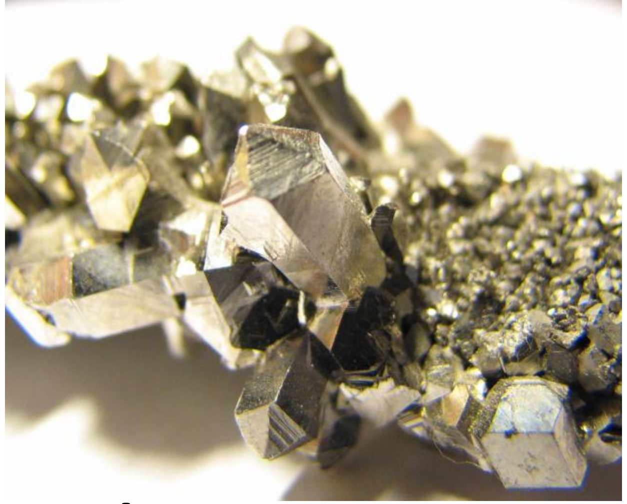


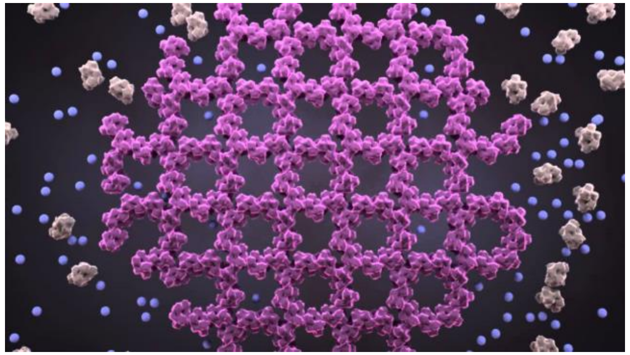



Crystal Growth Nano Lab

Glenn Johnson with Dave Schlicting

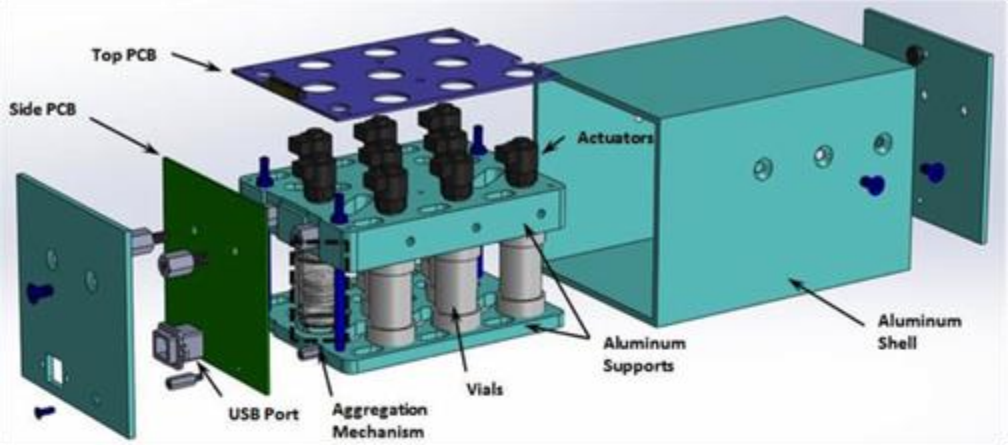
Research has shown that growing crystals in zero-g produces a higher quality of crystals than those grown on Earth. The reason is not well known but it is believed that the crystals are able to grow over a longer period of time without bumping into the sides of the containers that can cause imperfections. There are many materials that could be improved if larger more perfect crystals could be made— organic compounds like proteins for drugs, semi-conductors for computer chips, and metallic crystals for high quality metals. Researchers may have great questions that need to be answered but may not have the background or the time for putting together the equipment needed to fly their experiment to space.

Develop the box that could house a variety of different experiments and how to make the interior of the box so the person doing the experiment can arrange the components in the box to fit their needs.

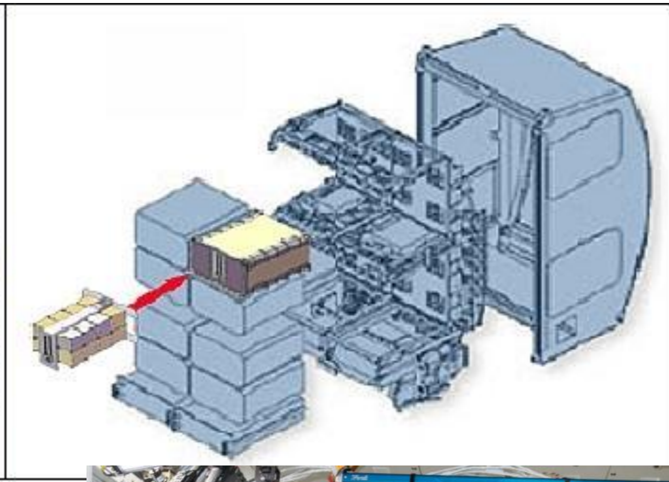




Nanolabs

- Nanolabs are small, autonomous, powered experiments that fit inside a specialized ISS Locker that are sent to the International Space Station for testing effects of microgravity on materials, processes, living organisms and many other experiments. These experiments are meant to be relatively cheap so many people and organizations can afford to develop an experiment for the space program. There are specific sizes and power requirements that the experiments have to meet. These are not new and many high schools, colleges and industries have participated in Nanolabs already.
- So far most of these Nanolabs have been specially designed for a very specific experiment. That will probably remain so for many future experiments. However, there are a lot of groups interested in doing an experiment in space but are daunted from doing it because they have to first develop the Nanolab platform for their experiment. This development can take a long time especially if you don’t understand all the requirements related to zero-g and the ISS.
- NanoRacks would like to partner with HUNCH students to develop a more generic Nanolab that would allow for a variety of experiments so people could concentrate more on the experiment they want to do rather than on the development of the Nanolab cube for their experiment.



Important General information about all Nano Labs



- All Nano Labs (modules) will be installed into a NanoRacks frame —up to 16 Nano Labs to an ISS Locker. This ISS Locker will travel up to the ISS on a supply vehicle and will be removed from the supply vehicle by an astronaut and placed in one of the EXPRESS racks on the ISS where it will be turned on by the astronauts. All of the Nano Labs inside the Experiment box will run autonomously for about 30 days. After that time, the astronauts will remove the Experiment box with all of the Nano Labs inside and place the Experiment box into a vehicle where it will be returned safely to the ground or be burned up in the atmosphere. You should expect that your Nano Lab will never be touched by the astronauts. All of the actions inside the Nano Lab will happen with out human hands. All of the data must come from the Nano Lab and into Space Station computers without human hands.
- All Nano Labs have to be sealed to prevent any contents of one experiment from contaminating another experiment or the living space for the astronauts. This also means there is little if any air exchange between the Nano Lab and the astronauts atmosphere.
- All electronics give off heat when in use. Heat transfer does not happen as fast in zero-g since there is no convection without fans to move the air. Heat transfer by conduction (contact between objects) works well. All of the NanoRacks modules will be cooled by air being blown into the ISS Locker from the EXPRESS rack. The exterior of the Nano Lab is made of aluminum and is a good heat conductor but the more plastic against the interior walls of the Nano Lab the slower the heat will transfer.

Shannon Walker activates NanoRacks

Crystal Growth NanoLab

Problem:

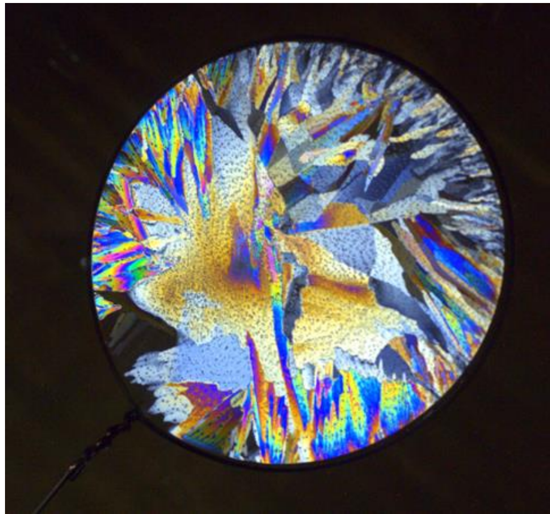
Research has shown that growing crystals in zero-g produces a higher quality of crystals than those grown on Earth. The reason is not well known but it is believed that the crystals are able to grow over a longer period of time without bumping into the sides of the containers that can cause imperfections. There are many materials that could be improved if larger more perfect crystals could be made— organic compounds like proteins for drugs, semi-conductors for computer chips, and metallic crystals for high quality metals. Researchers may have great questions that need to be answered but may not have the background or the time for putting together the equipment needed to fly their experiment to space.

Objective:

Develop the box that could house a variety of different experiments and how to make the interior of the box so the person doing the experiment can arrange the components in the box to fit their needs.

Requirements:

- Must fit into 10cm x 10cm x 20cm NanoLab
- The type of containers for good evaporation or electrolysis—this could be very complicated. As soon as you open the container so the liquid can evaporate and allow crystallization to occur, the surface tension of the liquid may allow the liquid out of the container and get all over the inside of your box.
- Methods for electrolysis.
- How should the containers be held so cameras can still see the formation of the crystals
- How **big** do the containers need to be? Can you find different sizes and options?
- Can there be different methods for how the reaction might be started once in zero-g
- Plan How cables for sensors and probes will be held in place
- If containers are rectangular would the corners become a nucleation site for the crystallization? Do the containers need to be cylindrical or some other shape?
- Find a good location for the control electronics that won't get wet but will allow good options for cable routing for the sensors and camera(s)—may need contact with aluminum NanoLab wall for conducting heat from electronics.
- Some of these methods for crystallization may not be possible because of the constraints in zero-g.



Methods of making crystals

- There are several ways to grow crystals and many different kinds of crystals that researchers may be interested in studying.
- Some of the Methods for growing crystals
  - Evaporation of solvent
  - Electro chemistry
  - Cooling from liquid state to solid state
  - Seeding a supersaturated solution with a crystal
  - Forming a solid by Precipitate—precipitates are usually considered amorphous solids . If they form slowly enough and with out bumping into a wall or the floor of the container, might they form into crystals?
  - Two liquids coming together to form a solid—epoxy,

- Because of the many different methods of growing crystals it may be difficult for a single crystal growth NanoLab to accommodate all of these options. It is helpful if your lab can do more than one of these types of crystal growth. Look for commonalities where possible
- https://www.popularmechanics.com/science/health/a21081495/crystal-grow-space-drugs/

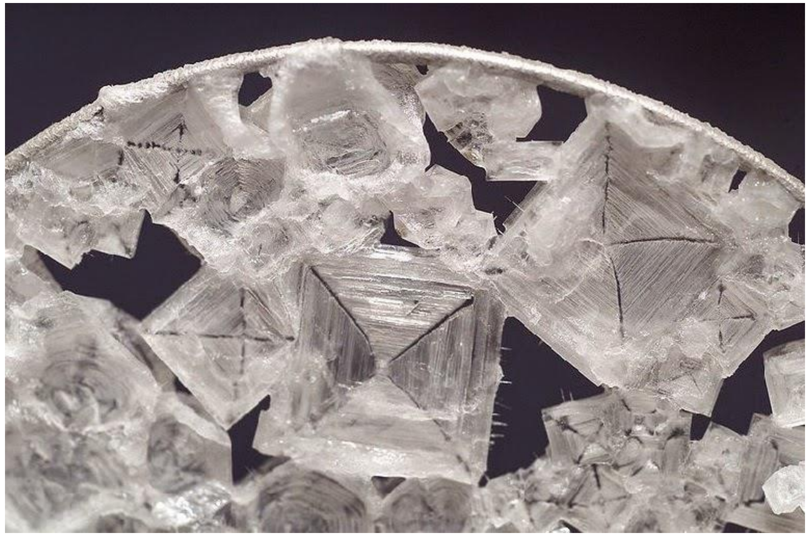
Evaporation of a solvent

A common method of making crystals is to dissolve a material like sugar or salt into water and then allow the water to evaporate and leave the salt or sugar crystals to grow. The longer the water takes to evaporate, the bigger the crystals may become. This could be done with many solutes besides sugar and salt and even with different solvents besides water. One of the difficulties with being inside of a Nano Lab is that there won't be much of an air exchange so there won't be much evaporation into the rest of the station.

Astronauts have evaporated salty water and brought home salt crystals grown in zero-g. They have also frozen water in zero-g and brought home ice crystals grown in zero-g.

http://lateralscience.blogspot.com/2014/10/nasa-microgravity-hopper-crystals.html

- Is it possible to use a desiccant pack to absorb moisture from the internal volume of the Nano Lab to allow evaporative crystallization to happen?
- Which kind of desiccant packs would be more effective?
- How is the desiccant pack held so it can absorb moisture but doesn't bump into the saturated liquid—no contact?
- How is the saturated solution held in place so it doesn't get all over the inside of the nano lab but is still able to have exposed surface area so the liquid is able to evaporate?
- What kind of lighting is needed to see the crystals forming?
- Are the concentrations of the materials needed to be observed and tracked as the solvent evaporates? Are there instruments that can provide data?
- What kind of container could be used to hold the liquid?
- Could a droplet of liquid be held at the end of a syringe and the crystals be allowed to form slowly then more liquid ejected from the syringe so that it is a somewhat continuous feed of liquid?



These are salt crystals that were grown on the ISS by way of evaporating the water out of a saturated salty solution that was held in a loop of wire. --Don Pettit https://www.youtube.com/watch?v=CDXyt2r9oNs

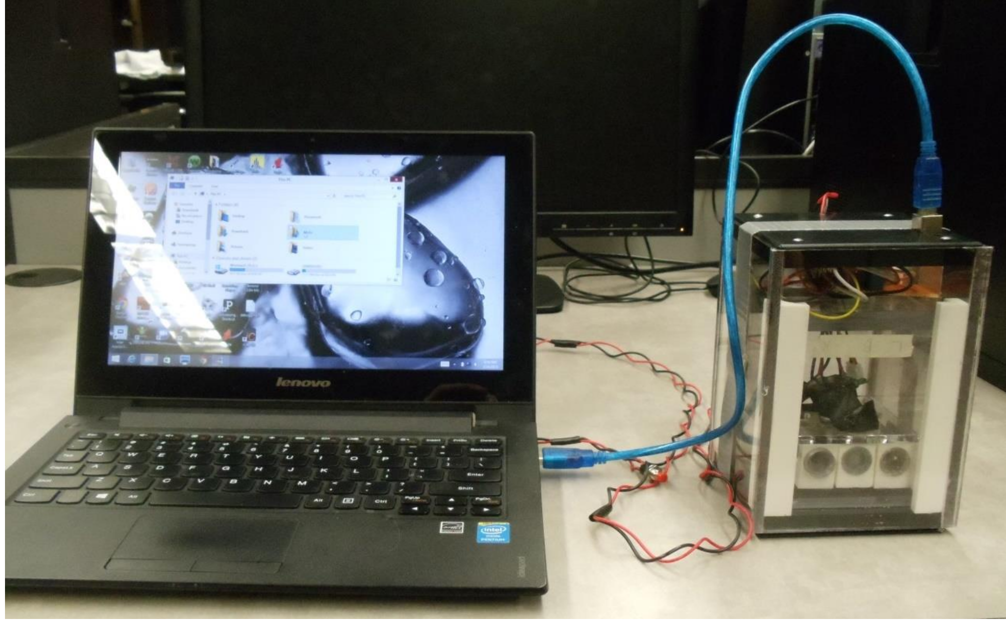
https://blogs.nasa.gov/letters/2012/05/30/post_1338407623748/

Electrochemistry

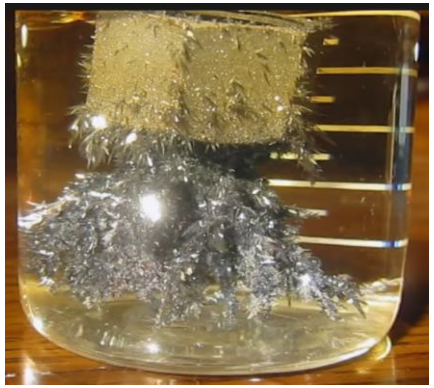
- Here are a few videos to help you understand some of what the researchers may be interested in.
- https://www.youtube.com/watch?v=teTkvUtW4SA
- https://www.youtube.com/watch?v=7b34XYgADlM
- Electroplating
- https://www.youtube.com/watch?v=NClagKbLUMM
- Electroplating part 2
- https://www.youtube.com/watch?v=0NwSY58g1uY

Driven by electric current

- The researchers will only have up to 5 Volts and 3 amps available
- They will need to avoid making hydrogen gas by using .8 volts or less (as applicable)
- Driven by electronegativity of another material
    - Example--Pressing zinc needle into a vial of lead acetate



This is an experiment done by students from Eaglecrest H.S. in Colorado where they grew silver crystals by way of electrolysis in zero-g from silver nitrate. There are 3 vials each with anodes and cathodes. There was a computer board to run the experiments through the twenty parabolas that provided each of the 20 seconds of zero-g.



Lead crystals forming on a brass nut (zinc) in a lead acetate. Single replacement reaction.

Cooling from liquid state

Most metals and compounds melt at fairly high temperatures that would be dangerous on the ISS even when contained within a Nano lab. (we don't want astronauts bumping into hot boxes) Because a Nano Lab is a sealed container, there is also a limit as to how much heat it will be able to reject within a certain time. There is airflow in the

There are a few elements and metal alloys that melt at low temperatures (less than 200 C, some less than 100C) and when allowed to cool slowly in zero-g may form metallic crystals that are different from what would be made on Earth. Studying metallic crystals that form by cooling could be valuable for understanding crystal formation in other metals or compounds.

Fields metal

- https://www.globalspec.com/learnmore/materials_chemicals_adhesives/metals_alloys/fusible_alloys

Bismuth

- https://www.indium.com/blog/the-6-alloy-families-bismuth.php

Some materials like silicon are purified by zone refining where impurities follow the melted liquid portion and a purified material remains in the re-solidified portion of the material. Its not our job to make this happen but if we can facilitate some of the initial studies, we are helping science along.

- Germanium purification by zone refining.
- https://www.youtube.com/watch?v=pgX4Xlw0NbM
- Silicon purification by zone refining
- https://www.youtube.com/watch?v=ROAB33vFVvQ

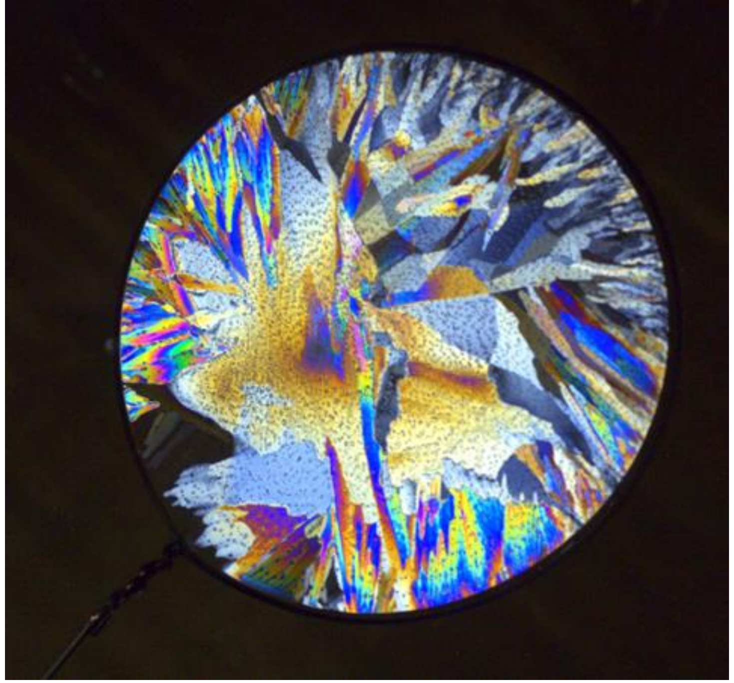
- Could you use a USB coffee cup heater to melt a low temperature metal or other substance once in zero-g and then allow it to cool over a long period of time?
- How would you arrange the heating element?
- If the meltable substance was stuck to the heating element like ice on a popsicle and then it gets melted, does the melted material need to be contained or would it just stick to the heating element?
- How long might it take for everything to cool considering its in the box and zero-g?
- How would the heat affect the electronics in the box?
- Less structure inside the box would allow the aluminum box to conduct heat out faster. Do you want it to stay hot longer or shorter for the crystal growth?

Coffee mug heater

- https://www.google.com/shopping/product/1?q=coffee+mug+heater+usb&prds=epd:1768413177385261158,eto:1768413177385261158_0,pid:1768413177385261158,prmr:1&sa=X&ved=0ahUKEwjJkZbOgOHxAhUCP6wKHfeWAuYQ9pwGCAc

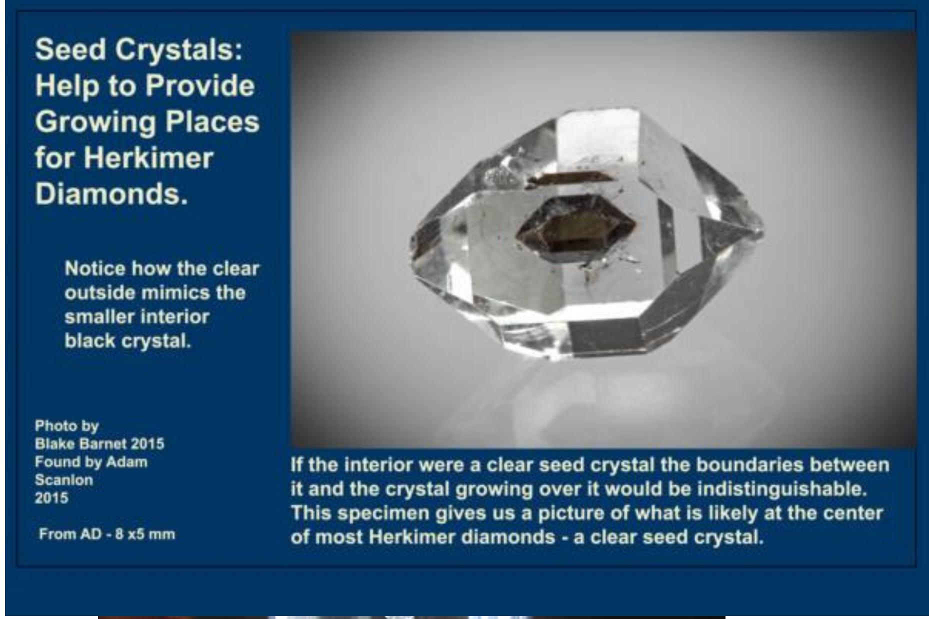
Low melting point metals

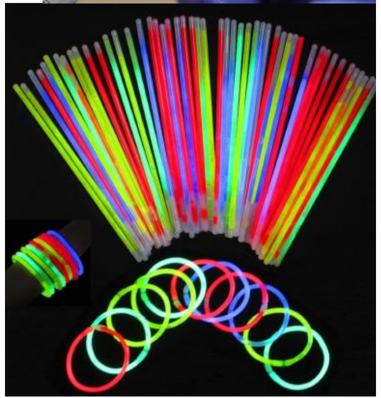
https://www.youtube.com/watch?v=JI9qKbQCukg



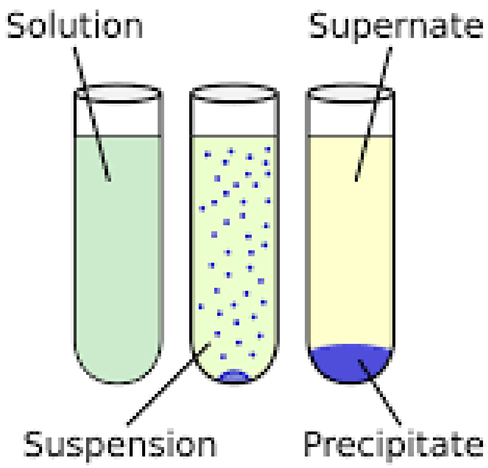
These are ice crystals grown in zero-g in an ISS freezer that were allowed to freeze as a thin film of water on a loop of wire. They are being viewed through polarized light to show the crystal structure.—Don Pettit https://blogs.nasa.gov/letters/2012/05/30/post_1338407623748/

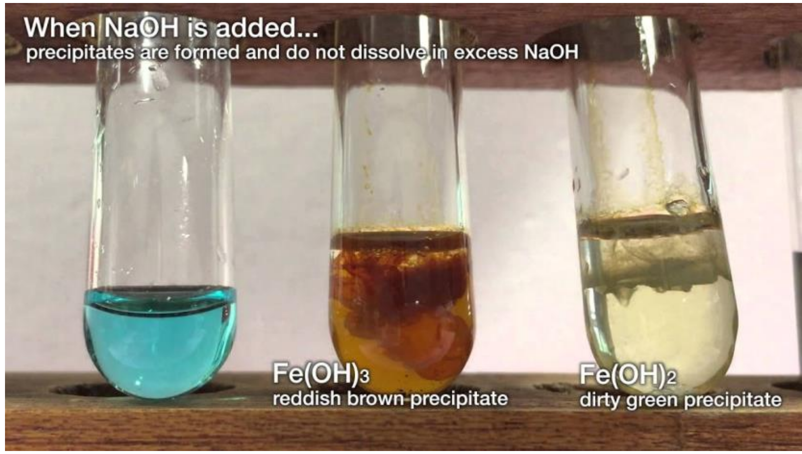
- Mechanical means of introducing materials to each other
  - If the solution is too highly saturated during launch, the vibrations could cause crystallization.
  - Seeding a saturated solution with a crystal to initiate crystallization
    - A rubber stopper of a vial containing a saturated solution could be penetrated with a needle containing a crystal
  - Seed crystals are contained in a separate vial that gets broken by mechanical motion– like in a glow stick

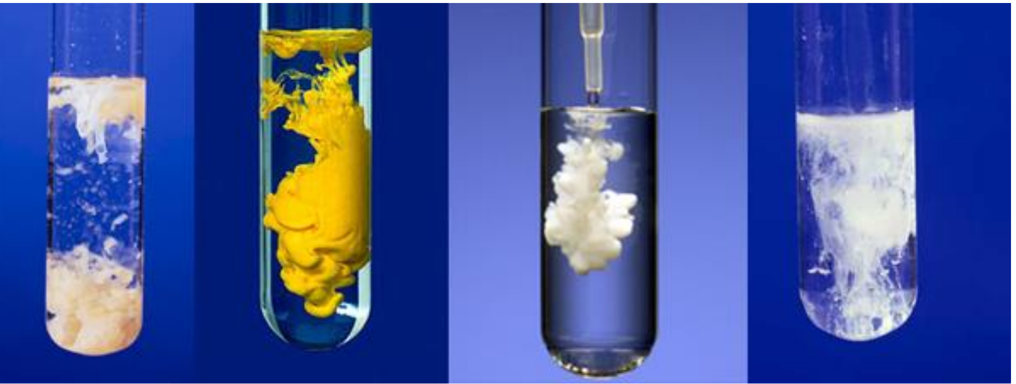




- Precipitate reaction
  - **Precipitation** is the process of generating solid from the solution caused by supersaturation when the concentration of the solute is higher than its solubility. This term is usually interchangeable with "**crystallization**", but differs in that it can also indicate the formation of amorphous (non-crystalline) solid.
    - Would precipitation in zero-g allow for crystallization?
    - If it happens slowly enough in zero-g would there be crystallization?
  - Example- CdSO4(aq)+K2S(aq)→CdS(s)+K2SO4(aq)



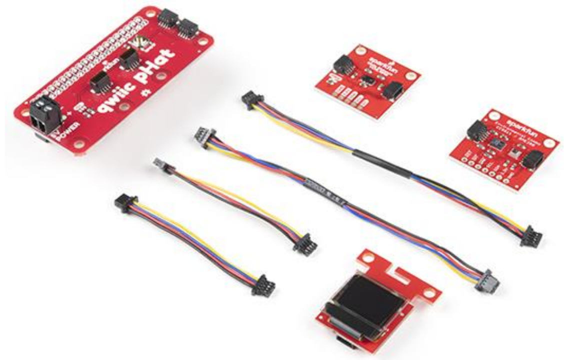




Hardware to consider

- **Crystallization Lab**
- Temperature (internal temp)
- Thermocouple (experiment temp)
- Humidity
- O2
- CO2
- Lights
- Camera(s)
- Motor (2)
- pH sensor (2)
- Infrared camera
- H2 sensor
- Voltage
- Resistance
- Amperage
- USB heater

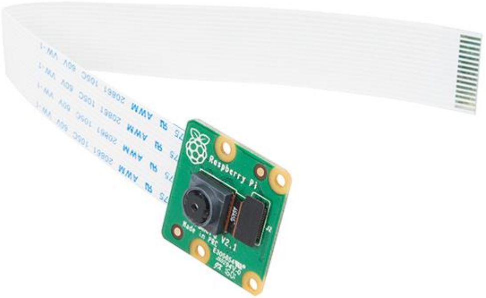
These are a few of the sensors and equipment that should be considered for your lab. You are trying to develop a NanoLab that many people could use to do their research with and not have to alter it significantly. It is impossible for your team to be the ‘everything lab’ for every researcher but try to give as many options as possible. There are limits for how many things can be in this confined space and still have enough room for mushrooms to grow. Remember to include cables and motor drivers as needed. There will be cables and they will need to be held down so they don’t vibrate loose during launch and then get in the way of cameras or get cut like the mushroom.

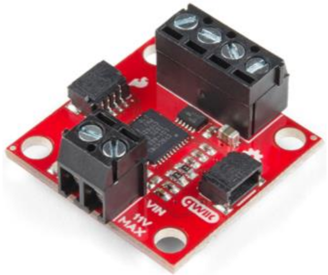


Read through the NanoLab GUI to understand the other team’s responsibilities.

Your job is to show a variety of ways how all the parts can be arranged inside the NanoLab and how they will attach so they don't vibrate out of place during launch. It is important for you to show where the lights, camera and other electronics go and even how it will look but you are not doing the programing. That will be the job of the students who are developing NanoLab Software GUI.
It is your job to work the mechanics of the how the NanoLab will function but still allowing room for the researcher to be creative(kind of like Legos-make it so you can do many things, not just one experiment).

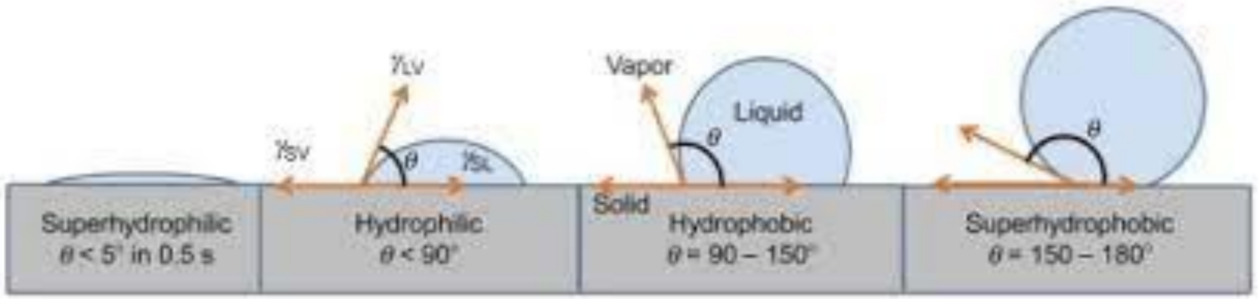
HUNCH can not afford to send everyone a Sparkfun Kit—only the GUI teams. In the table you can see the dimensions of many of the components that researchers may want to use. I found the dimensions on the Sparkfun web pages for the part (usually under features). You can get more detailed information for each of the parts from the Sparkfun website. You may also find other components that you think would be valuable for your NanoLab.





SparkFun Part Number	description	Qty	Notes
PRT-08430	Jumper Wires Premium 6\" F/F Pack of 10	1	155mm +/-5mm long, 26 AWG
TOL-13831	5.1V DC 2.5A Wall Wart (USB Micro-B)	1	AC to DC power supply
DEV-14028	Raspberry Pi Camera Module V2	1	25mm x 23mm x 9mmc, 15cm ribbon cable
PRT-14272	Pi Zero Camera Cable	1	
CAB-14274	MiniHDMI	1	
CAB-14276	USB OTG MicroB Cable	1	
PKG-14011	Large Red Box (9.25x6x2)	1	box it comes in
COM-15052	SparkFun Noobs card Raspberry Pi	1	
DEV-15470	Raspberry Pi Zero WH	1	65mm long x 30mm x20mm
ROB-15451	SparkFun Qwiic Motor Driver	1	25.4mm x 25.4mm x 12.5mm
PRT-16662	Jumper Wires Premium 6in. M/M Pack of 2: Red and Black	1	
WS2812B	SparkFun RGB LED Breakout - WS2812B w/ Headers	1	24 mm x 22mm x 5mm
KIT-16841	SparkFun Qwiic Starter Kit for Raspberry Pi	1	65.00mm x 30.5mm x 10mm
ROB-10189	Servo - Generic Continuous Rotation (Micro Size)	1	42.8mm x 33mm x 16.5mm

Hydrophilic vs hydrophobic



- These properties could be helpful in designing or choosing some of the materials for your NanoLab.
- Hydrophobic materials are things that repel water. Hydrophilic materials are things that attract water. Most materials are somewhere between. A freshly waxed car is more hydrophobic and you can see how the water beads up on the paint. However, a car that has been washed but not waxed, the water sprayed onto it will make a thin coating across the surface—hydrophilic.
- Depending on the solvent and solute, you might be able to find a container material that will contain it by the surface tension.
  - Example—by having a bottle that is hydrophobic you might be able to push water out of the bottle. By having a bottle that is hydrophilic you might be able to have water coat the bottle. By having a bottle that is hydrophobic on the outside but hydrophilic on the inside you might be able to keep it in the bottle

  https://www.youtube.com/watch?v=yxyCLoYfexo

  https://www.youtube.com/watch?v=GcdB5bFwio4

Beading of water shows that the water is being repelled. The unwaxed side (before) is hydrophilic and the waxed side (after) is hydrophobic.

What kind of container could be used for holding the solvents

Should be transparent for photos and video
Some type of sturdy plastic
Can install sensors in the container
Can hold pressure as the microbes make CO_2

Medical IV bags

Soda bottle blanks