

## **SUSTAINABLE HABITAT DEVELOPMENT**

**Donald Jacques**  
EarthSeed, Inc  
theDuck@EarthSeed.Space

### **Introduction**

The challenges of sustainable living beyond the biosphere of Earth on the frontier of the Moon and Mars, are innumerable. Most challenging are the issues involved in daily tasks to maintain the habitat/home ... in the wilderness, with little "timely" contact with others, back home.

With the estimated time involved in travel to Mars between 5-9 months, any human habitat must be self-sustaining at its establishment. Not only is supply an issue, but the day to day operations of the habitat present challenges in air and water quality, maintaining food supplies, and processing waste materials. The ability of local personnel to prosper after initiation of their habitat is dependent on the successful implementation of an integrated collection of systems including power production, food production, recycling, as well as healthy waste processing. All this is intended to afford the inhabitants the time to complete research at the site, all the while maintaining a manageable level of comfort.

The prevailing mind-set assumes that each destination for humans requires starting fresh with new technologies and methodologies because those destinations are so different. But this isn't necessarily true. If we take the view of the early pioneers and identify basic qualities required for a settlement, we can show commonalities between these destinations. Those commonalities permit the development of a common approach for defining habitats on several destinations.

The mission of EarthSeed is to build the methodology, and technologies to first survive, then thrive, and ultimately grow beyond this Earth. We will do this first on the Moon, then Mars, and after, on destinations further out such as Saturn's moon Titan, and Jupiter's moons Callisto, and Ganymede. To accomplish this, we are working to develop a Seed of life, a Biome that is a collection of species collaborating to survive as a whole, much as we have experienced here on Earth.

NOTE: We are not attempting to create a completely sealed mobile habitat, as the M.A.S.H. is a research and learning platform that we have begun to take to schools to demonstrate the Sustainable qualities of the test-bed vehicle. That being said, we have successfully isolated the habitat, its power needs, and reduced insect intrusions markedly this year. Our current focus is developing the most effective planting techniques for our media configuration. The more effective we can make the mini-farm, the more science in other areas a team will be able to accomplish once the beachhead is established on the moon.

### **Premise**

EarthSeed has been developing our system around the understanding that there is a connection between the various species contained within our habitat here on Earth. As well, that connection facilitates a Web Of Life that moves matter and energy through these various species to provide multiple cycles that process and *recycle* that matter and energy, and ultimately making the building blocks of life available to a wide diversity of life forms.

Food for humans on Earth falls into several areas: Herbs, Plants, Insects, Fowl, and Animals. Production of this food is benefited by the stable atmosphere, ready water supplies, and arable soil available. Our knowledge, technology, and developed infrastructure not only fosters the production, but also the distribution of that food to the consumer. In space, however, these core benefits are not available. We must establish them, and the requisite infrastructure to support them.

EarthSeed currently operates ongoing research on its Mobile Analog Sustainable Habitat (M.A.S.H.). We have been operating a single-pump aquaponics system utilizing both Nutrient Flow Technique (NFT), and

Flood and Drain (FD) in a single aquaponics system with integrated artificial lighting. The flow is also integrated into algae tubes, and a 5-stage water filtration unit to continuously produce drinking water. Our goals are to be able to define the selection of companion species suited to a 90-day-to-harvest crop rotation cycle.

Crop selections include but are not limited to:

- at least two fish species,
- a reasonable variety of leafy crops, i.e. lettuces, herbs, onions.
- a reasonable variety of fruiting crops, i.e. tomatoes, strawberries, squash, cucumber.
- a reasonable variety of root crops, i.e. carrots, potatoes, beets.
- a reasonable variety composting and waste consuming insects

## **Historical Progress**

In the years between 2010-2014 studies in hydroponics, aquaponics, and hybrid systems were performed. Specific goals of this research were to develop a low power, single pump circulation system with artificial lighting, as well as define the selection of companion species suited to a 90-day-to-harvest crop rotation cycle. The "crop" selections were to include at least two fish species, a reasonable variety of leafy, fruiting, and root crops.

During the years between 2014-2018 developments were refined, and applied to our Tiny Home Integration Prototype, a 4x8 trailer constructed specifically to house a "Habitat for one". While never intended to be functional for living in, rather to test integration of the assembled components. It was painfully clear how claustrophobic the closed environment became when the door was closed on the windowless unit. Even by integrating a desk/Murphy bed combo, 4x4 slide out section; the Tiny Home was microscopic by comparison to most other efforts with a total active space of 72 square feet. At the New Worlds conference in 2016, we presented our Tiny Home Integration Prototype.

In March of 2017, an 84-passenger bus was acquired for our next phase. The Tiny Home has since been retired, and what was learned was transferred into the M.A.S.H. with updated components. The M.A.S.H. provides nearly 300 square foot of living space. We first presented our M.A.S.H. demonstrator at ISDC in 2017. In the spring of 2019 we initialized our first mini-farm inside, and with incremental adjustments and improvements continue to progress.

The M.A.S.H. is equipped with basic necessities for up to three adults; bunks, toilet; kitchen area with fridge, 2 burner hotplate, microwave, and sink. A workbench with appropriate tool/and materiel storage was included inside to facilitate work/repairs on the garden and pond.

## **Components of our (near) Closed Loop Biome**

The EarthSeed Biome Demonstrator brings multiple techniques, technologies, and species together to produce not only food, but also recycle air, water, and waste stores for the inhabitants of the M.A.S.H. It's purpose is to identify, and implement companion species with specific interdependencies that can coordinate life-cycle processes: food production, building materials, water filtration, air recycling, and waste processing.

Most hydroponics systems experience a constant issue of clogging of the tubing, and delivery components as salts and wastes build up in the water. Hydroponics also requires rigidly consistent water changes to assure proper nutrient loading, and the resultant outgoing water is no longer useable.

While most aquaponics systems experience the clogging to a lesser degree, depending on the type of solids sump implemented, and with far fewer water changes.

Our system was designed with larger openings, and tubing in order to reduce not only the potential for clogs, but also the number of water changes needed, and lastly to reduce time needed for media-bed cleanouts. We have cleaned our bed out only once this year, and have gone through only the water-change necessary for system restart. Now, our water is added to on a weekly basis, as we work to reduce evaporation losses.

The M.A.S.H. incorporates:

1. **Fish Pond** - The pond has a capacity of nearly 200 gallons. The fish deposit their wastes into the water. These wastes increase ammonia, nitrites, CO<sub>2</sub>, and solids. An air pump and 4 6" aeration stones provide direct oxygenation of the water. We have installed an automated fish feeder, which provides a measured feed for the fish on a regular, twice a day feeding schedule. While the feeder is capable of providing nearly a month's food supply, it is monitored on a daily basis. Our initial crop of 90 Blue Nile Tilapia was initialized in February, of which 80 were still thriving as of September 2019. During those months we added two catfish, and 10 small snails.
2. **Pump** – A pond pump rated at 1500 gph is used to lift water up 10' through the radial flow solids catch and into a horizontal manifold. The pump runs 15 minutes out of each hour.
3. **Solids Catch** – The Solids Catch is designed to slow the flow of water and allow solid materials to settle to the bottom, while the bulk of the nutrient rich water moves up and into the horizontal manifold. The catch has a sewer-type cleanout that allows periodic removal of the collected solids. Solids can then be dried, and used as compost.
4. **Horizontal Manifold** – This serves as home to our nitrifying bacteria. These bacteria convert the nitrites from the water into nitrates more easily taken up by the plants. Ammonia is also reduced at this step. The water in the manifold drains directly into vertical planter columns supporting our leafy crops and herbs.  
The manifold has been extended across the room, and over a second planting bed. From this end of the manifold, a small ¼" tube will trickle pond water into our drinking water filter, and algae tube system.
5. **Vertical Plant Cylinders** - 13 2" net pots in each of 20 cylinders in two garden beds are home to plants that can prosper with near-continuous flow of water over their roots. The 15 minute pump run-time affords the plants not only nutrient flow/feed time, but non-flow time allowing the roots to draw in oxygen.
6. **Horizontal Planting Bed** – The planting bed is 9' long, 24" wide, and 24" deep, of which planting media fills approximately 18". Water drops from the cylinders into the planting bed of Hydroton clay pellets. The bed contains three layers: a) 4-6" of ¾" lava rock to facilitate water flow; b) a sheet of perforated weed cloth that allows water to percolate upwards into the Hydroton, and c) Hydroton clay pellets 12-14' deep provide support to the bedding plants, and allow quick movement of water up to the root systems, yet easy drainage to prevent over watering of root and fruiting plants.  
When plants are placed in the media bed, their roots are cleaned of potting soil/dirt, and sprinkled with a mixture of dry mycelium, to facilitate healthy roots, and foster mycelium network development in the growth medium.  
A second, 10' planting bed is under construction bringing our total length to 19' x 24" and doubling our crop space within the M.A.S.H.
7. **Bell Siphon Drain** – A Bell Siphon Drain is the control that facilitates water collection into the bottom of the bed, encouraging plants to drive their roots deep to feed on the water. The Bell Siphon is configured to build up water to a height 2-3" above the weed cloth barrier to reach the root systems, and then the weight of the water initiates a siphon action to drain the media bed.
8. **Waterfall Drain** – A pipe, beginning at the media bed drain, runs the full length of the Fish Pond and has 1/8" holes drilled at 2" intervals to allow water to fall back into the fishpond. The waterfall provides some aeration and oxygenation of the water as it falls back into the pond.
9. **Drinking Water Production** – Water is drawn from the end of the manifold and split, first into the 5-stage drinking water filtration unit. Water continuously flows through:
  - a) Biological Filtration, where beneficial bacteria consume harmful varieties;
  - b) Slow Sand Filtration, where the sand captures larger particulates from the water;
  - c) Ceramic Micro pore Filtration, that captures smaller particulates and pathogens;
  - d) Carbon Filtration, which neutralizes additional detrimental components in the water;
  - e) UV-C light sterilization, kills any remaining pathogens.
 Water then trickles into the 40-gallon fresh water tank, and is pumped on demand through the fresh water distribution system for drinking, washing, and showering.
10. **Algae Farm** – We have begun experimenting with algae tubes. Installed are 2 clear PVC tubes with a fluorescent lighting tube running up the center of each. The hope is to establish an ongoing colony of

spirulina to produce oxygen, and provide additional food source. These tubes, like the water filtration, will draw directly from the manifold feeding the algae with pond water, as well as with the room air.

11. **Composting Toilet** – is home to a colony of black soldier fly larvae, and adults. Human and food wastes are deposited. Adding a light dusting of dry materials during each deposit reduces odors. The larvae consume those wastes. What is left is a compost material that is manually removed on a weekly basis.

## Powering Our Biome

Originally, the Tiny Home was equipped with a 45-watt solar panel, and 2 6v batteries, feeding a 2000-watt inverter for 120v house power. The M.A.S.H. is installed with 8 solar panels that produce approximately 2400 watts of power to our charge controller. The storage system consists of 12 deep cycle, 225 AH 6-volt batteries configured in a series-parallel manner providing a potential of 1350 AH of power at 12 volts, served through a 3000 watt inverter providing 120v house current throughout the habitat.

Our current usage averages a near continuous 900 watts, with occasional peaks when the refrigerator cycles, or we are cooking. Typically, the panels produce enough energy during the day to fully power the M.A.S.H. *AND* charge the batteries through a typical 10-hour sunny-day cycle. At full charge, the batteries can run the system through its nighttime reduced cycles up to 12 hours before the charge drops below the inverter threshold.

## Results So Far

We have, as of this writing, been operating fully off-grid for 12 continuous months. The power system functions well, providing just enough power to maintain the pump and lighting through out one day-to-night 24-hour cycle without resorting to shore-power. We are regularly adjusting run-times, to reach a point where we can have a net positive power available in the morning so we can work towards more stable power management.

So far, we have worked four separate plantings with mixed results as we 1) develop seeding methods, 2) adjust media and plant selection, and, 3) adjust planting depth. We have planted assorted herbs, two varieties of lettuce, and other leafy greens in the vertical cylinders, and a wide variety of fruiting/root crops in the media bed. Most plants grow quickly, though we have not processed any crops to harvest yet. For lighting, our original single 4-tube fluorescent fixture has been expanded to a 12-tube fluorescent fixture. As we prepare to initialize our second planting bed, there will be an additional 12-tube fluorescent fixture to serve that bed.

Tending to the garden requires slightly less than an hour per day, i.e. checking the various plants for insects, appropriate exposure to water and light, and verifying our water quality and temperature.

Early on, we found ourselves adding nearly 50 gallons of water each week to maintain our levels in the pond. This amounts to nearly 25% suspected evaporation within our environment in the week. The area above the pond is enclosed on three sides and the top, and we have added clear panels to close the fourth side. As a result, we have seen a reduction in evaporation of nearly half over this past summer. Additionally, a dehumidifier has been installed, to recapture some of the evaporative moisture, reclaiming it for the fishpond. We did find an issue of leakage. When the waterfall is running, water was falling on floor supports and traveling out of the bus through the wall. We are working to remedy this, and our water losses are gradually diminishing.

It has been suggested that our filtration seems to be on the light side. Remember, that we approach everything in layers. There is, first, the Solids Catch, followed by the Manifold with nitrifying bacteria, followed by the plants, and finally the media bed itself. Our fishpond stays remarkably clear, and our quality rarely needs adjustment.

The sequence of the water flow, and the distance it travels seems to be equally as important as the quality of the individual filtration components. The pond operated for three months over the summer with no filtration present except for the media bed alone. To our surprise, the water remained within measurable limits throughout, though there was a noticeable increase in solids within the tank. Once returned to the vehicle, and having the water move through the Solids Catch and the Manifold, we have noted a marked reduction in the

solids, and our water has remained clear. Last month, we inserted 2 circulation pumps to push water along the floor of the pond to stir up the solids and facilitate their movement into the pump, and the Solids Catch. In the near future, we will be re-introducing catfish, snails, and hopefully prawns to facilitate in-tank cleaning and processing of some of these solids.

## Issues

A few key issues remain unresolved.

**Crops** - We are investigating the impact of varying densities of each of the biome's contributors. As one component expands, how does its output affect the next component in the cycle? What methods can be implemented to adjust that output without disrupting the cycling of the overall system?

**Power** – While we are stable in our current 24-hour power cycle, we would like to extend our ability to weather Non-Sun-time to nearly three days. There appears to be additional capacity of the panels to charge a larger quantity of batteries. However, we are working to identify how and where to place the additional batteries.

**Pumps** – Currently, we are only operating the pond pump. The fresh water system will add an on-demand pump to the system, as well; and a solar water heating system will add a continuous-circulation pump.

**Humidity** - In the small space of the demonstrator, we are seeing a rise in humidity. Current planning is leaning towards draining this moisture into the media bed. Draining into the fresh water line would seem proper, however this water is distilled from the air, and as a result lacks any minerals or nutrients. By dropping it into the media bed and allowing it to mix with the current body of water will serve to provide a small amount of “clean” water returning into the system, that can absorb minerals and nutrients, much as rainfall does in the Earth’s biosphere.

## Catastrophe

No long term project succeeds without some failure. And we experienced a whopper a few months ago. All was going well, our power system was working well, it had been weeks since a cloudy day precipitated a "short" day. And I had just installed our automatic feeder. The fish were doing well, getting big in fact. And I was beginning to look forward to a great fish fry soon.

I had checked the bus regularly for three straight days after installing the feeder, making minor adjustments, and circumstances and my sense of success lulled me. I had planned to visit on Monday, but an emergency prevented it. An unexpected event on Tuesday did as well. And on Wednesday, I just assumed all was well.

On Thursday evening, I visited the bus and opened the door to the odor of dead fish. As I stepped into the garden I saw the floating carcasses. Then, like a slap in the face, I heard the auto-feeder whirr, delivering the nightly feeding.

Before the cleanup, I took time to assess, and determine the cause of the failure. First, the pump had stopped running. The reason it had stopped running became clear very quickly. The timer it was plugged into had a 3prong to 2prong adapter, into which was plugged a multi-plug, into which was plugged the air and water pumps. The weight of the collection had caused the timer to progressively sag at the outlet over a period of days, until it no longer made solid contact with the outlet and shut down. Solids increased with the 3 times a day feeding, and nitrites and ammonia built up even faster, ultimately killing the fish.

It took three days to first clean up, then wash, sanitize, and re-line the pond. While it was down I took the opportunity to redesign the baffles, and with some help from a friend, rebuild the media bed. We lost 84 of our tilapia, and 2 catfish.

## The Future

Unlike Biosphere, which sought to duplicate the Earth's ecosystems with technological prowess, we seek to understand the interdependencies, and interactions found within the ecosystem, and learn to maintain them in a

smaller habitat. As we continue to make progress in harnessing the Living Biome, we will, of course, expand its scope to be ready when we establish our first settlements off-Earth.

Our Future is Out There. Come Sail with us ... Out There.