

Hybrid Piezoelectric–Solar Power, SymPonics (Combined Aquaponics, Aeroponics and Hydroponics) Agriculture and more for Prospective Space Settlements

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Energy Sources

The Mission will rely on a new type of energy source, that is, a Hybrid Piezoelectric-Solar Based Power Generation System. To store the energy generated by this the settlement uses a sodium-ion battery, as it is more environmentally friendly than lithium-ion batteries.

Hybrid Piezoelectric-Solar Based Power Generation System combines solar panels and piezoelectric crystals to harvest both solar energy and mechanical vibrations. The combined output is regulated by a Buck-Boost convertor to provide a stable supply.

Energy from both sources will go into energy management electronics with an energy system like sodium-ion batteries.

The Hybrid Piezoelectric-Solar Based Power Generation System would also be equipped with an algorithm to analyze incoming sunlight, vibrations, and the crew's activity patterns in real time. This software predicts when energy will be plentiful or when more power will be needed and tells the Buck-Boost convertor to send the right amount of electricity to the sodium-ion batteries. The result is a self-adjusting power setup which will ensure there is always enough energy.

LEDs will be used to light up the settlement due to their low-energy consumption. The light intensity can be modified as needed.

Food Cultivation Techniques

The settlement will have different food cultivation techniques located in a section of the inner rim. Some cultivation methods will be aeroponics, hydroponics, aquaponics, Bioregenerative life support systems (BLSS), Advanced Plant Habitat (APH).

3D Food Printing Techniques

3D food printing in space utilizes additive manufacturing techniques to create shelf-stable meals for astronauts. This is enhanced by inkjet printing which adds flavors. Although binder jetting and laser

sintering investigate the production of solid foods from powdered ingredients, more experimental techniques such as biomanufacturing use cellular agriculture will be there to create meat-like textures.

Substrate-based (porous media) systems

Polyurethane foam, basalt or biochar granules, expanded clay pellets (LECA), sintered glass beads, and specially designed "plant pillows" composed of layered nonwoven textiles. Each of the shallow trays that make up the cultivation modules has plant compartments that are connected to a central reservoir by porous membranes or capillary wicks. By enabling drainless operation, this technique stops fluids from forming that float freely in microgravity. Vents help maintain stable root area conditions by preventing the accumulation of air pockets. Meanwhile timed, small injections of water and nutrients are administered directly into the pillows or through passive capillary recharge from the reservoir.

Bacterial Electroculture Bioreactor

Microorganisms in the bacterial electroculture bioreactor are powered by electricity provided by the piezoelectric crystals and use carbon dioxide and water to produce nutrients and usable, healthy food produce. This doesn't require sunlight or soil hence conserving resources in space.

Recycling and Resource Management

The settlement will consist of 3 main recycling machines. The first will be the Water Recovery System, which will convert urine, sweat and other waste into water. It will put the waste liquid through crystallisation, nitrification, electrodialysis, mixing, nanofiltration, reverse osmosis to convert it into a usable form.

The second will be the Air Revitalization System. This system will remove carbon dioxide and refill oxygen using chemical scrubbers, plants or algae tanks.

The third is the Food Recovery System. This system has numerous different methods to convert waste into edible food for people on the space settlement.

Food Recovery System

Hydrogenotrophic bacteria can convert (like *Cupriavidus necator*) can convert $\text{CO}_2 + \text{H}_2 \rightarrow \text{protein paste}$ (~60% protein). This can act as a nutrient dense microbe meal that can be mixed into other meals to increase the protein content in the meals.

Fungi like *Aspergillus oryzae*, *Rhizopus* can digest complex waste like cellulose, food scraps, and human waste. Their mycelium can then be harvested as edible biomass or used to grow mushrooms. Some strains even produce vitamins during digestion.

SymPonics

This system on the settlement is a combination of aeroponics, hydroponics, and aquaponics. The name SymPonics is drawn from 'Sym' and 'Ponics'. 'Sym' refers to cooperation between systems and 'Ponics' means working without soil.

It will have nine core components-

1. Fish Tank (Aquaponics)
2. Mechanic Filter
3. Biofilter (Nitrification)
4. Hydroponic zone
5. Aeroponic chamber
6. Sump/Reservoir
7. Pump + Valves
8. Controller
9. Lighting and Frame

This system will work in the following way-

First, fish will be fed in the tank. They will produce waste (ammonia). The solids will settle down in the mechanical filter and that water will go to the biofilter in which the bacteria turn the ammonia to nitrite and then nitrate.

After that, the nitrate rich water is separated and sent to two chambers: -

1. Hydroponic Channel: Water flows through NFT pipes or media beds so that it can feed large plants like tomatoes, carrots, sweet potatoes and cucumbers.
2. Aeroponic Chamber: Pressurized pump will atomize the water into a fine mist (10–50 μm droplets) around roots of fast-growing plants like collard greens, spinach and herbs.

In aeroponics, fine mist maximizes oxygen exposure → super-fast growth.

In hydroponics → nutrient film provides steady hydration and minerals

Extra water will get collected inside the sump → it will get filtered again → it gets pumped back to the fish tank.

The cycle repeats continuously hence forming a closed loop ecosystem.

Advantages of SymPonics over conventional space farming

CATEGORY – SYMPONICS - NORMAL SPACE FARMING

WATER USE PER kg FOOD - 15-20 dm^3 PER PRODUCE - 200-300 dm^3 PER PRODUCE

LAND USAGE EFFICIENCY - 1 m^2 YIELDS ~ 35 kg/YEAR - 1 m^2 YIELDS ~3 to 5 kg/YEAR

ENERGY USE PER kg OF FOOD - 0.8-1kWh - 2-3kWh

FERTILIZER USE - 0 (FISH WASTE ONLY) - 2-3kg

CO2 EMISSIONS - 0.5kg - 2-3kg

(Based on experiments and tests done in real life)

Crop and Fish Selection (Crops or Fishes that will be grown/cultivated)

1. Carrots, Spinach, Sweet Potatoes (They give good vision and strong immunity)
2. Goldfish (Ammonia in their faeces)
3. Salmon, herring and trout (They are rich in Vitamin D)
4. Collard greens (Rich in Calcium)
5. Tomatoes, Herbs, Lettuce, Cucumbers and other crops preferred by the crew on the settlement
6. Onions and Bell Peppers

Diet Plan

Morning 7-8 AM Amaranth granola with spirulina yogurt, sliced kiwi, baobab drizzle - Protein, fibre, antioxidants, vitamin C

Noon 9-11 AM (optional meal) Purple sweet potato sticks, walnuts - Fiber, vitamin A, omega 3

Afternoon 12-2 PM Grilled salmon or trout, roasted sweet potatoes, steamed collard greens lettuce, herbs - Protein, omega 3, calcium, magnesium, vitamin C

Late Afternoon 2-4 PM (optional meal) Cucumber, carrot stick with hummus - Fiber, vitamin K, healthy fats

Evening 6-9 PM Fonio pilaf, herring, potatoes, sautéed collard greens - Protein, iron, omega 3, vitamin A and C

Nighttime 10-11 PM (optional meal) - Bowl of berries Antioxidants, fibre

This diet plan will ensure at least these many nutrients in a person's diet- ~2000 kcal, ~70g protein, ~82.5mg, iron ~13mg, calcium ~900mg, omega-3 ~1.5g, ~28g fibre, vitamin C

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