

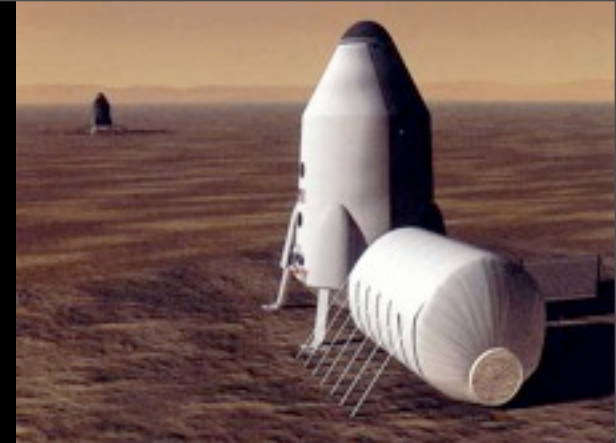


Membrane Based Habitat Wall Architectures for Life Support and Evolving Structures

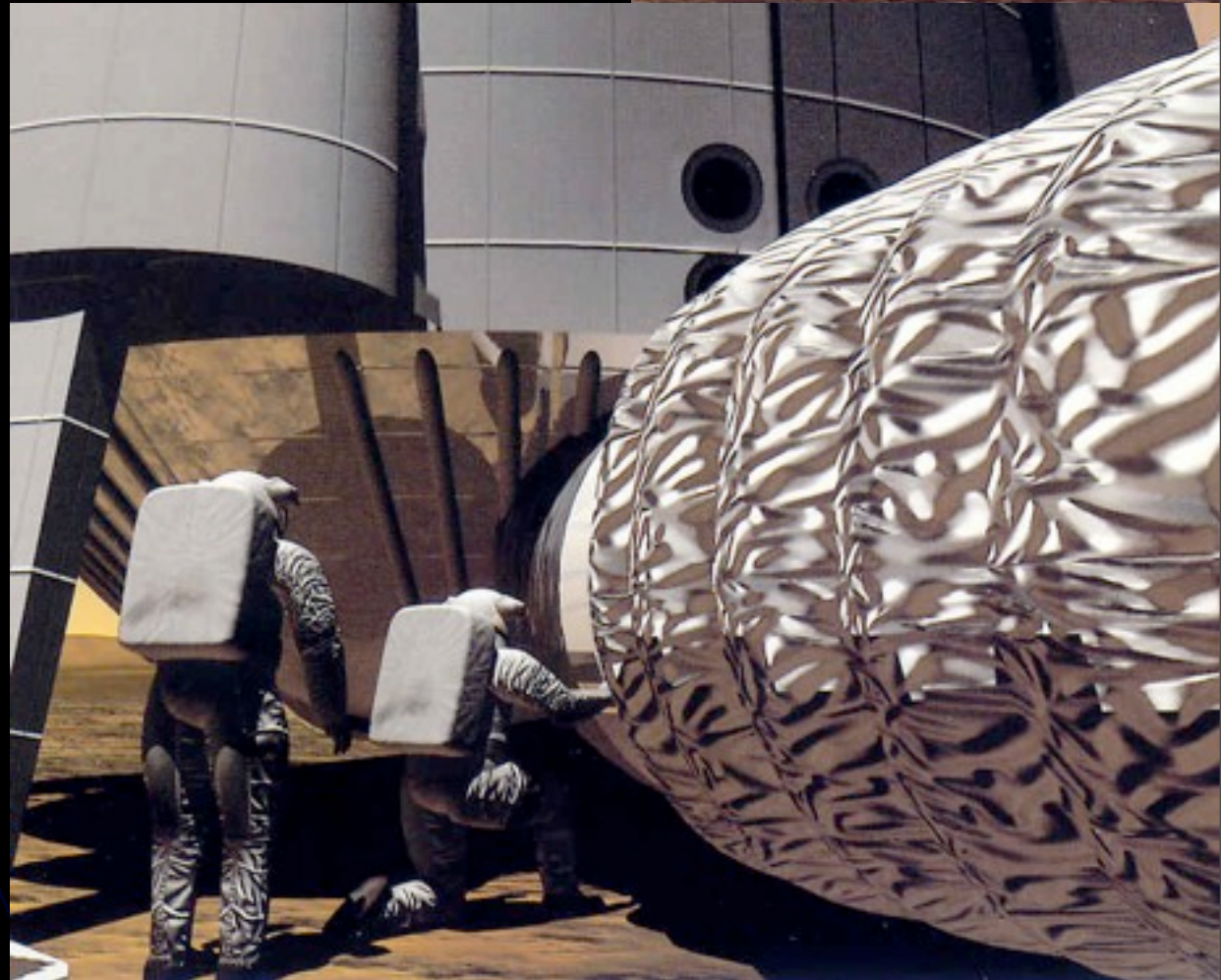
Space Studies Institute
Space Manufacturing
NASA Ames Research Center
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Introduction: The Water Wall

- The membrane water wall concept proposes a system for membrane based water, solids and air treatment functions that are embedded into the walls of inflatable habitat structures
- The approach provides novel and potentially game changing mass reuse and structural advantages over current mechanical life support hardware operating within ridged habitat envelopes.



FO is flexible and could be incorporated into the wall material of inflatable structures



John Frassanito & Associates ©

Saturday, November 20, 2010

Introduction: How

- This approach would allow:

water recycling

air treatment

solids residuals treatment and recycle

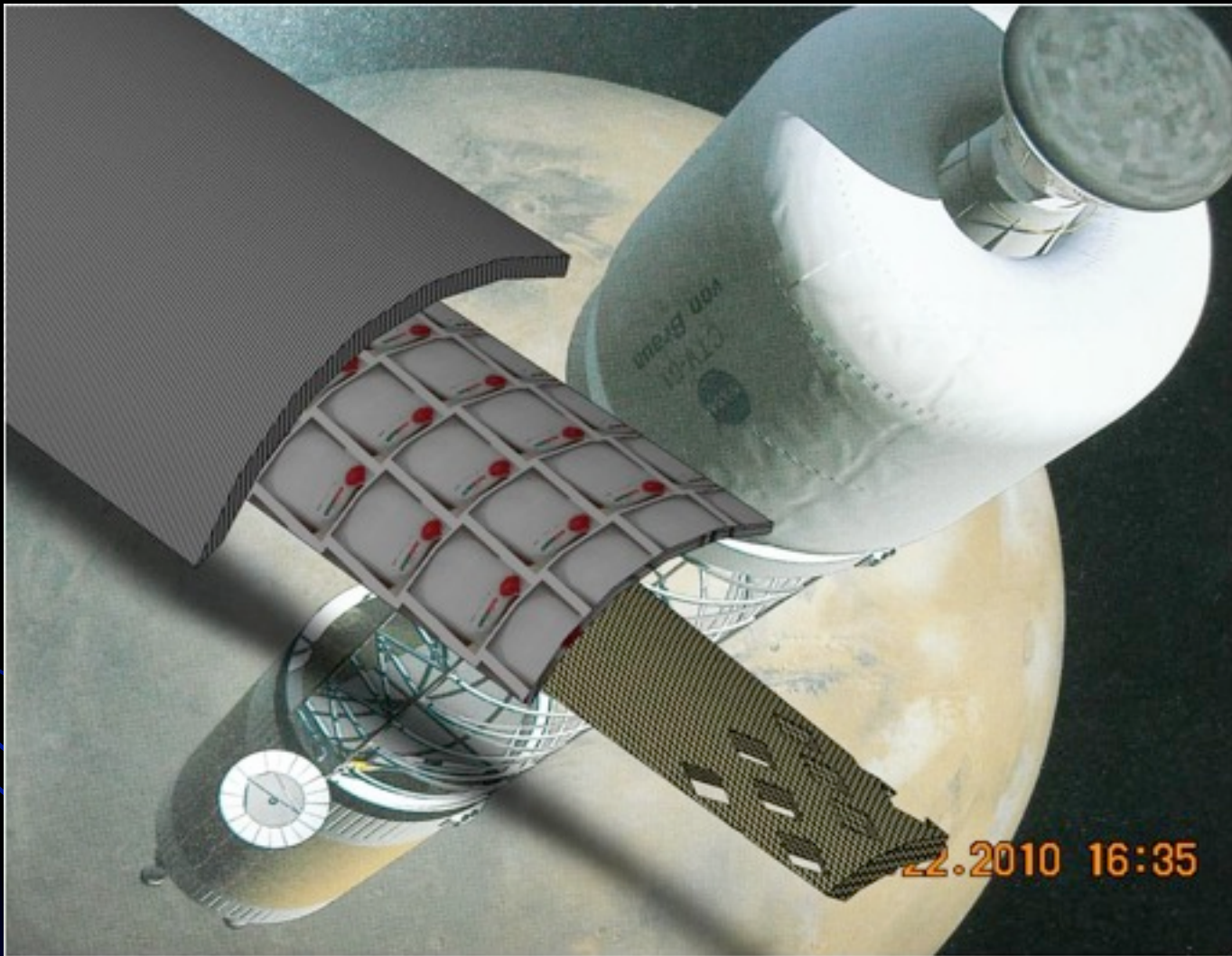
to be removed from the usable habitat volume into the walls.

- It would provide a mechanism to recover and reuse water treatment (solids) residuals to:

strengthen the habitat shell

provide thermal control

provide radiation shielding



Introduction: Know Process and Materials but a New Architectural Option

- The technology used is not speculative, but is rather based on established water recovery technology being developed by NASA:

Direct Osmotic Concentration (DOC) system

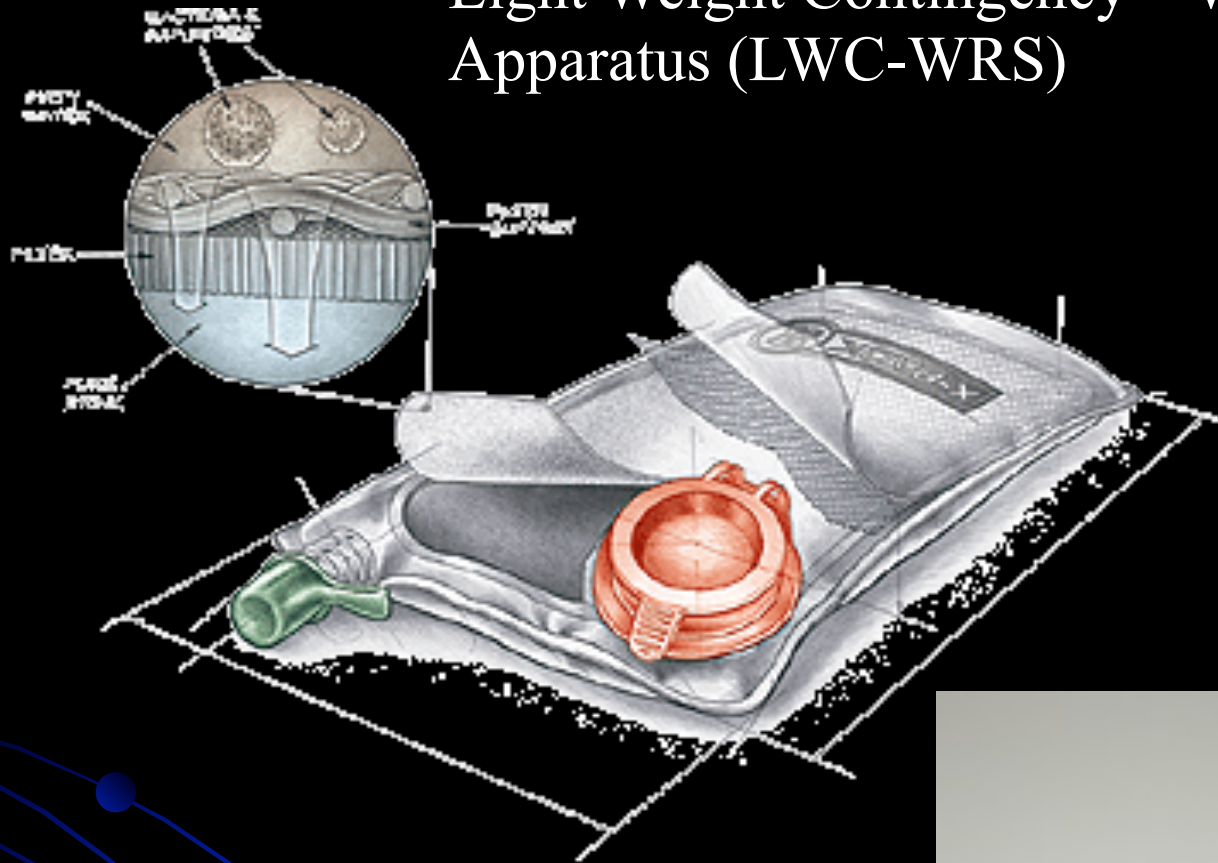
Osmotic Distillation

Light Weight Contingency – Water Recovery Apparatus
(LWC-WRS)

Forward Osmosis Power

Offshore Membrane Enclosures for Growth of Algae
(OMEGA)

Light Weight Contingency – Water Recovery Apparatus (LWC-WRS)



Off the shelf cellulosic triacetate forward osmosis membrane treatment bag (Hydration Technologies, Inc.®)



Advanced Concepts Based on the Forward Osmosis (FO) Bag Material Design

- Move FO element for FO/RO gray water system into the wall.
- Wall FO element would be a much enlarged version of the hydration bag.
- Urine and humidity would be treated separately prior to being re-introduced to the main gray water treatment system.
- Water bags would be used for radiation shielding and thermal control.
- Water bags would have pervaporation membranes facing inward and would provide capability to remove CO₂ and trace organics from the atmosphere.

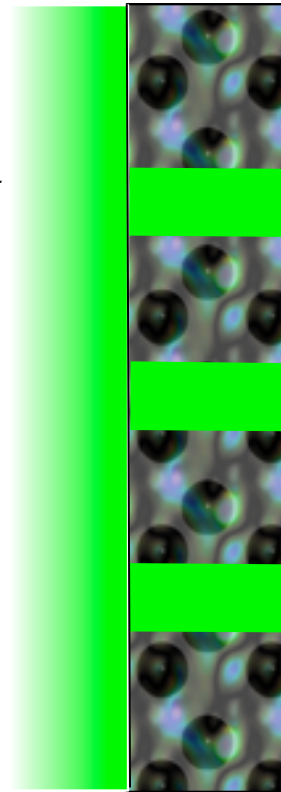
Why Do Membranes Foul?

Water mass transport through the membrane is diffusive but does require pores

Electrostatic charge barrier

Fouling particle

Ions are striped from the solution by electrostatic rejection at the membrane surface

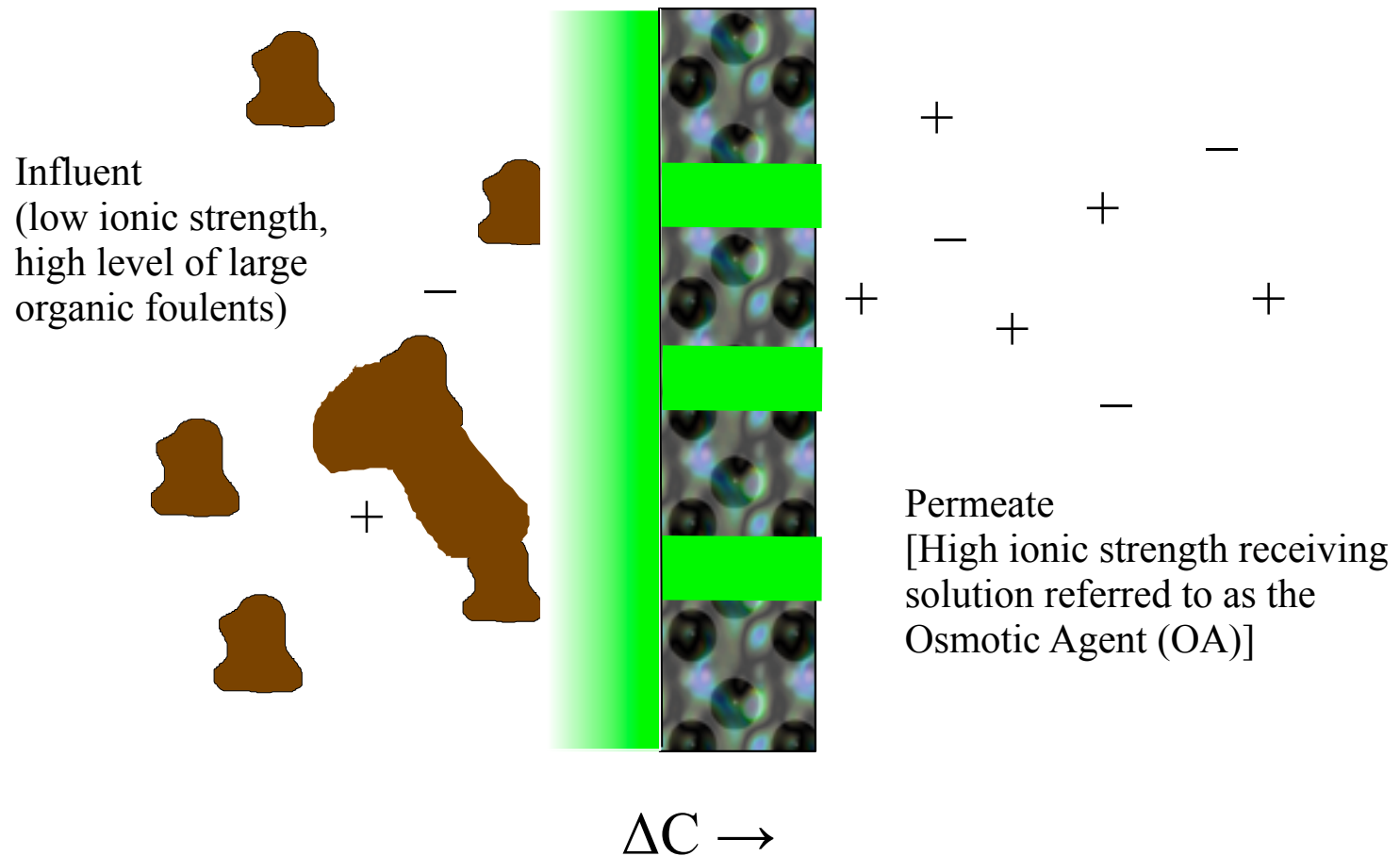


Microporous membrane material

Under pressure, particles may be driven into the entry pores of the membrane blocking further water flux

Forward Osmosis (FO)

Used to reduce fouling in the initial stage of membrane treatment for highly contaminated waste streams



Wall FO Bag Life Cycle

- Packed as dry element in a flexible/inflatable habitat structure wall.
- Initially inflated with sterile saline water and maintained as a freshwater supply and radiation shield.
- As the initial water supply is consumed, the treatment bags are filled with wastewater and take on a dual role of active FO water treatment and water wall radiation shielding.



Wall FO Bag Life Cycle

- When FO element is exhausted, fouled, and/or stalled by excessive waste side residuals, treatment ceases in that element and is moved on to the next bag in the wall.
- Exhausted FO bag elements are drained, fluids are mixed with dehydrated feces, solid organic wastes, and/or advanced water treatment residuals, and re-injected for sludge treatment, or simply curing in place of stable solids

Wall FO Bag Life Cycle

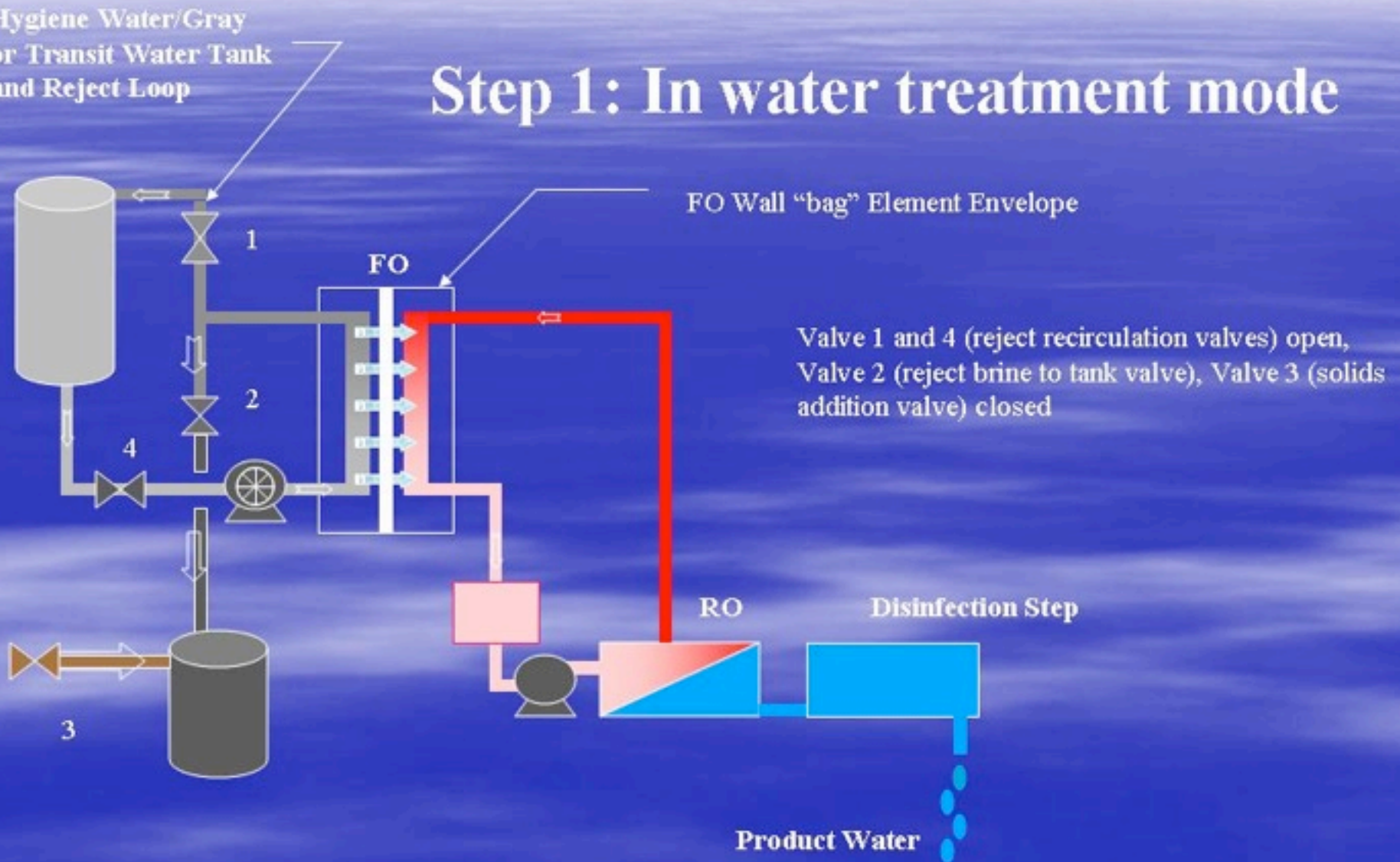
- Bags now work as organic/solids composting digesters/driers.
- Anaerobic digestion will produce CO_2 and CH_4 which will be harvested, compressed and processed for use in O_2 generation.
- Ammonia and VOC handling and control may be more flexible and useful depending on the waste stream.
- Methanogenic composting will reduce the water content and stabilize the biosolids, producing humus and recovering a substantial percentage of the remaining water.
-

Wall FO Bag Life Cycle

- Nitrogen rich urine dominated brines, the “Transit Mission” waste profile, combined with thermally stabilized solids (charcoal and/or ash) would be aerobically treated to drive off ammonia and odor causing VOCs and dried to “sheet-rock” in place.
- Once the humus or urine salts (sheet rock) are biologically stable, the bags become a permanent hydrocarbon/hydrated precipitate radiation shield.

Water Wall and Supporting Treatment System

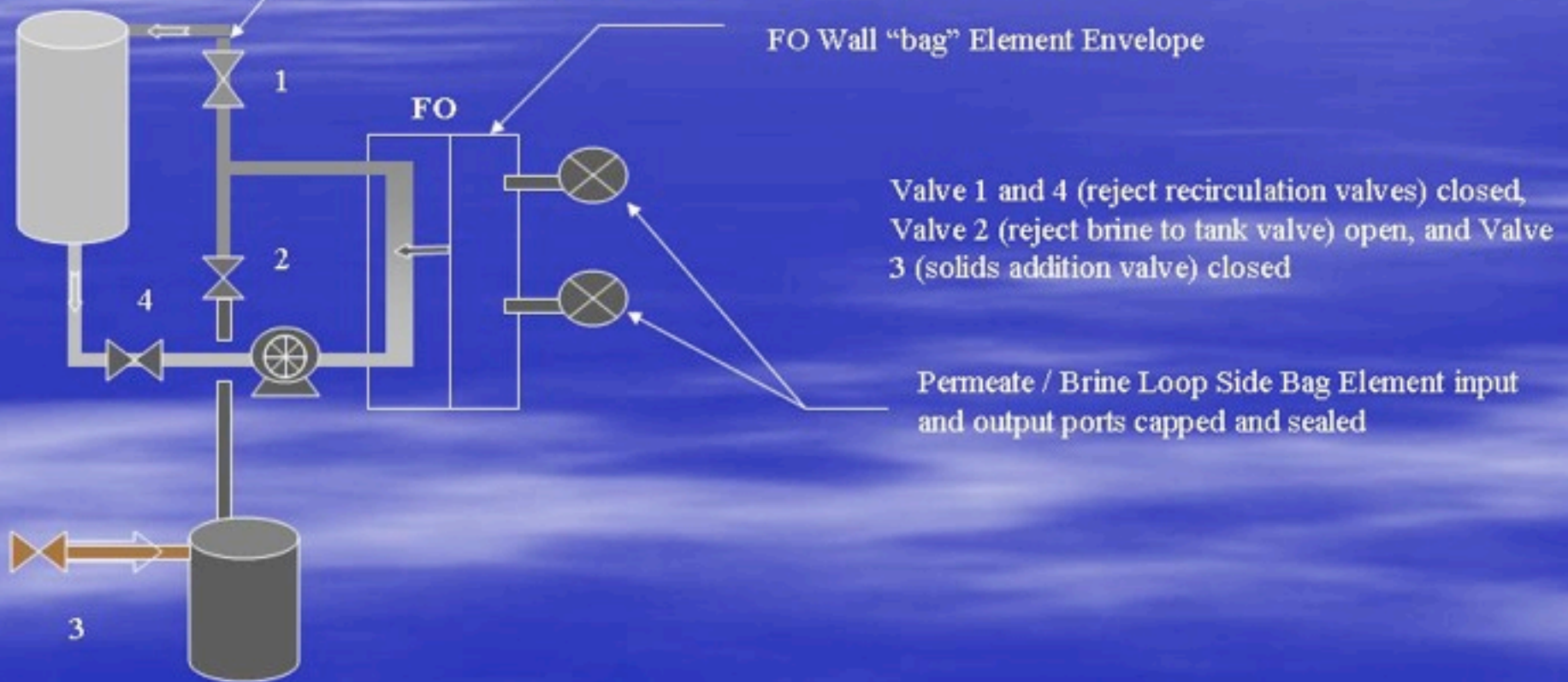
Step 1: In water treatment mode



Water Wall and Supporting Treatment System

Step 2: In water treatment residuals dump mode

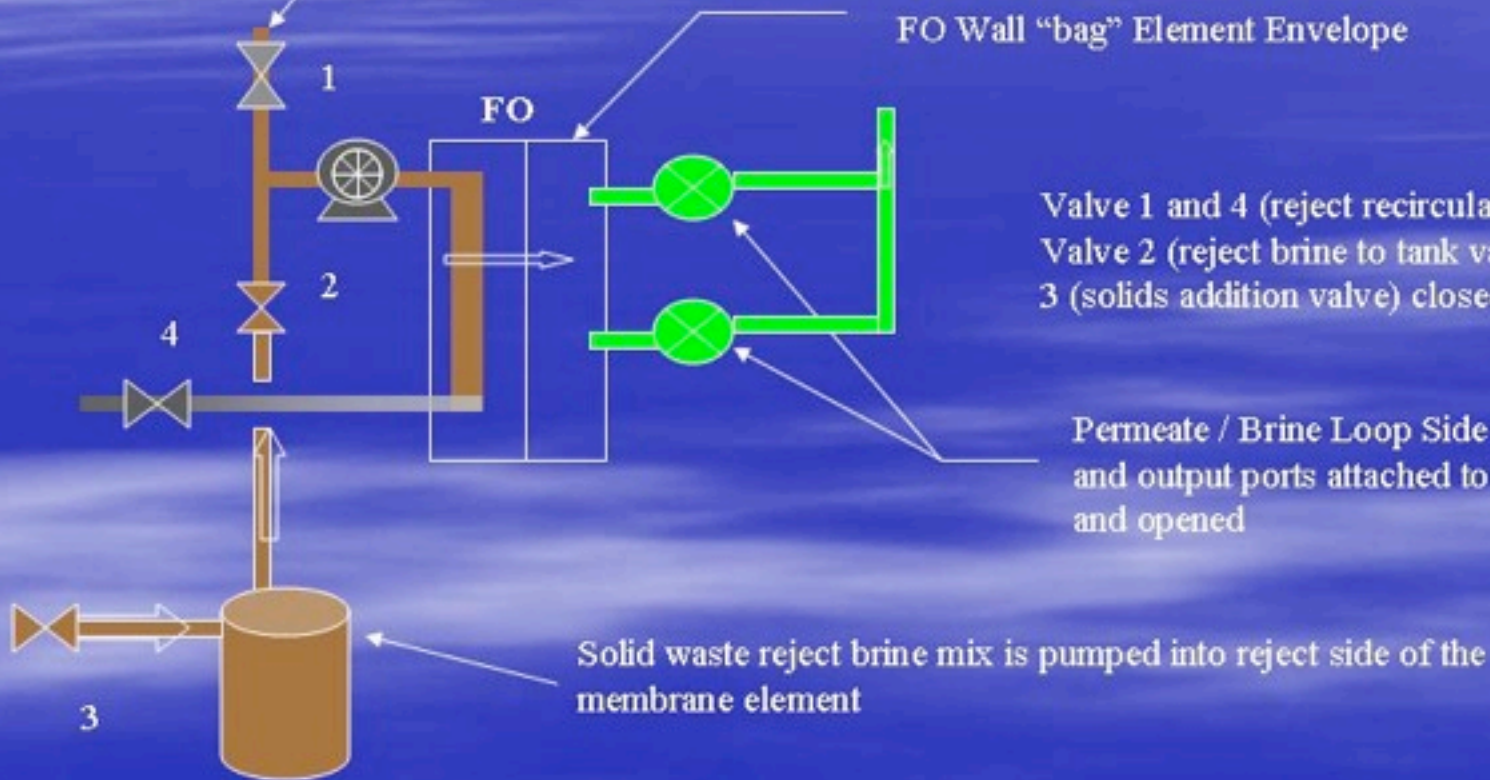
Hygiene Water/Gray
or Transit Water Tank
and Reject Loop



Water Wall and Supporting Treatment System

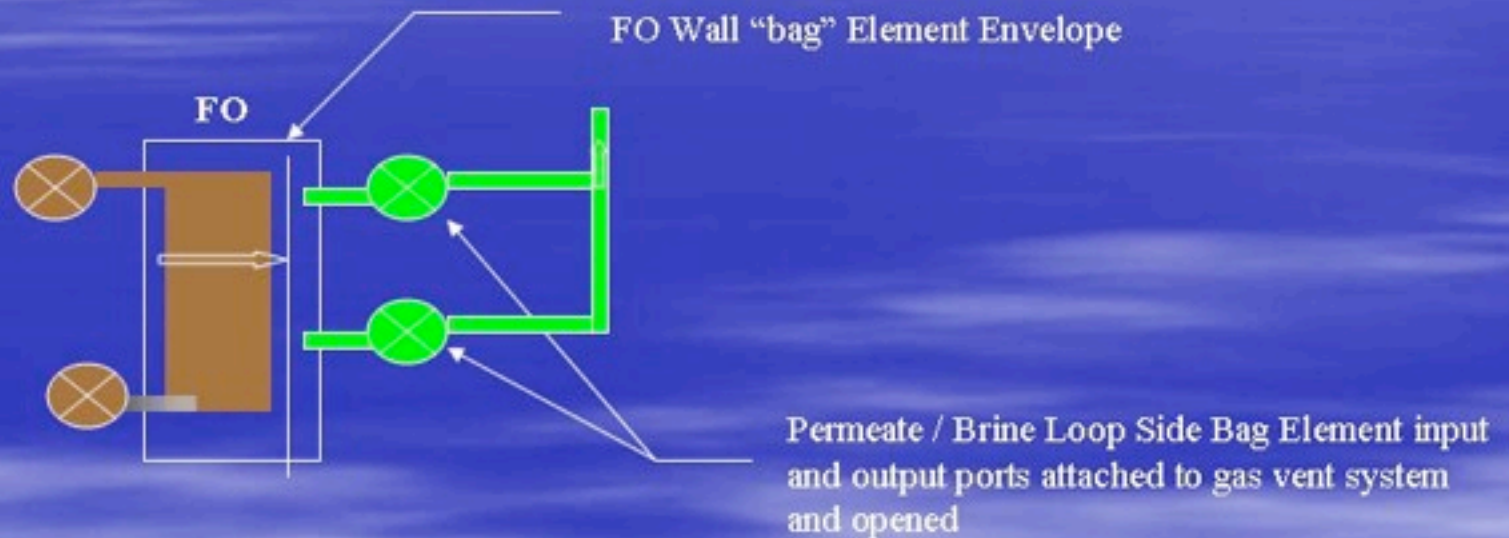
Step 3: Solid waste mix and fill mode

Hygiene Water/Gray
or Transit Water Tank
and Reject Loop

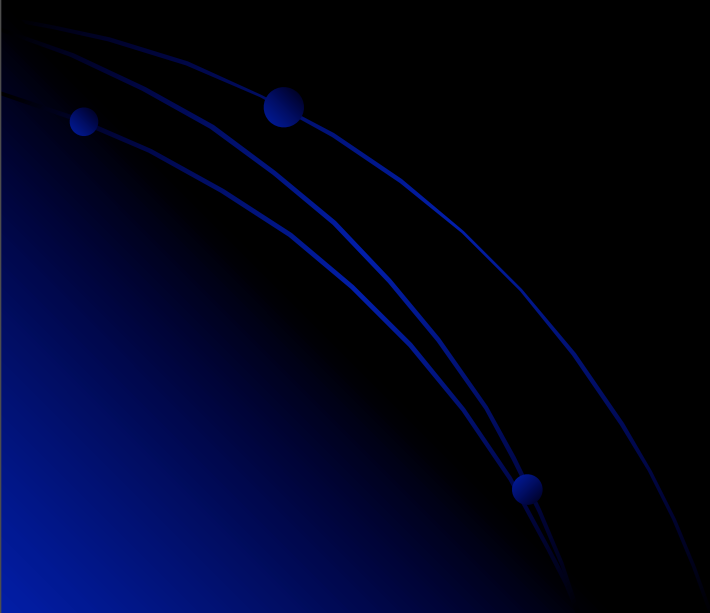


Water Wall and Supporting Treatment System

Step 4: Solid waste digestion mode

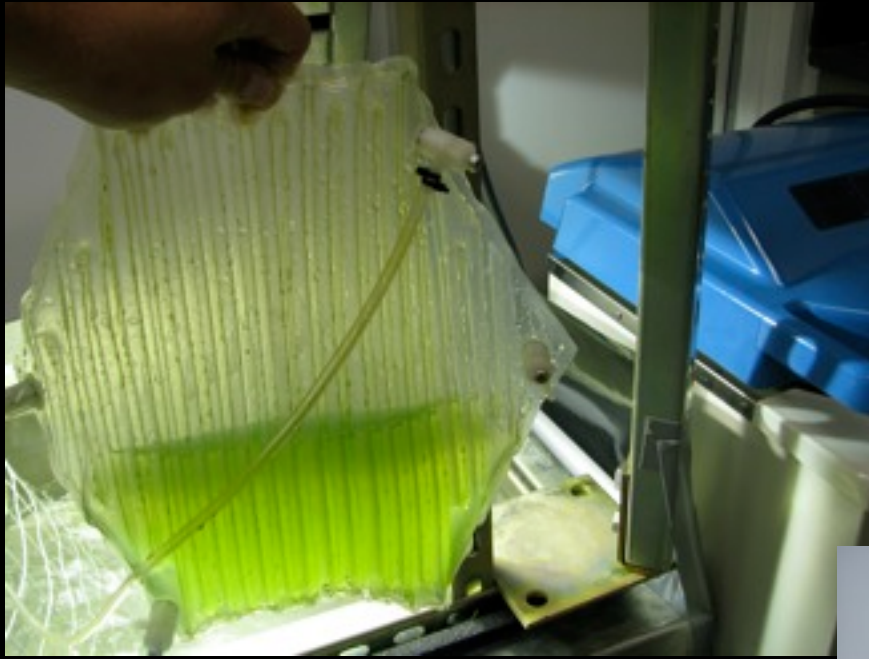


So what about air?



Gas Exchange Membrane Water Walls as Air Treatment/Scrubbing

- Physical/Chemical absorption / vapor liquid equilibrium based water wall CO_2 and trace organic removal
- Biological/Algae systems CO_2 to O_2 , NH_3^+ , VOCs and
- Trace Toxics to O_2 and biomass for thermal processing



Air process



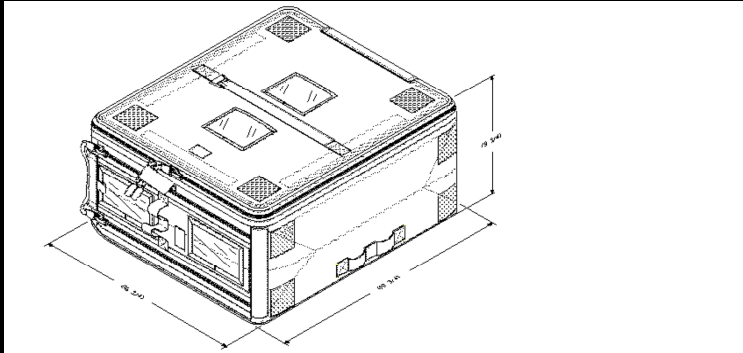
Biomass Sequestration

Biological/Algae Systems

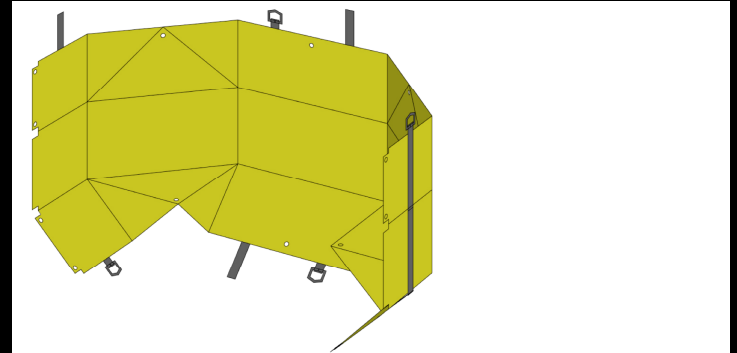
- Gas water walls to be layered with FO water wall bags
- Gas water wall are simple 3 layer construction with clear polyethylene (PE) front and back and an internal PE gas exchange membrane welded to the back outer envelope as a labyrinth.
- Internal algal biomass periodically harvested and concentrated by FO bags and processed thermally with other biosolids, thus sequestering ammonia nitrogen and trace absorbed contaminants.

Future Directions

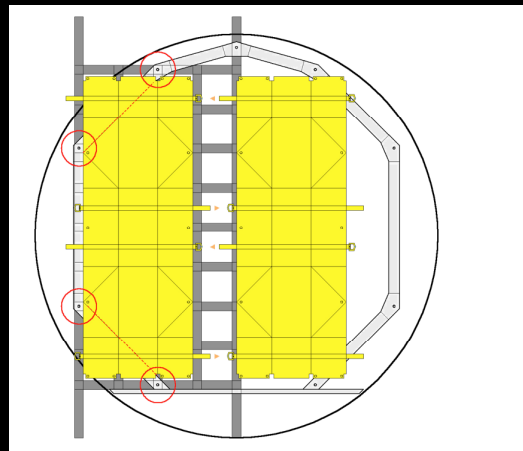
Proposed Collaboration With Scott Howe JPL



A standard Cargo Transfer Bag (CTB)



CTB Unfolding.



CTB Unfolding

Future Directions

Proposed Collaboration With Scott Howe JPL



Unfolded CTBs Incorporated Into Wall Elements (LSSP Habitation Team)

Conclusion

- This feasibility study was funded through a NASA IPP grant.
- The proposed technology is based upon known engineering solutions that will be analytically and experimentally demonstrated.
- The concept of using water walls for thermal and radiation shielding is currently being evaluated by NASA for flexible path missions.
- This study evaluated integrating life support functions into the inflatable structure water wall architecture.