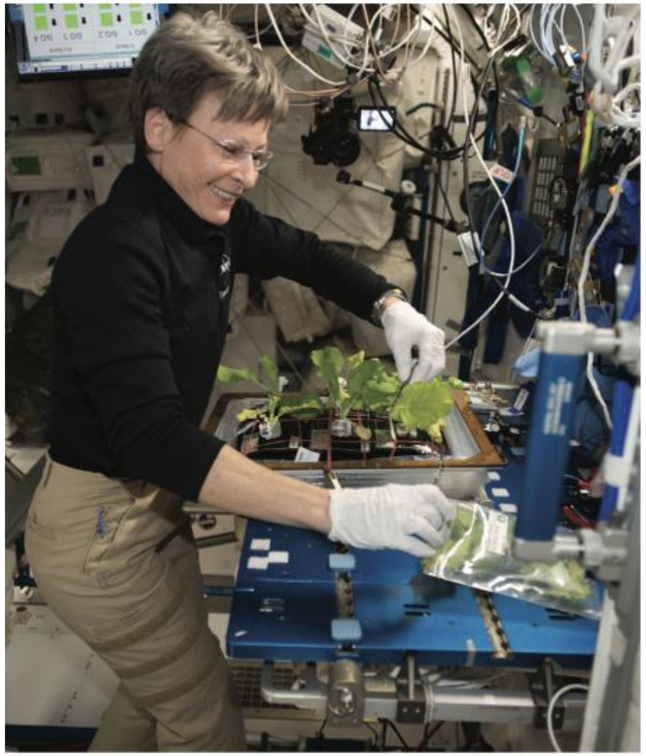
Nanolab for Space Crop Production

Project Background/Description
As humans begin to explore space, ensuring that astronauts are well-nourished and satisfied through their meals will ensure that they have the capability to conduct research and push the bounds of the human presence in our universe. NASA identified the development of space crop production systems as a potential solution to provide astronauts with a proper food supply. While many have developed and deployed, one fundamental issue persists: water delivery.

Fluid management includes fluid transport to orbit, liquid storage/supply, fluid transfer/resupply, and integral thermal control. However, liquid storage/supply and transfer/resupply has been a challenge for all space crop production systems, which prevents astronauts from relying on them for food supply. This issue stems from the lack of understanding of the fluid physics in porous media (i.e., a material containing pores or voids) under low-gravity conditions. Due to the limited resources in space travel, the ideal water delivery system would be completely passive (i.e., requiring no mechanical or electrical inputs) and have reduced input needs (i.e. growth media).



Challenge Objectives:
Design, build, and test a fully functional 2U Nanolab for a material testing system where NASA researchers can explore the fluid physics of different potential growth media materials to improve upon the design of space crop production systems for space.

Requirements for Nanolab for Space Crop Production

Challenge Objective:
Design, build, and test a fully functional 2U Nanolab for a material testing system where NASA researchers can explore the fluid physics of different potential growth media materials to improve upon the design of space crop production systems for space.

The system should:
- Include the option/method to change the growth media materials
- Have a method for moving fluid in and out of the growth media
- Include any required sensors, electronics needed, etc. to study the overall system and be self-contained.
- Programmable circuit board (Arduino, Raspberry Pi, etc)
- Camera
- Light – So camera can record images, especially when the Nanolab is sealed.
- Sensors (temperature, humidity, PH, etc. Teams decide what they need to measure)
- System will have continuous power via a 5V USB

Designing a fully functional Nanolab experiment is a formidable challenge. We strongly recommend that at least three teams work together:
- Team 1: Mechanical Team: Design, test, and build the 2U Nanolab. See the reference page for a google drive link for a "Universal Nanolab" CAD designs that previous HUNCH teams have been developing. These designs are primarily for the internal structure to house the experiment, electronic attachments, and experiment chamber. You may also build from scratch if you prefer.
- Team 2: Programming Team: Create the GUI program or logic control that will run the experiment. This will include the programmable circuit board that will control the sensors, cameras, light and provide power to the 2U Nanoloab
- Team 3: Material Team: Design and test the substrate experiment. You want to find the right type of material that will allow water to enter in and out of the material and also find a plant to grow in the material.

Finalists for the HUNCH Showcase must submit video verification that their Nanolab is fully functional. One team from the Showcase finalists will be selected to have their Nanolab tested in the Zero-Gravity Testing Facility at the NASA Glenn Research Center. Team members and their teacher will be invited to NASA GRC for testing and site tours. Travel expenses are the responsibility of the Nanolab team.

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 Nanolabsalready
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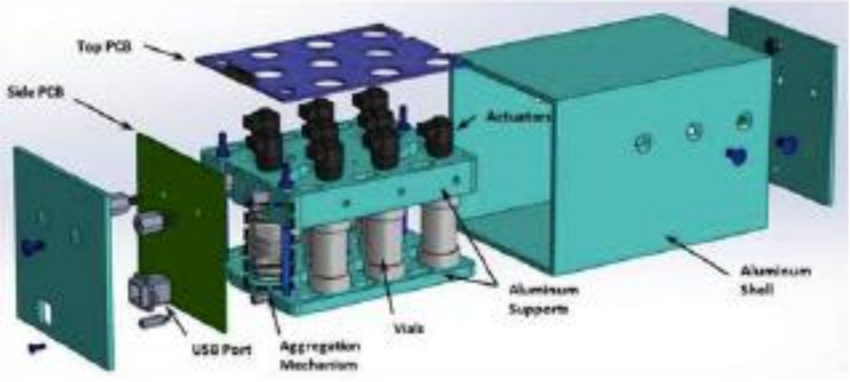
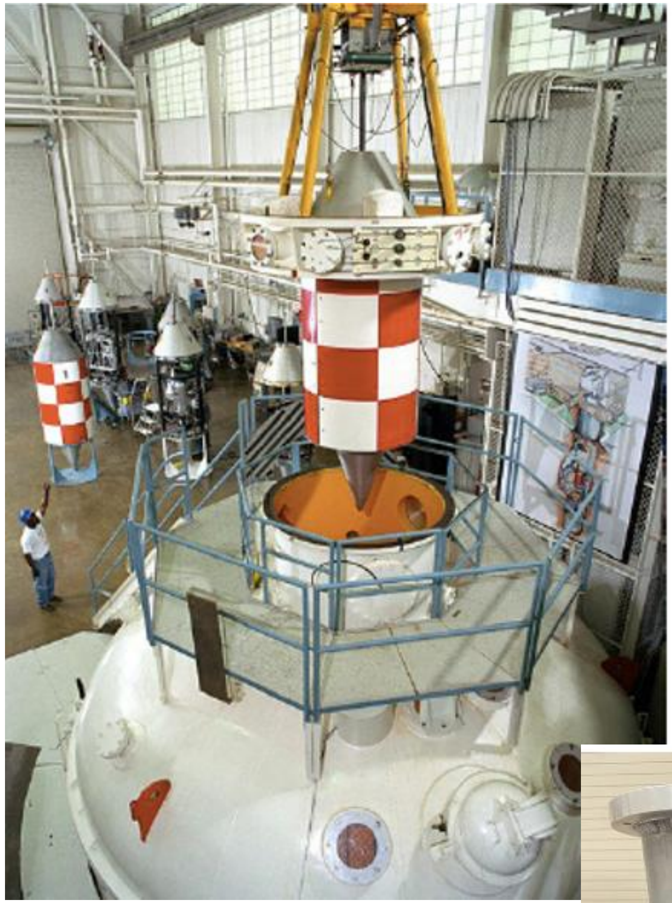
- So far most of these Nanolabs have been specially designed for a very specific experiment. That will probably remain so for many future experiments. However, there are a lot of groups interested in doing an experiment in space but are daunted from doing it because they have to first develop the Nanolab 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.



Zero-Gravity Facility Nanolab



- NASA Glenn has designed NanoLab Hitchhiker investigation. The Nanolab investigation operates as a piggyback to the primary experiment conducted in the Zero Gravity Research Facility, riding in a sealed vessel located in the top cone of the drop vehicle.
- The Zero G Facility will accommodate 1U and 2U size NanoLabs and will offer a USB interface for power and data exchange.
- The Zero G Facility will also offer investigators the capability of varying the pressure and atmosphere around the NanoLab with ambient pressure capability ranging from vacuum to 1 atm.

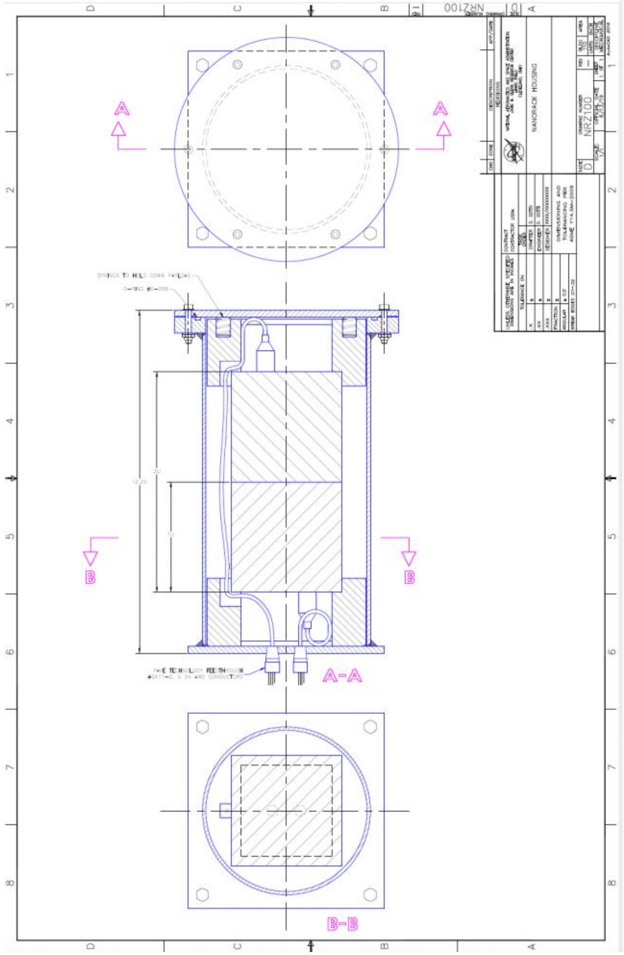
- Nanolab Volume will consist of either:

1U (10 cm x 10cm x 10cm) or 2U (20 cm x 10 cm x 10 cm)

- Low Gravity Duration: 5.18s
- Atmosphere: Air or user requested atmosphere, vacuum to 1 atm
- Communication: USB 2.0 or 3.0
- Power: 5 VDC, 0.9amp, via USB
- Up to 2 tests per day
- Investigation is oriented vertically

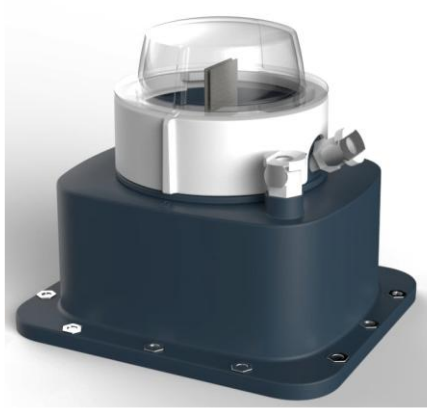
Zero-Gravity Facility Nanolab FAQ

- **Is the USB port on the nanolab used for powering items in the nanolab?**
  - Yes the nanolab is powered by usb.
- **What is the voltage and amperage in the USB connection?**
  - 5VDC, 500mA
- **How is the nanolab activated?**
  - The drop vehicle supplies 24VDC, sends the drop command signal and release signal to the Nanolab controller box.
- **How is the nanolab oriented for a drop? It's 10x10x20cm so is the longer side vertical or horizontal? Can the orientation be requested or is it fixed?**
  - It is oriented vertically (long ways), and that is fixed. We are unable to change this orientation.
- **Where is the location of the USB port on the nanolab?**
  - It is on the top portion of the 2U housing.
- **Do you have a drawing that shows the location of the USB port?**
  - See photo on left and the file can be shared with student teams.



Different types of material delivery system that flew on ISS

Passive Orbital Nutrient Delivery System (PONDS)



Opaque PONDS module

Clear PONDS module

Veggie

Left: Astronaut Drew Morgan checks on plants in Veggie

Below: Pillows (containing arcillite) sitting on "water reservoir"

Advanced Plant Habitat

Astronaut Megan McArthur checks chile plants in APH

APH Science Carrier

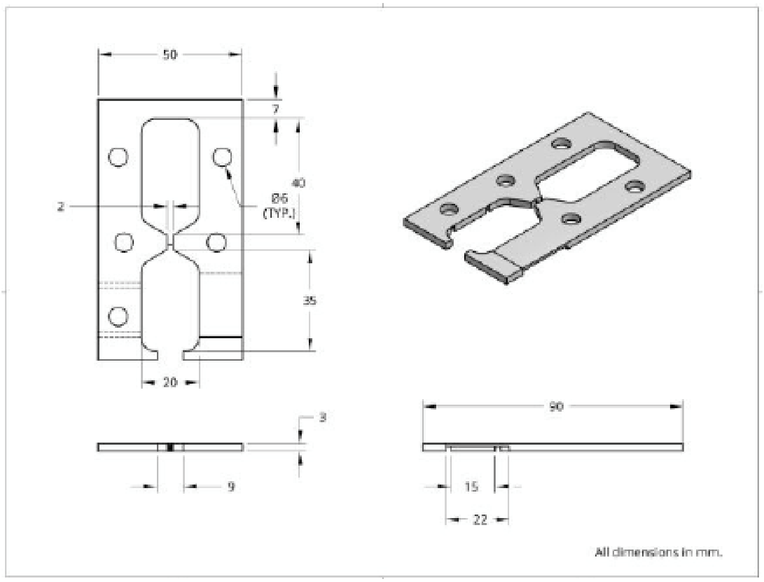
Plant Water Management – Soil

PWM Soil Test Cell Aboard ISS in JEM

Above: Astronaut Mike Barratt Primes PWM-5 with test fluid.

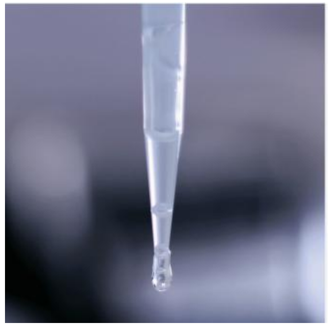
Methods for liquid movement.
There are many ways that you can move fluids:

Hele-Shaw Apparatus is a device used to demonstrate 2D flow.

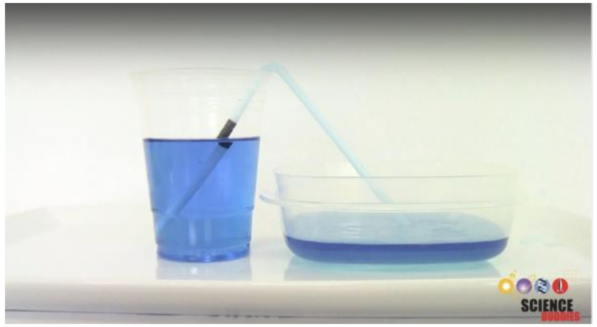


Hele-Shaw designed used with permission from The Ohio State University Design Team

PVC pipe gardens



A pipette



Syphon Straw

Things to Keep in Mind

To study the fluid physics seen in a space environment, researchers on Earth can exploit scaled capillary models to utilize surface tension forces to drive fluid flow rather than gravitational forces.

Static shape of gas-liquid interface

- In absence of other forces, the interface wants to assume minimum surface area to volume – a spherical shape.
- Contact angle must be satisfied. Sharp edges will "pin" interface –keep it from moving

Factors Impacting Surface Tension & Contact Angle

- Temperature Increases . . .
  - Decreases Surface tension
  - Increases evaporation at Contact line
- Mixtures and/or impurities affect both surface tension and contact angle.

Capillary Action Demonstration

Utilize one jar with arcillite and other with water w/ food coloring.
Use nylon string to connect the two jars and observe over time.

START

5 MIN

30 MIN

60 MIN

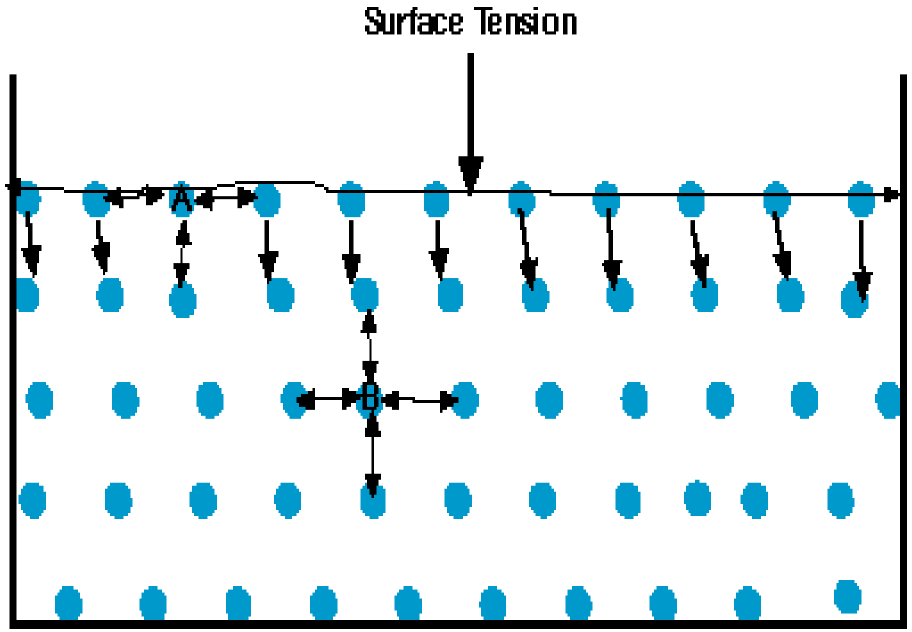
100 MIN

150 MIN

Photos used with permission from UT at Austin Design Team

Surface tension

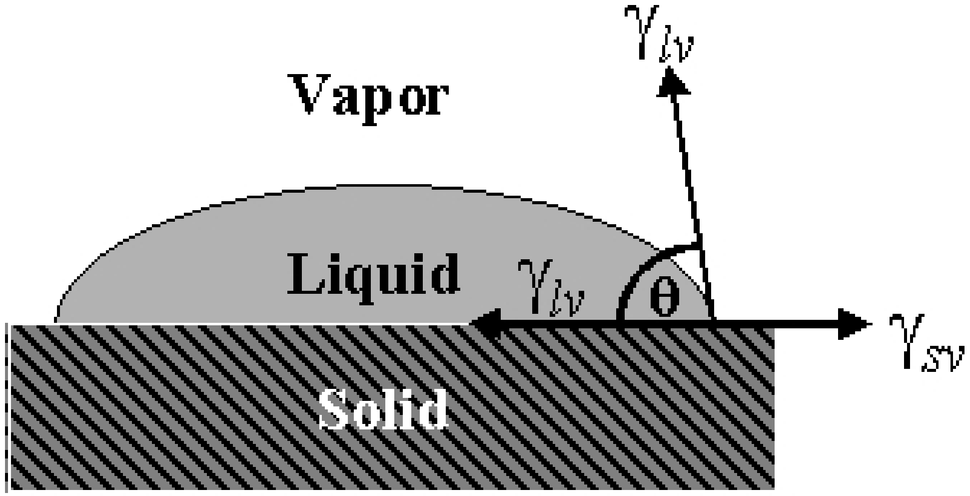
- Water is made up of molecules which attract each other.
  - In the middle of a body of water, molecules attract each other in all directions.
  - On the surface of the body of water, however, the water molecules are more attracted to the water molecules inside the body than they are to the air molecules surrounding the surface.



- Water in air tries to pull itself into the shape that results in the least contact between air molecules and water molecules. This shape is a spherical drop.
- The molecules on the surface of a liquid behave like an elastic sheet and can be stretched and poked.

Contact Angle

- Another surface tension related property.
- Angle formed where three two fluid phases and a solid come together.



- A condition is considered to be "wetting" when contact angle is less than 90°.
- A condition is considered to be "non-wetting" when contact angle is greater than 90°.
- Barrier coatings can be place on surface to alter wetting behavior, e.g., water spreads on car surface, but apply car wax and water "beads" up on the car.

Resources and Links:

Nanolab resources:

https://nanoracks.com/products/nanolabs/

https://nanoracks.com/wp-content/uploads/Nanoracks-Nanode-IDD.pdf

https://www.hunchdesign.com/uploads/2/2/0/9/22093000/how-to-build-a-nanoracks-payload.pdf

Nanolab CAD resources

https://drive.google.com/file/d/1C8teEPlKzLn_0ukokXT8t4zZWqxp_NKZ/view?usp=sharing

https://drive.google.com/drive/folders/1gm5sa8cedOTokNrj_1Lj8vdic8TLJGaa?usp=drive_link

Material Delivery Systems that flew on ISS resources

https://science.nasa.gov/mission/veggie/

https://science.nasa.gov/mission/advanced-plant-habitat/

https://www1.grc.nasa.gov/space/iss-research/mwa/plant-water-management-pwm/

https://www.nasa.gov/mission/station/research-explorer/investigation/?#id=7884

https://issnationallab.org/facilities/passive-orbital-nutrient-delivery-system/

Requirements for NanoLab for Space Crop Production

1. This is a test for learning about capillary action in zero-g. 5.1 sec of drop time.
2. 10cm x 10cm x 20cm Nanolab should be in the vertical orientation—(20cm up)
3. Test Container for at least one substrate material for capillary action connected to the water reservoir
4. Have a second test container for an alternate substrate material for capillary action.
5. Container for no more than 50 ml of water
6. Method of opening connection from the water reservoir to the substrate material container that can be opened just before dropping
7. Controlling circuit board (Arduino or raspberry Pi or…., ect) Camera, light(s), sensors for measuring water movement in substrate, control to actuator for letting water into substrate material
8. USB connections on the top of the Nanolab to receive power, data and a signal from the payload. System will have continuous power via a 5V USB
9. Camera, lights, and sensors should be capable of measuring fluid movement during 5.1 sec. drop test.