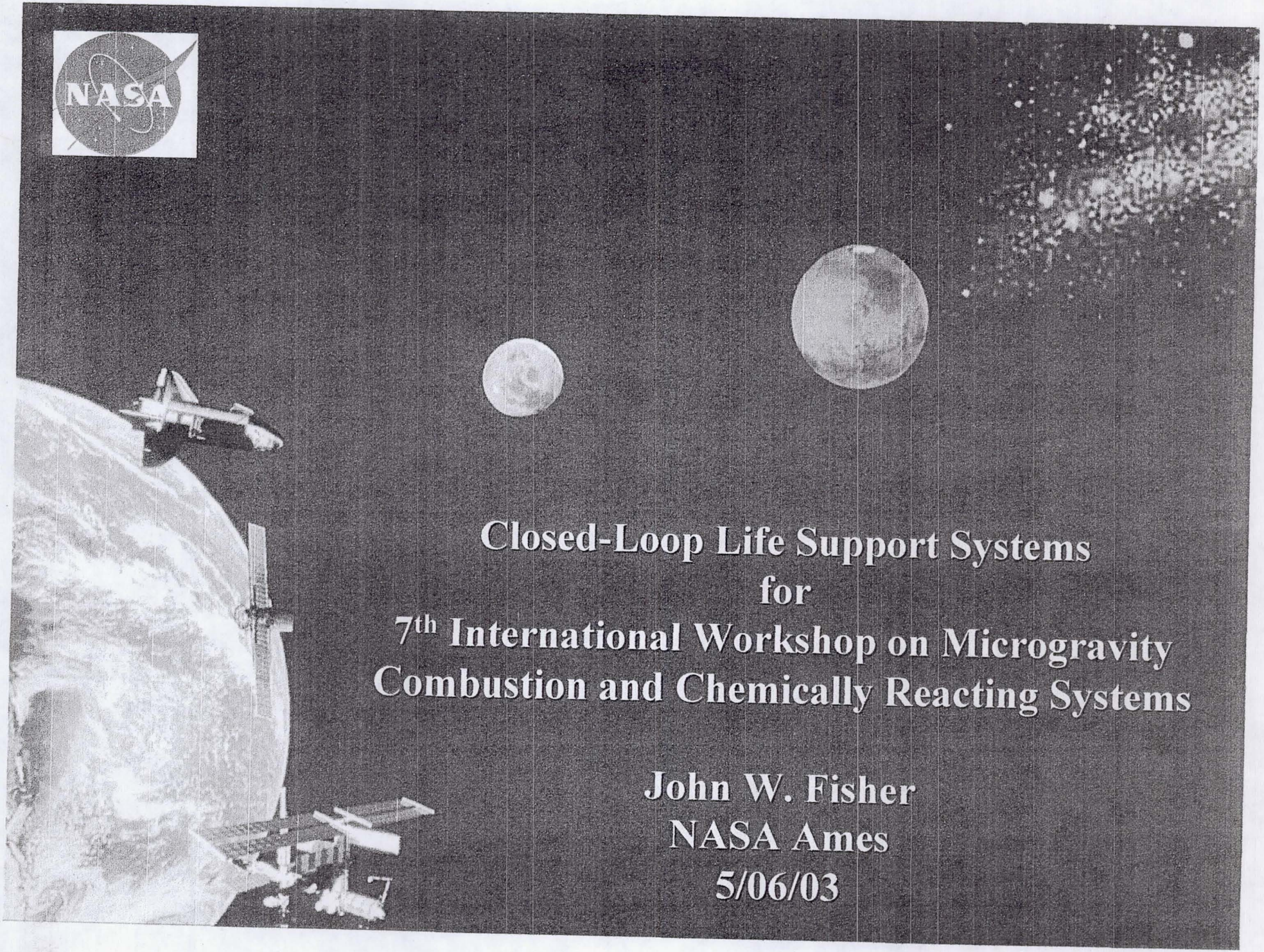
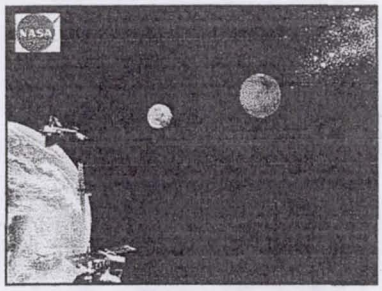
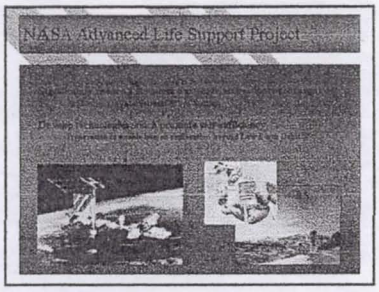


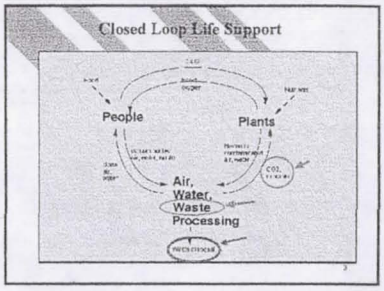
Closed-Loop Life Support Systems for 7th International Workshop on Microgravity Combustion and Chemically Reacting Systems

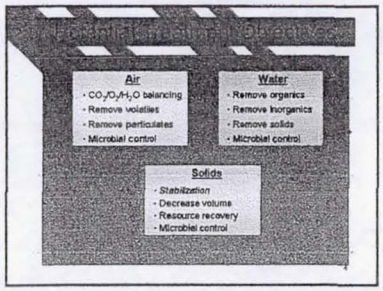
John W. Fisher
NASA Ames

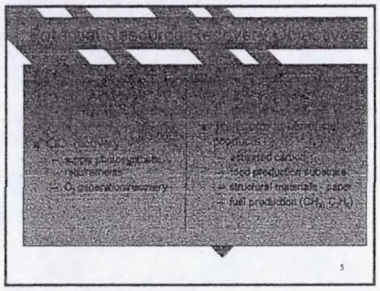
5/06/03

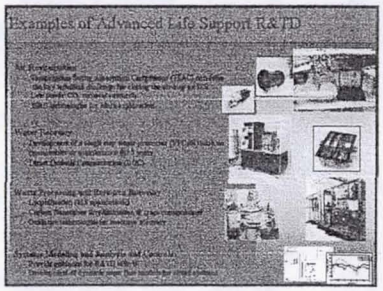


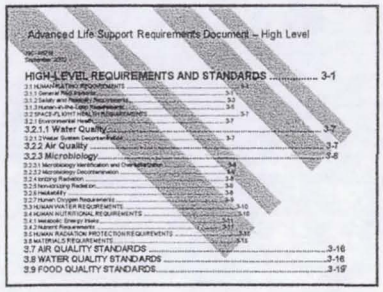


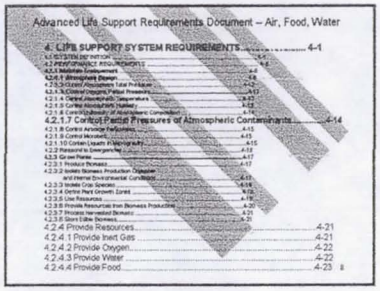


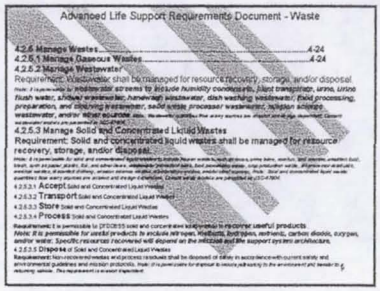










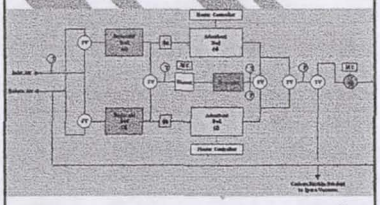


should print this larger

Example Technologies that Satisfy Requirements

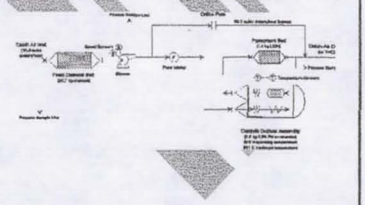
10

Air System – Carbon Dioxide Removal



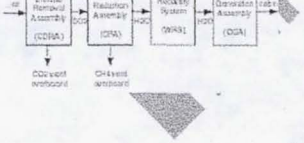
11

ISS Trace Contaminant Control



12

Air – Sabatier

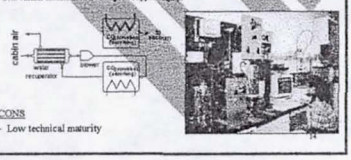


13

Air System
Hybrid Membrane/Adsorption CO_2 Removal

Proposed Technology: Water Recuperated CO_2 Sorbed

PROS
- Lower power than cdrA due to reduced/eliminated need for water desorption
- Uses similar materials to existing life support space.



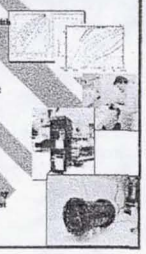
CONS
- Low technical maturity

14

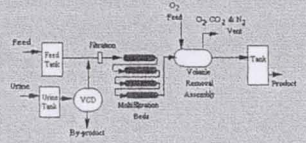
Temperature Swing Adsorption (TSA) CO_2 Compressor

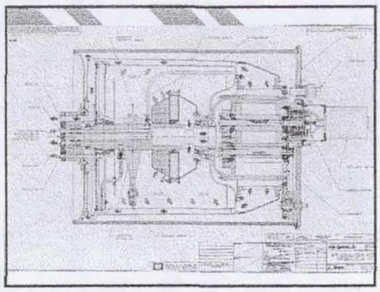
- A single-bed partial unit was developed and tested with the MSFC 4ENS hardware in FY00.
- Design and development of a liquid-cooled assembly was initiated in FY01.
- The liquid-cooled TSA compressor assembly will be completed in FY02. An air-cooled design (new flight requirement) has been initiated in FY02.
- The TSA compressor is expected to be capable of providing 4 kg CO_2 per day from the CDRA with:
  - lower power
  - quieter and vibration-free operation
  - expected better reliability and lifetime

  than the mechanical compressor alternative.
- If successful, this technology would solve one of the key technical challenges to closing the air loop for the first time on International Space Station.

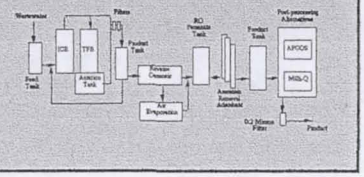


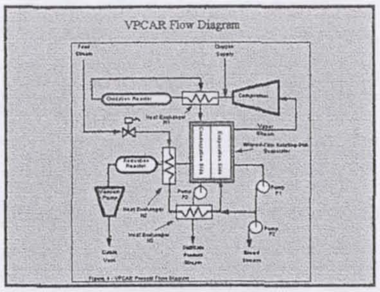
International Space Station Water Treatment Subsystem

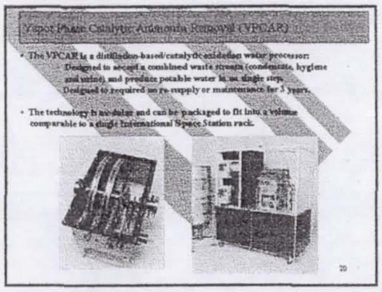


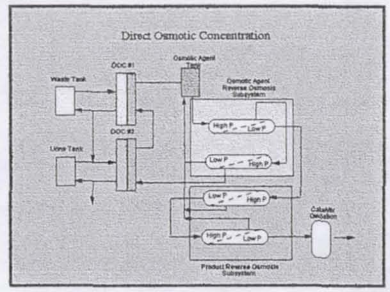


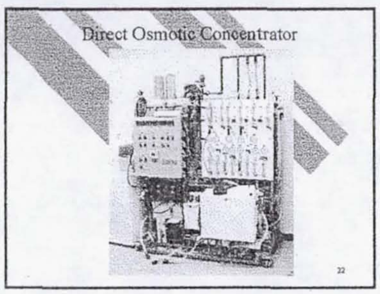
JSC Bioreactor System

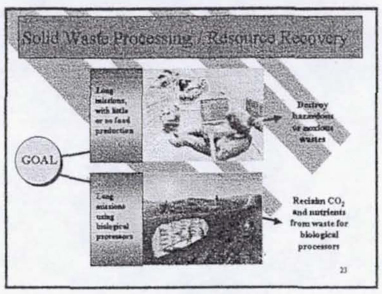


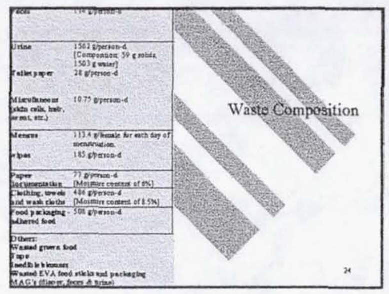

VPCAR Flow Diagram

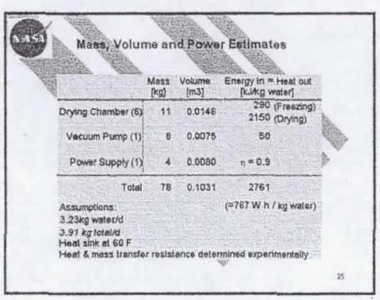

Vapor Phase Catalytic Ammonia Removal (VPCAR)
The VPCAR is a distillation-based/catalytic oxidation water processor:
Designed to accept a combined waste stream (condensate, hygiene and urine) and produce potable water in a single step.
Designed to required no re-supply or maintenance for 3 years.
The technology is modular and can be packaged to fit into a volume comparable to a single International Space Station rack.
20

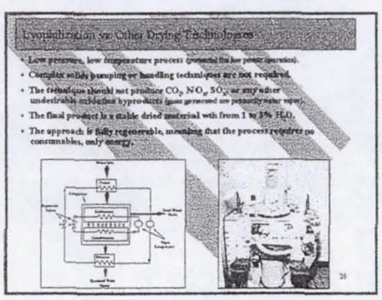

Direct Osmotic Concentration
Waste Tank
Urine Tank
DOC #1
DOC #2
Osmotic Agent Reverse Osmosis Subsystem
Product Reverse Osmosis Subsystem

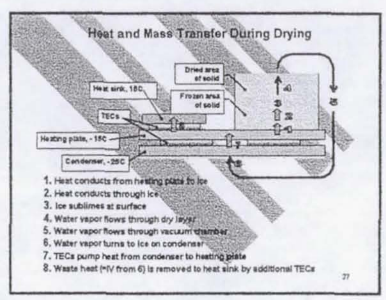

Direct Osmotic Concentrator
22

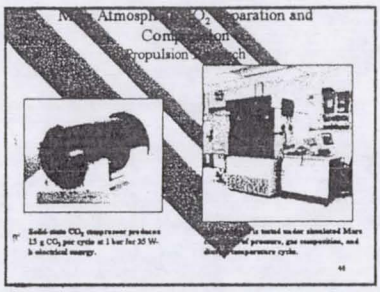

Solid Waste Processing / Resource Recovery
GOAL
Long missions, with little or no food production
Destroy hazardous or noxious wastes
Long missions using biological processors
Reclaim CO2 and nutrients from waste for biological processors
23

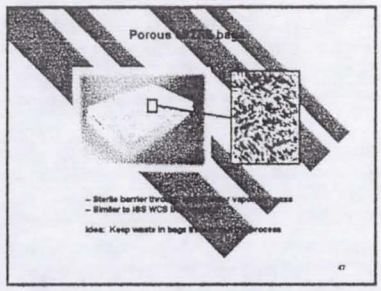

Waste Composition
Urine 1562 g/person-d [Composition: 59 g solids, 1503 g water]
Toilet paper 28 g/person-d
Miscellaneous (skin cells, hair, sweat, etc.) 10.75 g/person-d
Menses 113.4 g/female for each day of menstruation.
Wipes 185 g/person-d
Paper documentation 77 g/person-d [Moisture content of 6%]
Clothing, towels and wash cloths 486 g/person-d [Moisture content of 8.5%]
Food packaging - adhered food 508 g/person-d
Others:
Wasted grown food
Tape
Inedible biomass
Wasted EVA food sticks and packaging
MAG's (diaper, feces & urine)
24

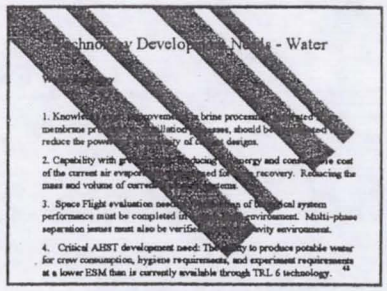

Mass, Volume and Power Estimates
Mass [kg] | Volume [m3] | Energy in = Heat out [kJ/kg water]
Drying Chamber (6) 11 0.0146 290 (Freezing) 2150 (Drying)
Vacuum Pump (1) 8 0.0075 50
Power Supply (1) 4 0.0080 η = 0.9
Total 78 0.1031 2761
(=767 W h / kg water)
Assumptions:
3.23kg water/d
3.91 kg total/d
Heat sink at 60 F
Heat & mass transfer resistance determined experimentally
25


Lyophilization vs Other Drying Technologies
Low pressure, low temperature process (potential for low power operation).
Complex solids pumping or handling techniques are not required.
The technique should not produce CO2, NOx, SOx, or any other undesirable oxidation byproducts (gases generated are primarily water vapor).
The final product is a stable dried material with from 1 to 3% H2O.
The approach is fully regenerable, meaning that the process requires no consumables, only energy.
26


Heat and Mass Transfer During Drying
Dried area of solid
Heat sink, 18C
Frozen area of solid
TECs
Heating plate, - 15C
Condenser, -25C
1. Heat conducts from heating plate to ice
2. Heat conducts through ice
3. Ice sublimes at surface
4. Water vapor flows through dry layer
5. Water vapor flows through vacuum chamber
6. Water vapor turns to ice on condenser
7. TECs pump heat from condenser to heating plate
8. Waste heat (=IV from 6) is removed to heat sink by additional TECs
27


Solid state CO_2 compressor produces 15 g CO_2 per cycle at 1 bar for 35 W-h electrical energy.


Porous
– Sterile barrier
– Similar to
Idea: Keep waste in bags


1. Knowledge
membrane
reduce the
2. Capability with
of the current air
mass and volume of
3. Space Flight evaluation
performance must be completed
separation issues must also be
4. Critical AEST development need:
for crew consumption, hygiene requirements, and experiment requirements
at a lower ESM than is currently available through TRL 6 technology.