DESIGN PRINCIPLES FOR SUSTAINABLE SETTLEMENTS IN HOT DESERTS

by

Dr. Yuriy Polyakov, USPolyResearch

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SPACE TECHNOLOGY LIFE SUPPORT SYSTEMS AS THE BASIS

Hot deserts are characterized by

- Abundance of free solar energy
- Water scarcity
- Nearly complete absence of organic life

This makes them similar to extreme habitats studied by space life support science. The problem of designing sustainable settlements in hot deserts has much in common with the corresponding problem for Lunar and Martian settlements.

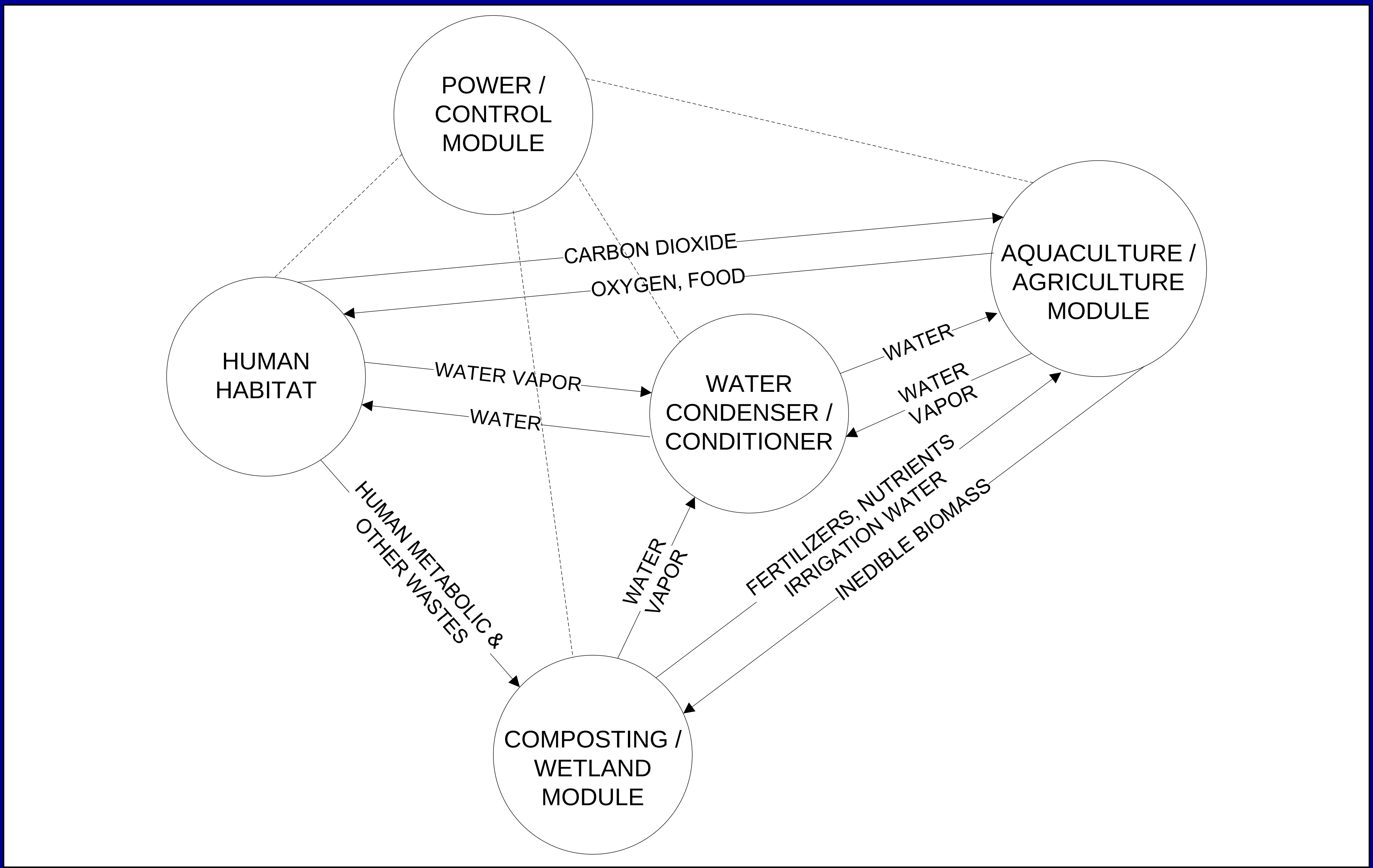
Bioregenerative life support systems confined into greenhouses in which all the transpired and evaporated water vapors are collected and condensed can be used as the basis for hot-desert settlements.

EXTRATERRESTRIAL SETTLEMENTS VS HOT-DESERT SETTLEMENTS

In contrast to Martian or Lunar surface, hot deserts have the following advantages:

- Air is provided by Earth’s atmosphere
- Most of Sun’s harmful radiation is blocked by Earth’s atmosphere
- Earth’s gravity, which is optimal for plants
- Mineral-rich soils
- Initial stocks can be easily provided
- No stringent land area restrictions

PRINCIPAL FLOW DIAGRAM OF HOT-DESERT BIOREGENERATIVE LIFE SUPPORT SYSTEM



DESIGN PRINCIPLES: ENHANCED PLANT GROWTH

- Key optimization criterion is the **carbon cycle time** (turnover of carbon and biogenic elements). The less the carbon cycle time, the faster the plant growth and the shorter the harvesting time.
- The main parameters that determine the growth rate of higher plants are **light intensity**, **temperature**, **carbon dioxide**, **oxygen** and **nutrient concentrations**, and **air velocity over the plant canopy**.
- Aquaculture/agriculture modules should be separated from the residential area because the optimal conditions for enhanced plant growth (high concentration of carbon dioxide, relatively high temperature) are different from the optimal conditions for human life.
- Suggested higher plants: wheat, tomato, cucumber, potato, radish, lettuce, soybean, cowpeas, pinto bean, rice, strawberry, duckweed, and the like.

DESIGN PRINCIPLES: ENERGY

Renewable energy input

Should be powered only by solar and wind energy or their derivatives.

Diversification of solar energy consumption

The consumption of solar energy should be diversified: production of electric power by photovoltaics and power plants with sunlight concentrators, photosynthesis, heat accumulators for dark periods, conversion into hydrogen by water electrolysis, heat for the fermentation of biomass, and biofuel production from starch, cellulose, and lignocellulosic biomass.

DESIGN PRINCIPLES: WATER

Closed water loop

Should collect and condense all transpired/respired water vapors and recycle water from all liquid wastes using thermophilic-bacteria composting technology and/or subsurface flow wetland systems. The water vapors and collected water should be treated by methods as close to the natural treatment processes (electrostatic ionization, soil infiltration, percolation, etc.) as possible to provide its biological activity.

Biological water production

Excess water should be produced by microorganisms and other living organisms.

DESIGN PRINCIPLES: WASTES

Wastes of one process should be an input to another

The processes to be integrated into the system should be able to use its wastes and/or products as feedstocks, with all the wastes, including the wastes of these processes, being completely processed by the system.

Waste formation rate = waste consumption rate

The rate of waste formation should not exceed the system's capacity of processing the waste.

No foreign materials

Foreign substances that can poison or slow down the regenerative processes are strictly prohibited.

DESIGN PRINCIPLES: LAND AREA REQUIREMENTS

Sufficient land area

Should be as large as necessary for consuming all wastes in due time (system should be wasteless), generating enough electric and thermal power by solar-powered generators, and producing enough food and water.

Localization

All subsystems and units should be as close to each other as possible to reduce the transportation expenses and losses.

DESIGN PRINCIPLES: MONITORING

- The system should be carefully monitored and effectively controlled to achieve the highest efficiency.
- Computer-based monitoring systems developed for controlled environment agriculture (greenhouses), such as CEA-Pro by Hydro-Gardens, should be used for monitoring and controlling the plant growth and yield in hot-desert settlements. Such systems read the data from environmental sensors, log and display them, and change environmental conditions when specific thresholds are exceeded.
- Visual analysis tools, such as *Machine Vision* for image acquisition and analysis, may also be used for non-invasive monitoring the health and growth rate of plants.

RESEARCH GUIDELINES: CENTRAL DATABASE

Prior to performing pilot studies in hot deserts, it is necessary to analyze and systematize the data of many space technology life support experiments performed in ground-based facilities:

- Key metabolic and other data for humans and plants: light intensity, carbon dioxide concentration, oxygen concentration, concentration of each nutrient, air temperature, air velocity, planting density, air humidity, daily production of edible and inedible biomass, daily production and consumption of water.
- Key parameters related to human needs: daily consumption of food and potable, kitchen, laundry, and personal hygiene water; air humidity; and air temperature.
- Key parameters for waste processing: physicochemical characteristics of wastes (biological oxygen demand, chemical oxygen demand, content of organic and inorganic elements, and so on), the performance parameters and growth dynamics of the populations of algae, bacteria, microorganisms, and fish, and the kinetics of nutrient and water production.

RESEARCH GUIDELINES: SIMULATIONS AND EXPERIMENTAL STUDIES

- The mathematical models developed in space technology together with the central metabolic database should be used for developing a software package for simulating and designing hot-desert life support systems.
- Computer simulations should then be performed to identify the candidate life support systems that can be used for conducting experimental studies.
- The experimental studies can be performed at the existing space technology facilities located in hot deserts, such as Biosphere 2, or specially built new facilities.

HOT DESERT LIFE SUPPORT SYSTEMS AS "BIOREACTORS"

Life support systems in hot deserts can be considered as the basis for building sustainable settlements there:

- Can provide organic food, produce fresh water, process solid/liquid wastes, and produce biofuel and/or hydrogen for hydrogen fuel cells.
- May meet not only the needs of local residents in food, water, and waste processing, but also produce food, water, and fuels for other areas.
- Can be regarded as carbon sinks because the highest crop productivity can be reached at elevated concentrations of carbon dioxide.
- May provide a stable supply of energy and plant food throughout the whole year.

POTENTIAL BENEFITS OF SUSTAINABLE SETTLEMENTS IN HOT DESERTS

- Slowdown and eventual reversal of desertification
- Reduction and potential reversal of population migration from arid lands
- Increased availability of potable water and food in deserts
- Development of new residential infrastructure on the territories that are currently considered as wastelands
- Billions of dollars spent by UN on desertification consequences and poverty in Africa may be used to develop infrastructures that will make poor African countries self-sustainable
- Economic benefits may be a potential boom of long-term investments in desert lands, which would help minimize the risks of economic crises such as the one we are currently experiencing

Q & A