Designing Food Processing Systems for Manned Space Explorations

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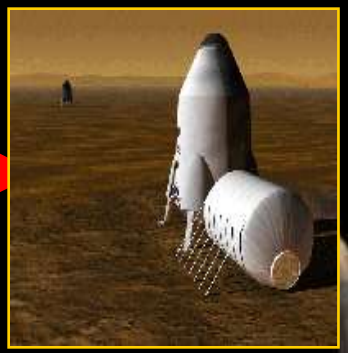
Long Duration Space Travel

Manned Mission to Mars

Mars is 55 - 400 Mkm
from Earth

6 – 8 months



MARS SURFACE
18 months
HYPOGRAVITY ***(1/3 Earth***
Planetary food system
Prepackaged food system
Crop processing
Hydroponic growth
Bulk storage

MICROGRAVITY
Prepackaged food system

EARTH

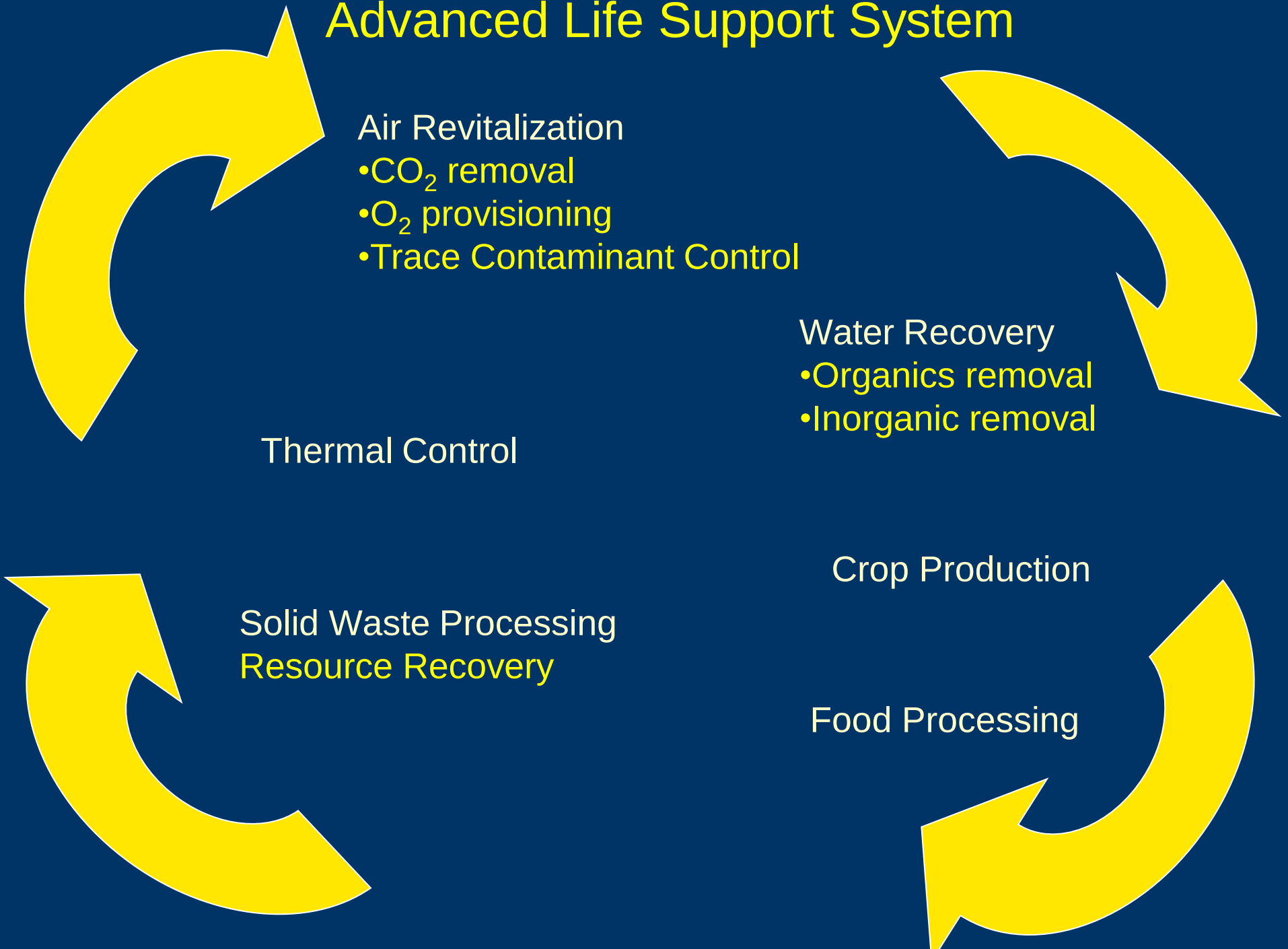
6 – 8 months

The minimal distance between the planets occurs once every 18 months

Regenerative Life Support System

- CELSS -1978 (Controlled Ecological Life Support System)
  - To integrate regenerative biological and physicochemical processes
    - a system that will produce food, potable water, and breathable atmosphere from metabolic and other wastes
  - Use higher plant photosynthesis

Advanced Life Support System



Nominal Crew Member Life Support Requirements

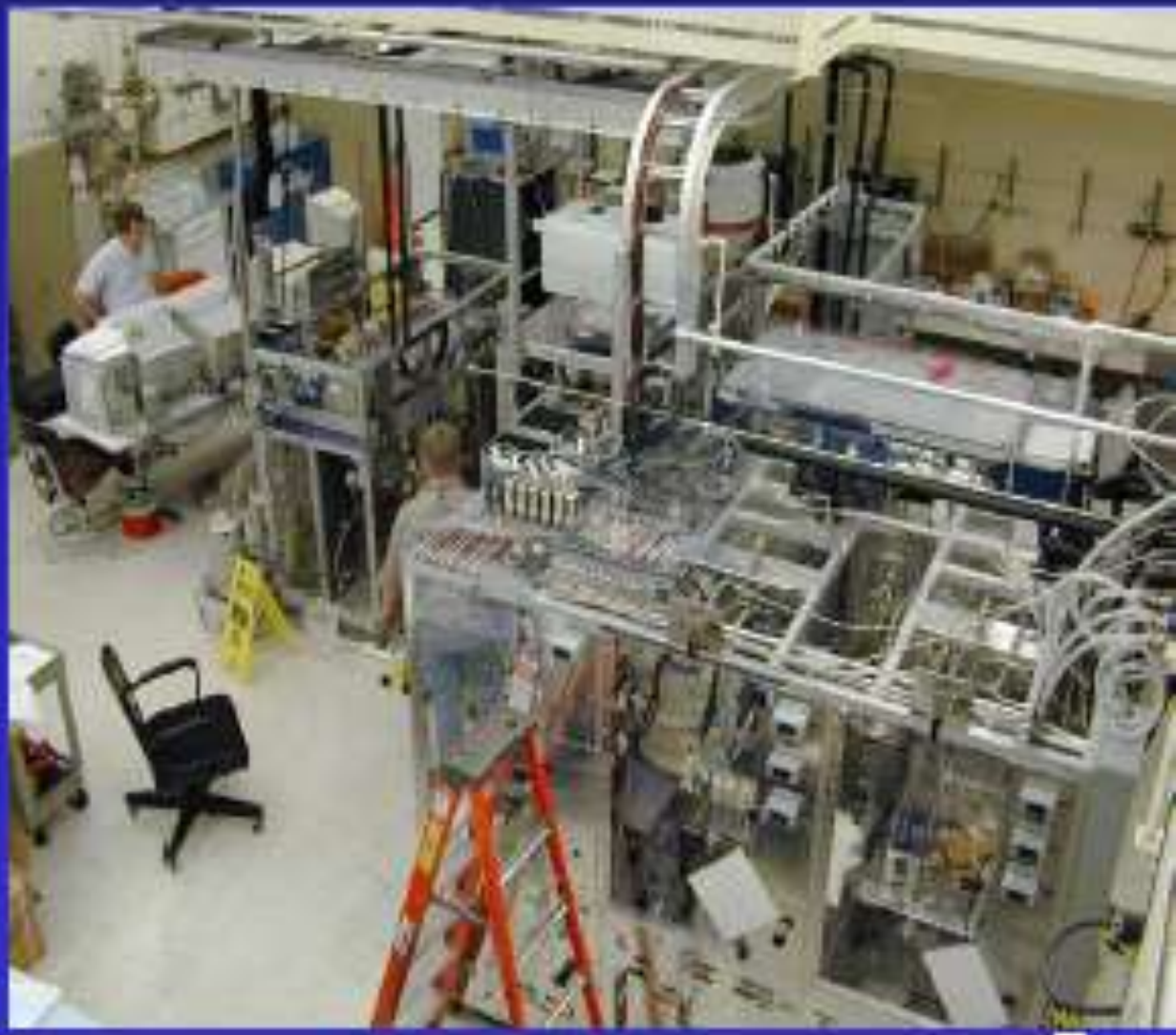
(Does not include paper, plastic, soap, power supply)

Consumables	kg/person day	Wastes	kg/person day
Gases, Oxygen	0.84	**Gases** Carbon dioxide	1.0
Water		**Water**	
Drinking	1.62	Urine	1.50
Water content food	1.15	Perspiration/respiration	2.28
Food prep water	0.79	Fecal water	0.09
Shower and hand wash	6.82	Shower and hand wash	6.51
Clothes wash	12.5	Clothes wash	11.90
Urine flush	0.5	Urine flush	0.50
Solids		Humidity condensate	0.95
Food	0.62	**Solids**	
		Urine	0.06
		Feces	0.03
		Perspiration	0.02
		Shower and hand wash	0.01
Total	24.8 kg	Clothes wash	0.08

Design Characteristics

	Space Station	Lunar Habitat	Mars Habitat	
Air	Resupplied	Regenerated	Regenerated	
Water	Resupplied & Recycled	Recycled	Recycled	
Food	Stored	Most stored Some grown	Stored and Grown	
Waste	Stored	Stored	Recycled	

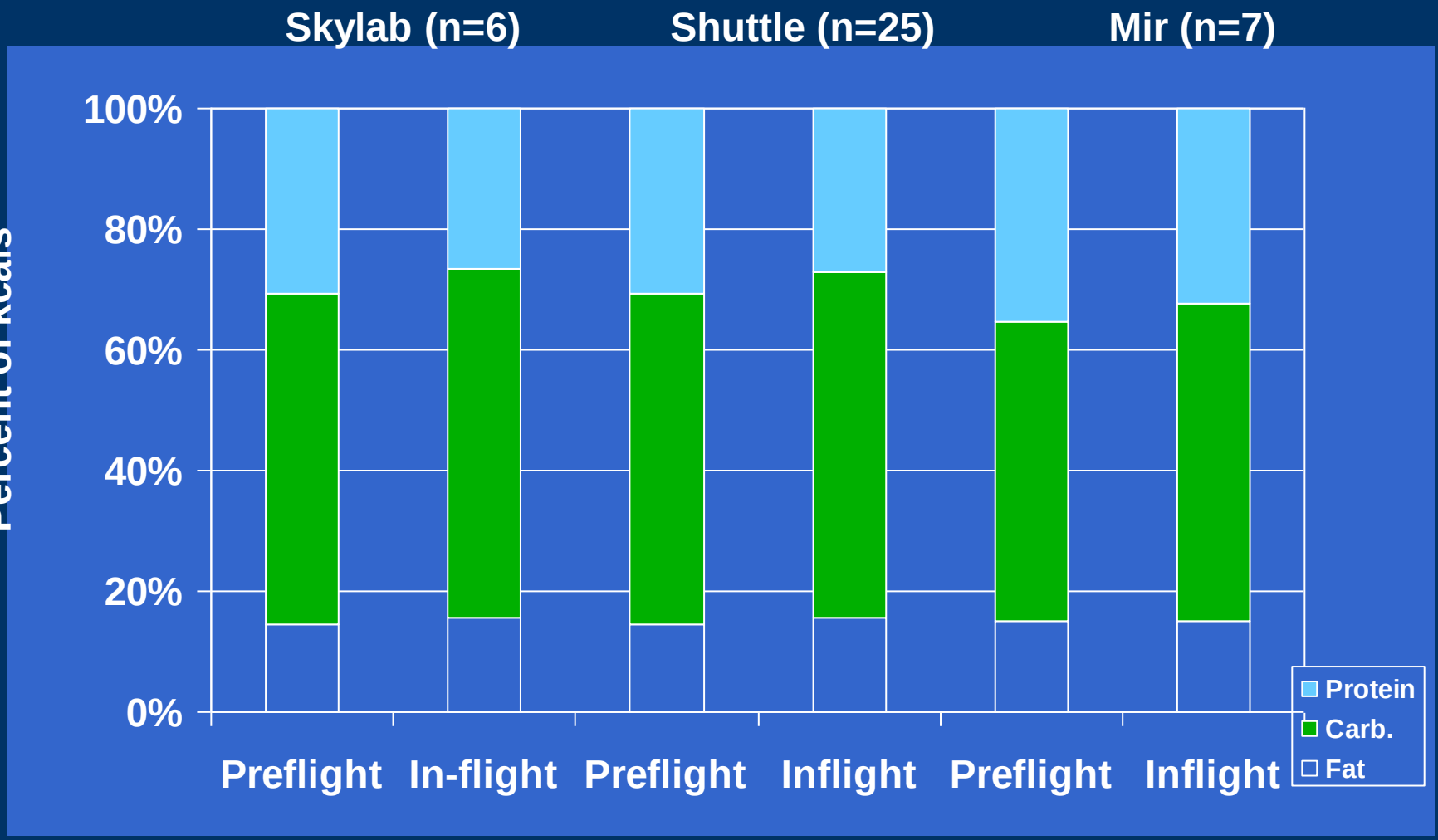
Water Recovery Systems Laboratory



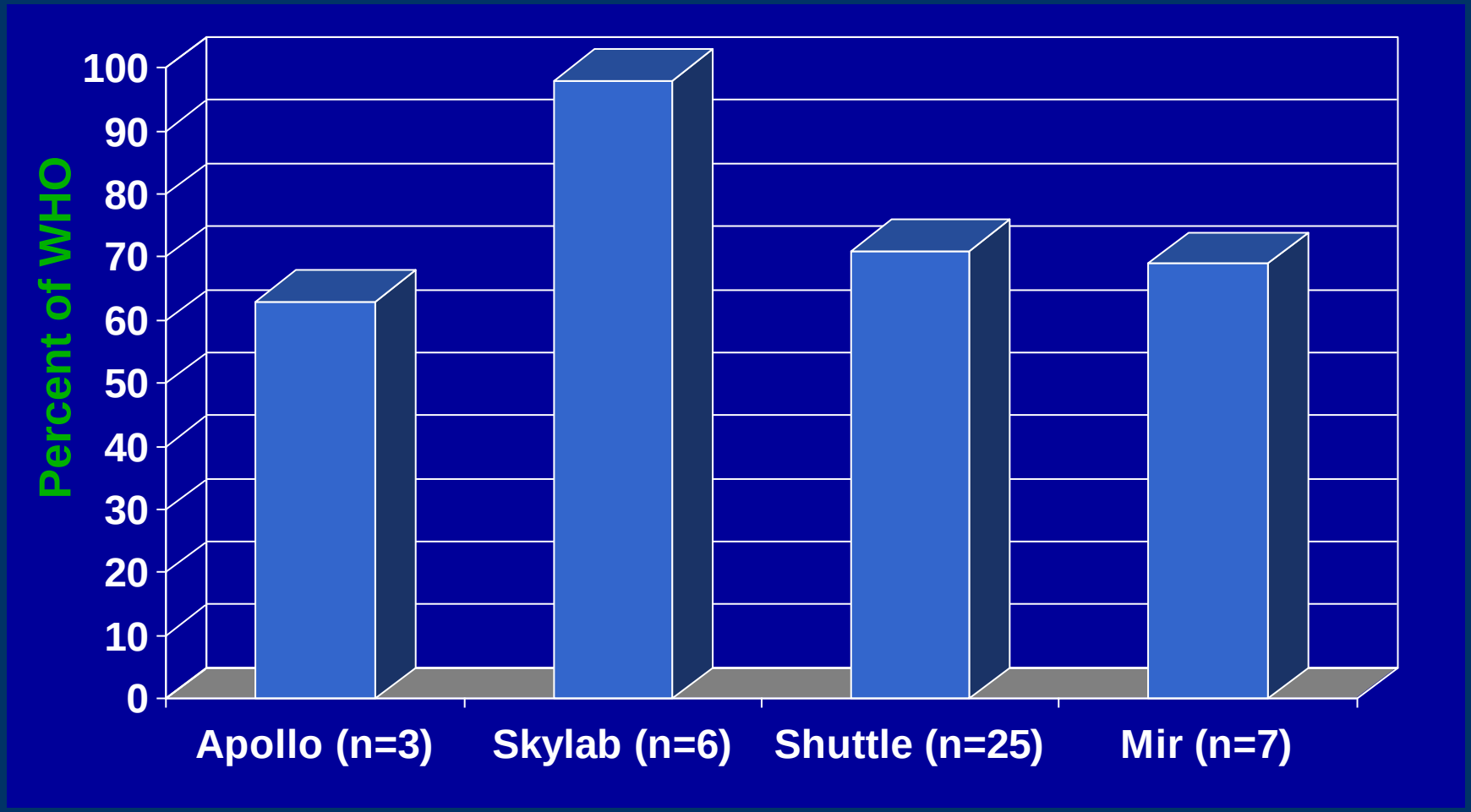
Consumer ?


David Wolf, US Astronaut
119 days on Mir

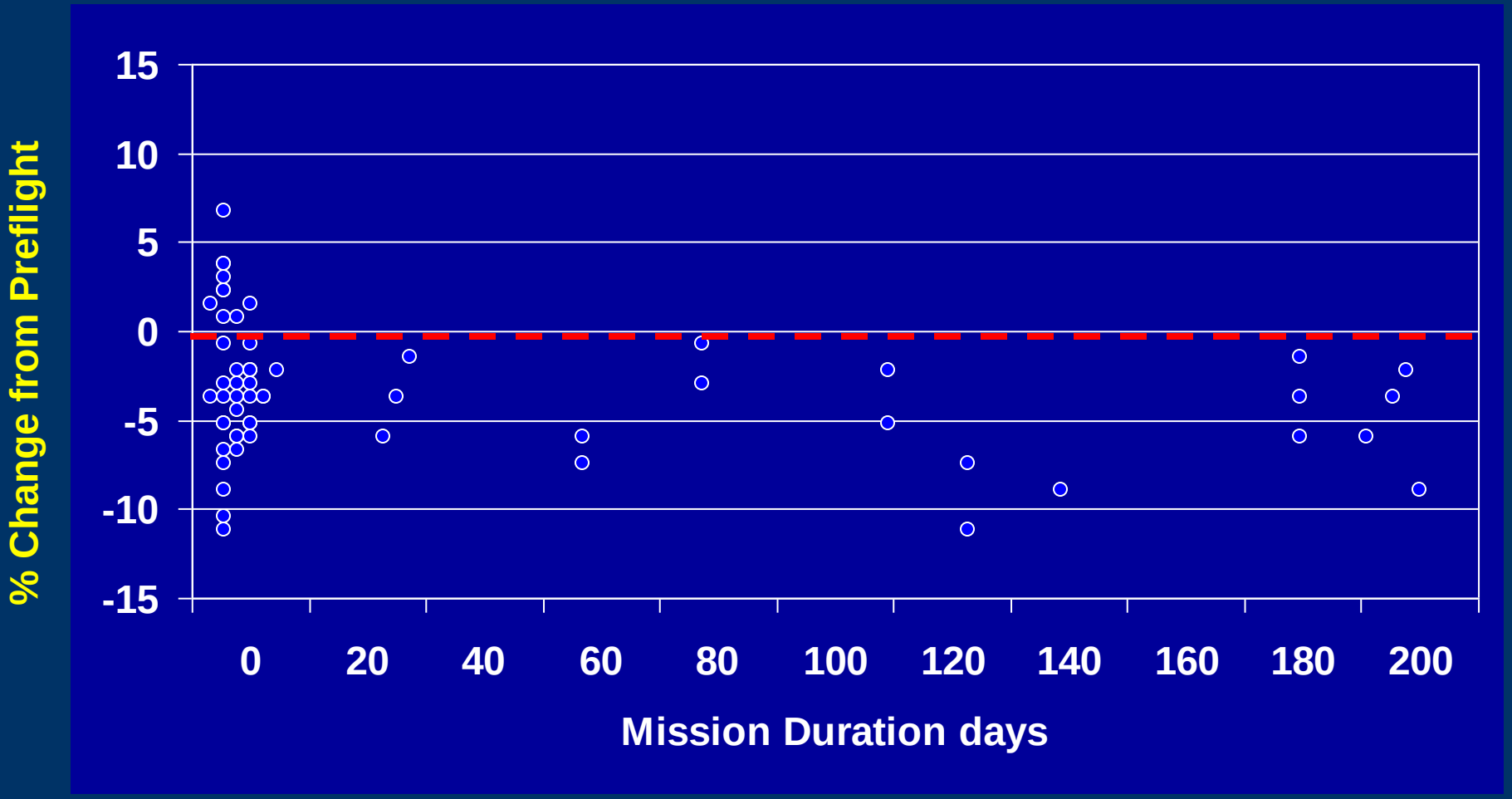
Diet Composition



Calorie Consumption

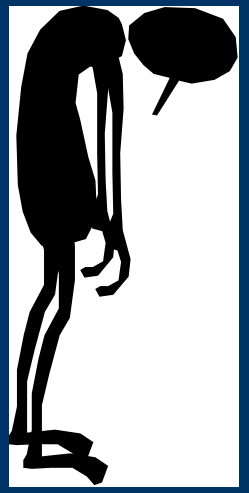


Body Weight


% Change from Preflight
15
10
5
0
-5
-10
-15
0
20
40
60
80
100
120
140
160
180
200
Mission Duration days

Physiological Effects Of Spaceflight

- Weight loss
- Fluid shift
- Dehydration
- Constipation
- Electrolyte imbalance
- Calcium loss
- Potassium loss
- Decreased red blood cell mass
- Space motion sickness



Psychological Effects of Long Duration Missions

- Long-term Confinement
- Separation from home, family and traditional sources of emotional support, country, culture, planet
- Reduced ways to safely ‘let off steam’; fewer emotional and physical outlets; fewer ways to renew

– Disruptive events on orbit and on earth

Crew Stress Factors

- death of family member
- death of friend
- depressed mood
- crew friction
- prolonged insufficient sleep
- dark/crowded station
- work underload and overload
- anger with ground team
- periods of low motivation
- mild anxiety
- delayed return to earth
- onboard fire
- Over-scheduling & insufficient timeline control
- inappropriate or incorrect direction from ground
- language difficulties
- cultural misunderstandings
- persistent system failures

- Normal people placed in an abnormal environment for long periods of time

- Food has a different and an important role on long duration flights

Lettuce growing under red and blue LED's.

Peanuts growing under light transmitted via fiber optics.

Sweet Potatoes growing under high pressure sodium lights.

The "Salad Machine"

Proposed for the International Space Station as a system to produce fresh salad crops for fresh consumption by the Astronauts.

Food Processing Equipment
Design and Operating Constraints

- Multi-purpose equipment: flexible methods, products
- Automated but can be manually controlled
- Ease of cleaning
- Safety
- Power
- Size
- Water use
- Air contaminants
- Waste generated
- Noise

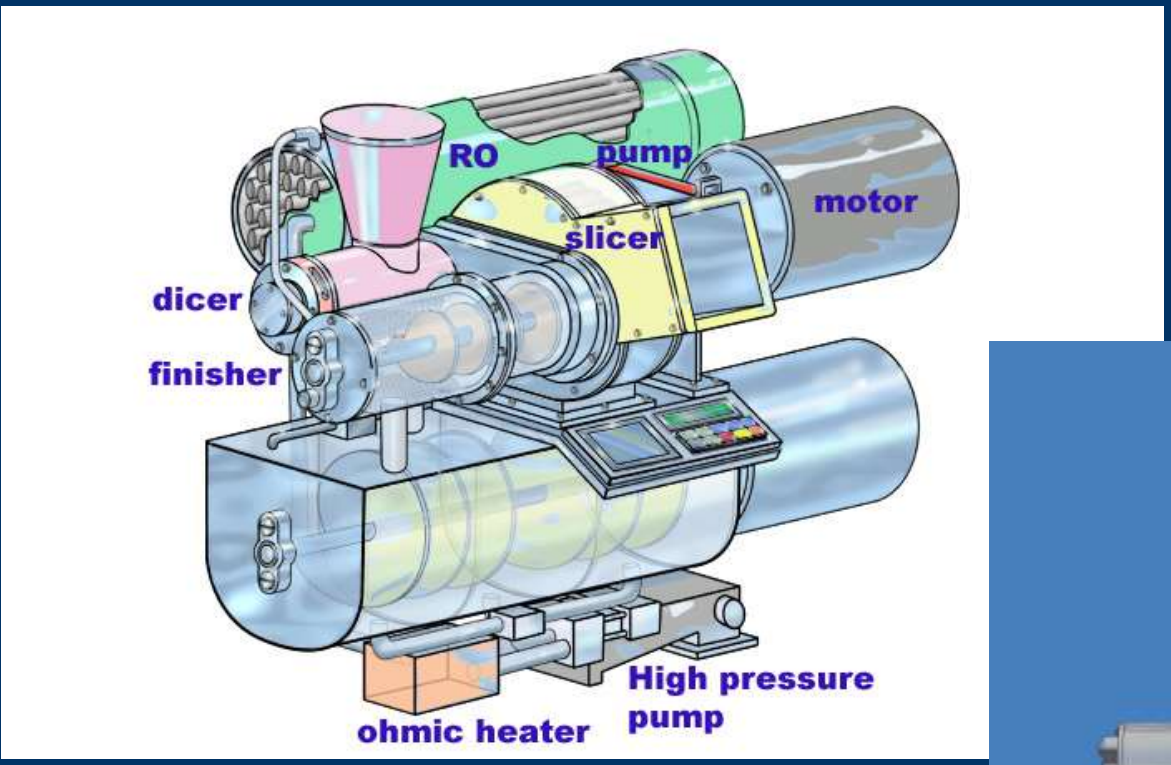
Multi-purpose Fruit and Vegetable Processing System

NASA Contract with UC Davis 2003-2007

- Multiple products
  - Sliced tomatoes
  - Diced tomatoes, Salsa
  - Tomato juice
  - Tomato sauce
  - Tomato soup
  - Tomato Ketchup
- Incorporate additional vegetables such as carrots, chard.

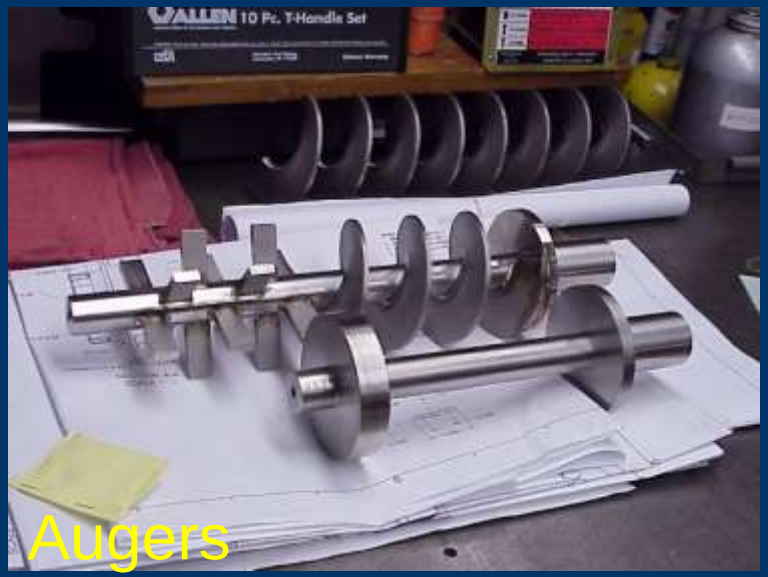
Multipurpose Fruit and Vegetable Processor (MFVP)

Size Reduction → Heating → Separation/ Concentration



Construction progress

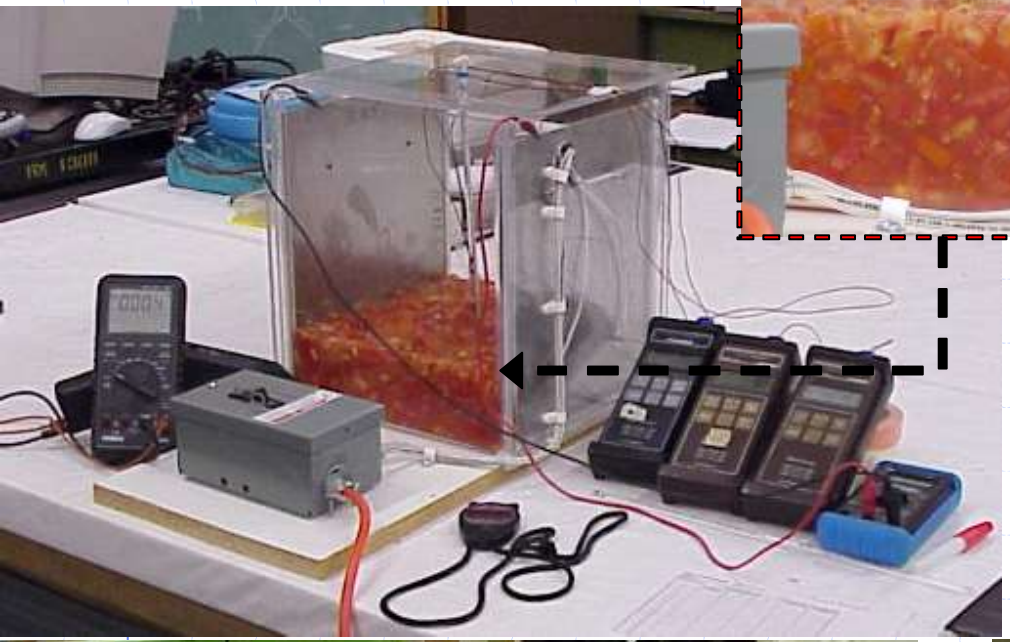

Slicer Housing



Augers


Pulper/Dicer

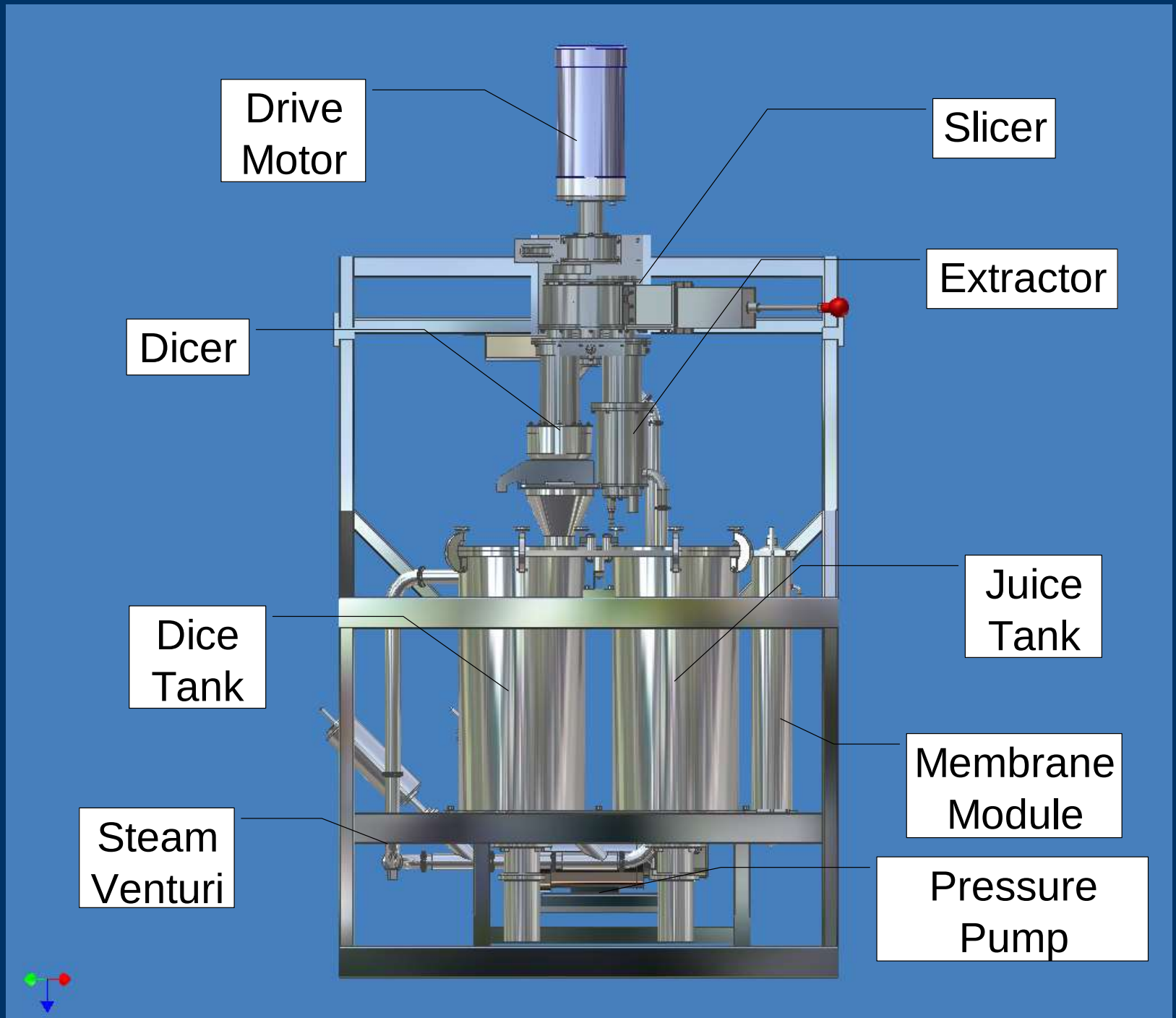

CIP Pump



Optimizing for ESM **(Equivalent System Mass)**

$$\mathbf{ESM = M+(V.V_{eq})+(P \cdot P_{eq})+(C \cdot C_{eq})+(CT \cdot D \cdot CT_{eq})}$$

- Minimizing ESM is accomplished by reducing:
  - Mass (M)
  - Volume (V)
  - Power (P)
  - Cooling, heat generation (C)
  - Crew Time (CT)


Drive Motor
Slicer
Extractor
Dicer
Juice Tank
Dice Tank
Membrane Module
Steam Venturi
Pressure Pump

Opportunities for Food Engineers

Resources

Packaging

Water

Food Processing Equipment

Energy

Sensors, Controls

Environment

Flexible processing

Production systems

Harvesting

Coperinicus

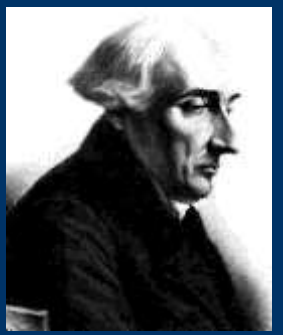
Cassini

Newton

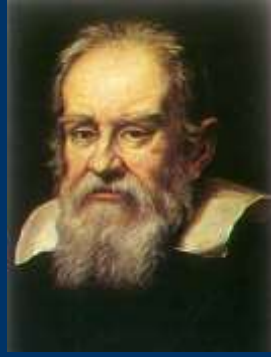
Halley

Bessel

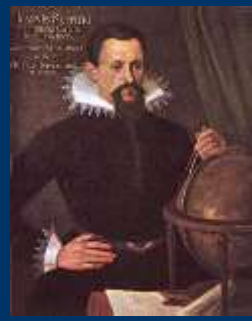
Huygens



Lagrange



Galileo



Kepler

Laplace