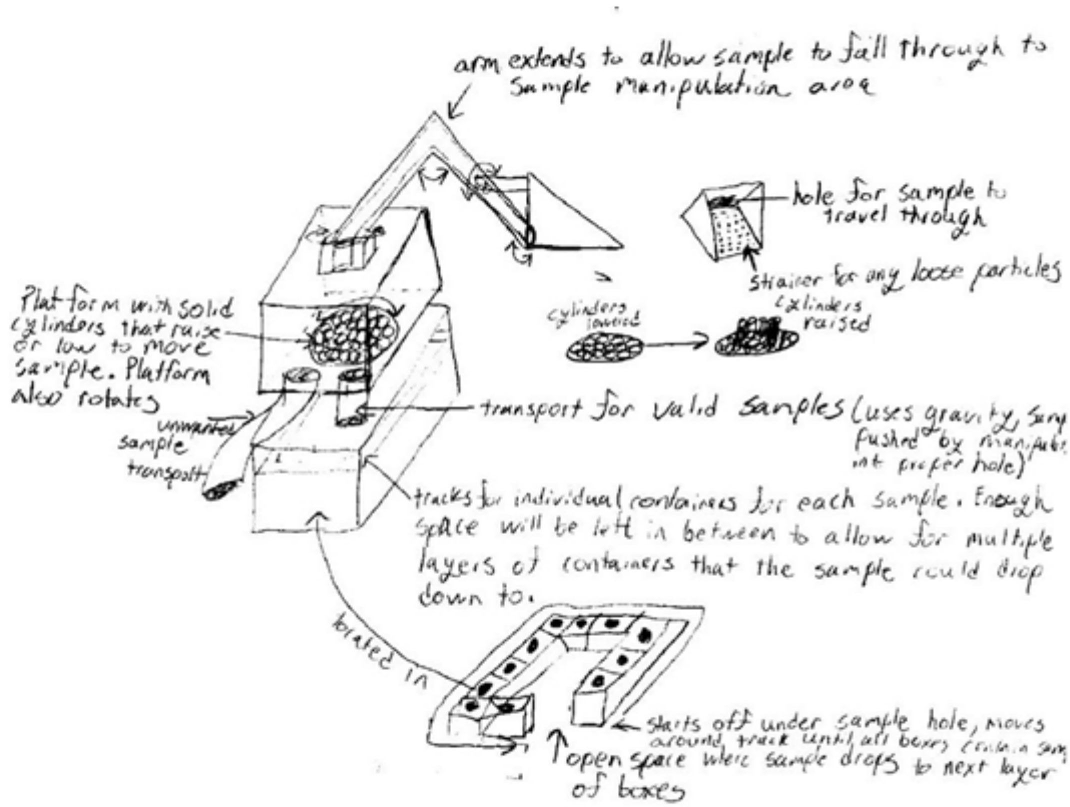
Concept 3

A scoop attached to a robotic arm will scoop up a sample. The bottom of the scoop will be made of a material that will allow just sand to easily fall through. The arm will then extend allowing the sample to fall through the hole at the back of the scoop and travel through a tube along the arm into the sample manipulation area.

Within the sample manipulation area there are two holes, one for unwanted samples, and one for wanted samples. The manipulation device is a circular platform with small cylinders making up its surface. These cylinders raise or lower to manipulate the sample. The platform itself also rotates. When the quality of a sample is determined, the cylinders will raise in such a way that make it fall into the proper hole. The transportation methods of the samples use gravity.

The storage location is a large container that has numerous levels of tracks with boxes on them. Each box will be filled with one sample. One space between the boxes is left for when all the boxes on one level are filled, so that the sample could then fall to the boxes on the next level.

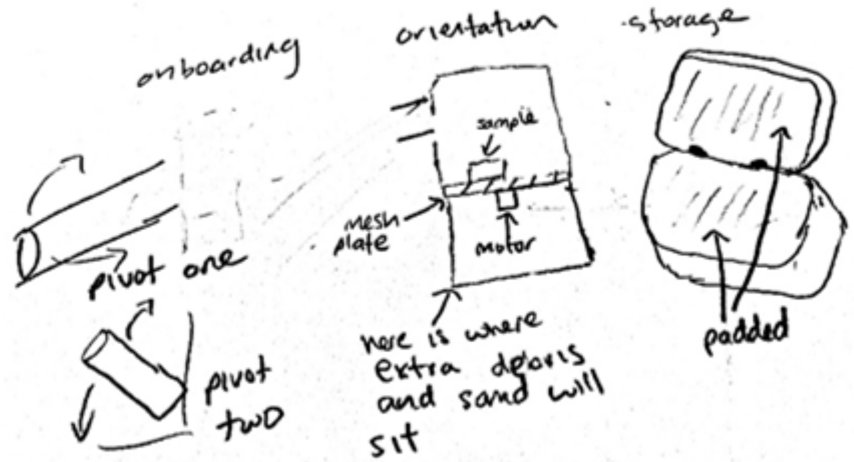
Figure 5



Concept 4

To on-board the samples a vacuum would be used. The arm for the vacuum will have two pivot points. One will go from left to right and the other will angle the vacuum up and down. Inside the container, into which the vacuum feeds, there would be a metal mesh plate to hold the sample. This would be so that any dirt and debris would fall through to a separate compartment and the sample could be inspected uncontaminated. The mesh plate used to hold the sample has a dual purpose. It is connected to a motor on the bottom that rotates the sample for the manipulation and orientation portion. To store the sample after there will be boxes with foam padding next to the plate for each sample to collected into. This ensures that the samples are not damaged in the transportation process.

Figure 6

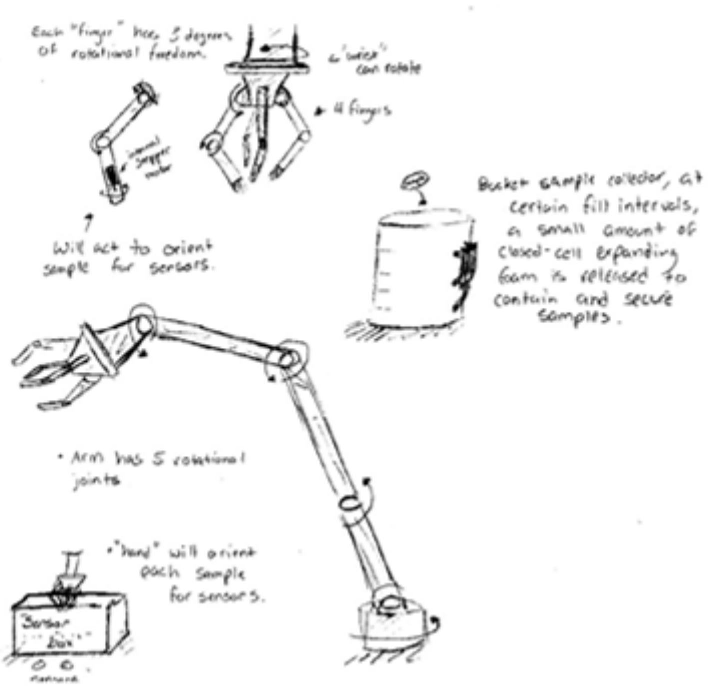


Concept 5

To combine the orient and onboard systems, this concept allows the end-effector of the onboard system to orient the sample. Each finger of the end-effector can rotate at the contact point. To manipulate the sample, 2 opposite fingers will hold the sample simultaneously and rotate in tandem. The other 2 fingers can grasp the sample, after which the first two let go, then the sample can be rotated about a second axis. This would allow any point of the sample to face the sensors.

The onboard/manipulator arm will move the sample from the sensor box to the storage container. The storage container is a bucket with a container of expanding foam. This foam expands to produce air-tight containment and will secure the samples from motion during transport and return mission. The foam will be able to be used as the container fills through several fill channels.

Figure 7



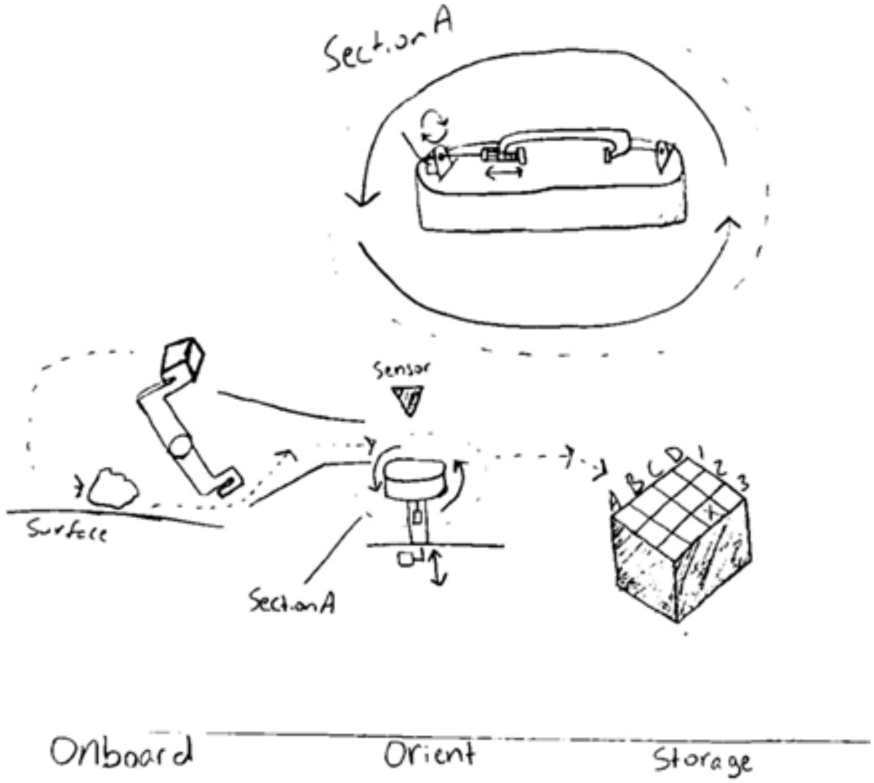
High Fidelity Concepts

After the development of the five medium fidelity concepts, the group refined and expanded upon these concepts into three high fidelity concepts. Drawings and detailed descriptions of the three high fidelity concepts are discussed below.

Concept 1

This design utilizes an idea from the Marshall Rock Picker. This device uses to paddles that spin about an axis close to the ground to scoop rocks off the surface and into a bucket. Instead of a bucket, the rocks will be scooped into the orientation area where the testing will be performed.

Figure 8



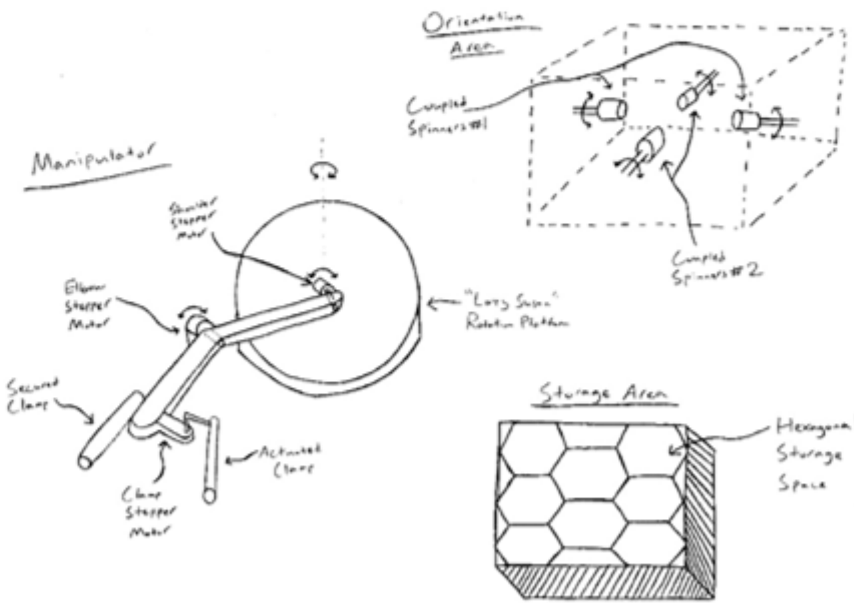
The orientation aspect is accomplished using a 360-degree rotating pedestal. On top of the pedestal sits a clamp attached to a motor. The clamp will also be able to rotate 360-degrees about the motors output shaft. This will allow for 2-axes revolutions of the sample so that the entire surface of the sample can be seen. The pedestal will also have vertical motion that is achieved by an actuator underneath.

A modular storage bin will be used to hold the samples. It will have a set number of compartments that are labeled so that testing data can easily be traced back to a specific sample. For example, after performing tests on a sample the data will be stored under file name "3C" and then the sample will be stored in compartment "3C." This is useful so that samples are not confused or lost. The storage bin will be sealed with a single lid that will slide on and off the storage modules by a single actuator.

Concept 2

This design utilizes an actuated double linkage robotic arm to manipulate the sample. Three stepper motors are located along the length of the robotic arm. Operation of the end effector position is produced by a stepper motor at both the shoulder and elbow joint of the robotic arm. Two clamp rods are attached to the end of the arm to act as the end effector. One rod will be secured and stationary while the other will be actuated by the third stepper motor. The robotic arm assembly is placed on a platform, like a Lazy Susan, which will provide rotation of the manipulator. A motor will be used to generate the rotation of the platform.

Figure 9



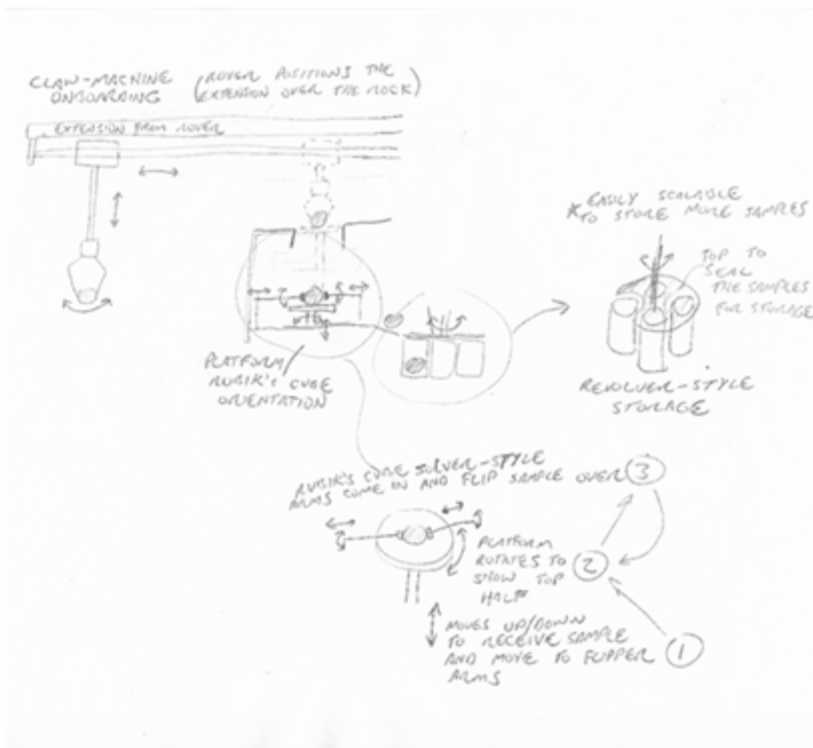
Once the sample has been collected, the manipulator will transport the sample to the other systems of the design. To begin, the manipulator will position the sample within the orientation area. When the sample is properly positioned the four orientation spinners will apply a force to secure the sample. The orientation spinners will be coupled with the spinner parallel to it. To reorient samples, a coupled set of spinners will retract from the sample allowing the other set of spinners to rotate the sample. This process of alternating retraction and rotating a set of spinners will allow any desired orientation of the sample to be achieved.

When the orientation process is complete the sample will either be returned to the surrounding environment or secured within the sample storage area. This is dependent on the sample's evaluated status from the sensors and scientific instruments. The manipulator will secure the sample from the orientation area using its end effector and transport it to its new area. If the sample is deemed unacceptable, the manipulator will return the sample to the surrounding environment. If the sample is deemed acceptable, the manipulator will place the sample within the honeycomb sample storage area. Honeycomb, hexagonal patterns provide high packing factors while remaining structurally sound. Each sample will be placed, by the manipulator, into one of the individual hexagonal storage containers.

Concept 3

This concept was generated by combining concepts from the morphological chart. For onboarding, the claw machine concept was taken. This concept consists of a 1D claw machine: the rover orients the extension over the rock, then the claw slides out and extends down to pick up the rock.

Figure 10



After the rock has been secured, it is moved inside the rover and placed on a plate or disc that both rotates and moves up and down. The plate lowers down to where the Rubik’s cube arms can securely attach and flip it over so the bottom of the sample may be scanned. After the sample has been tested, it is either discarded through a hole in the rover or it moves on to the storage section. The selected storage section is the revolver-style storage. It consists of cans or cups that rotate around after one has been filled. The cups would be padded to prevent damage to the sample and there would be a top plate that covers all but one cup to prevent the samples from accidentally falling out of the cups. The path on the morphological chart is shown below in Figure 11.

Figure 11

Subproblem Solution Concepts		
On-Boarding	**Orientation**	**Storage**
Robotic arm	Rubik's cube solver	Moon rock storage
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