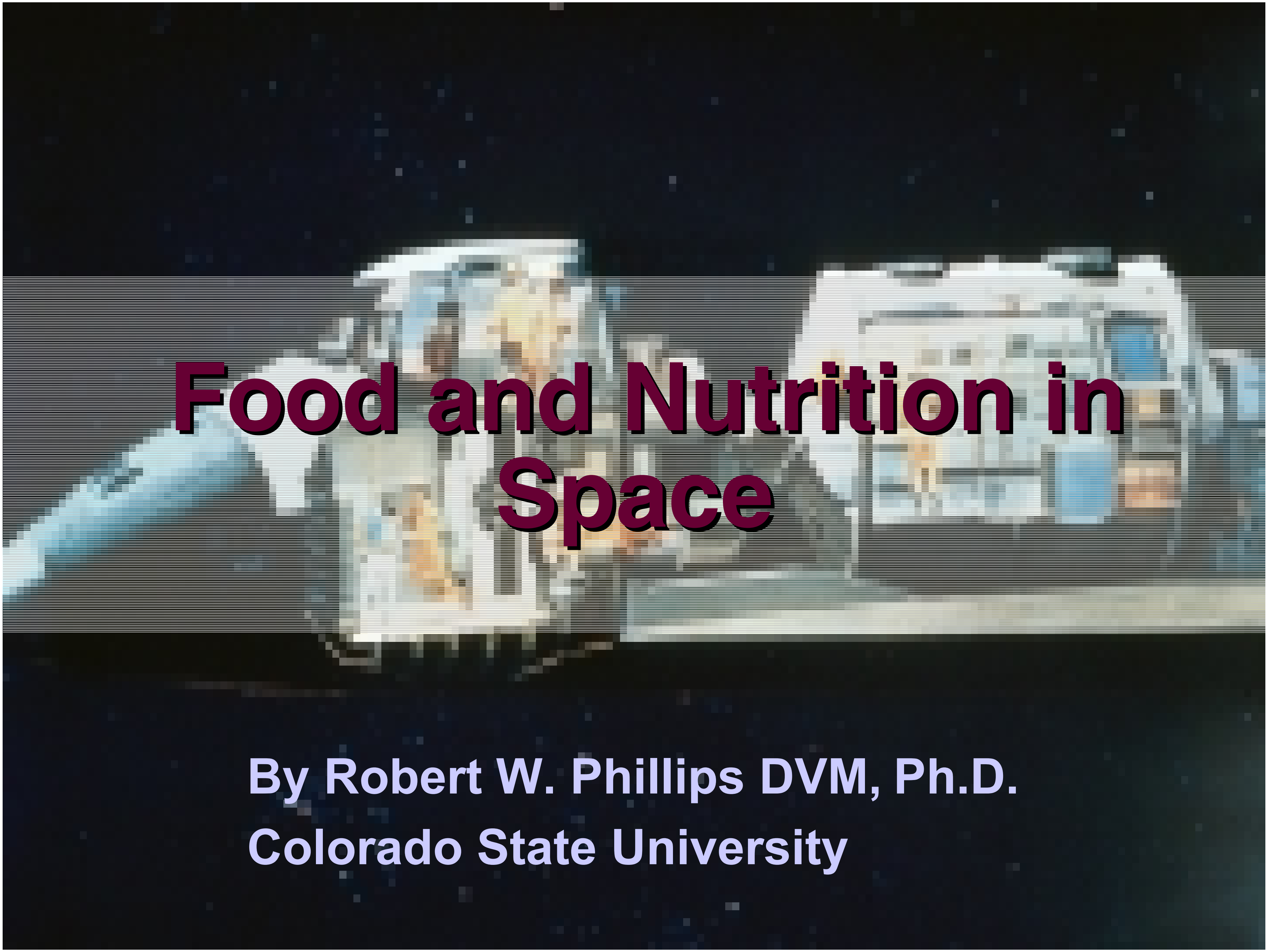
Food and Nutrition in Space
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Chronology of Space Food Development

- Mercury 1961-1963
- Gemini 1964-1967
- Apollo 1968-1972
- Skylab 1973-1974
- Space Shuttle 1981-present
- Shuttle-MIR 1995-1998
- International Space Station 2000-

Mercury 1961-1963

- Completely prepared
- Bite size, energy dense, palatable food
- Toothpaste like tubes i.e. applesauce

Gemini 1964-1967

- Completely prepared
- 2500 kcal/person/day provided
- Bite size or tube squeezable
- Energy dense
- Sensory acceptable

Apollo 1968-1972

- Dehydrated foods - fuel cell water was available
- Canned and irradiated foods
- First utensils for eating, spoonbowl packaging
- Food bars for space suits on lunar surface

Fuel Cells

- Fuel cells combine hydrogen and oxygen to provide energy for the space vehicle. In the process water is formed which can then be used for drinking

Apollo era thermostabilized (canned) food container with lift off top

Nutrition in Space

Skylab squeezable drink containers
-could have either water or juice

Skylab 1973-1974

- Refrigerator and freezer available as well as food warmers.
- All planned food for the missions launched with the lab
- No dehydrated food as all water was launched with lab
- Frozen and thermostabilized foods packed in cans
- 72 foods with 6 day cycle menu including steak, lobster and ice cream

Skylab:
Thermostabilized (canned) main course

Skylab:

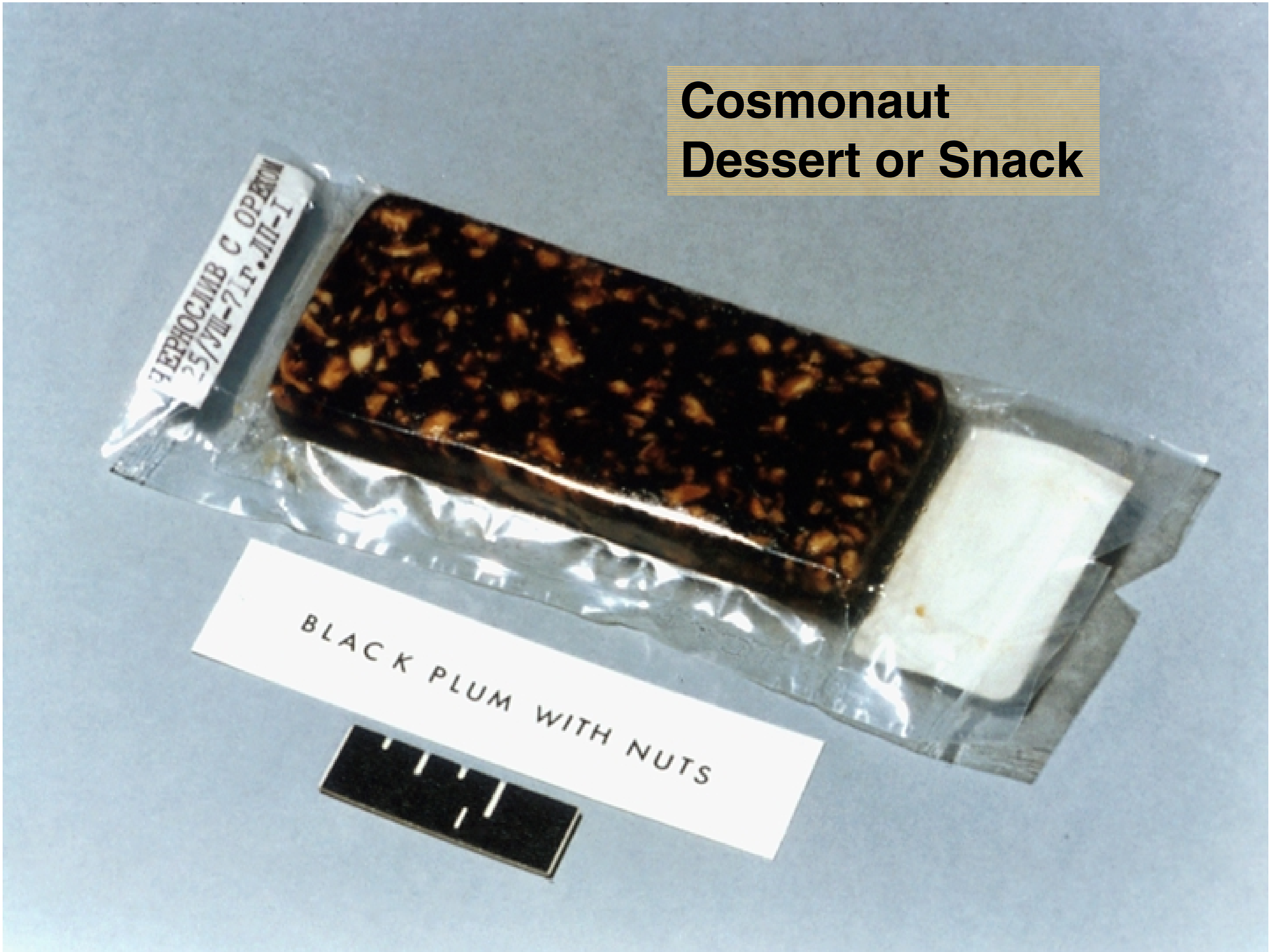
Dehydrated peach ambrosia with pears. Comes in pouch, served in can.

Russian prepackaged vitamin pills

Russian Cosmonaut meal using squeeze tubes, 1972

Cosmonaut Green Cabbage Soup

Cosmonaut Dessert or Snack



Cosmonaut Coffee with Milk in a squeezable tube, circa 1972

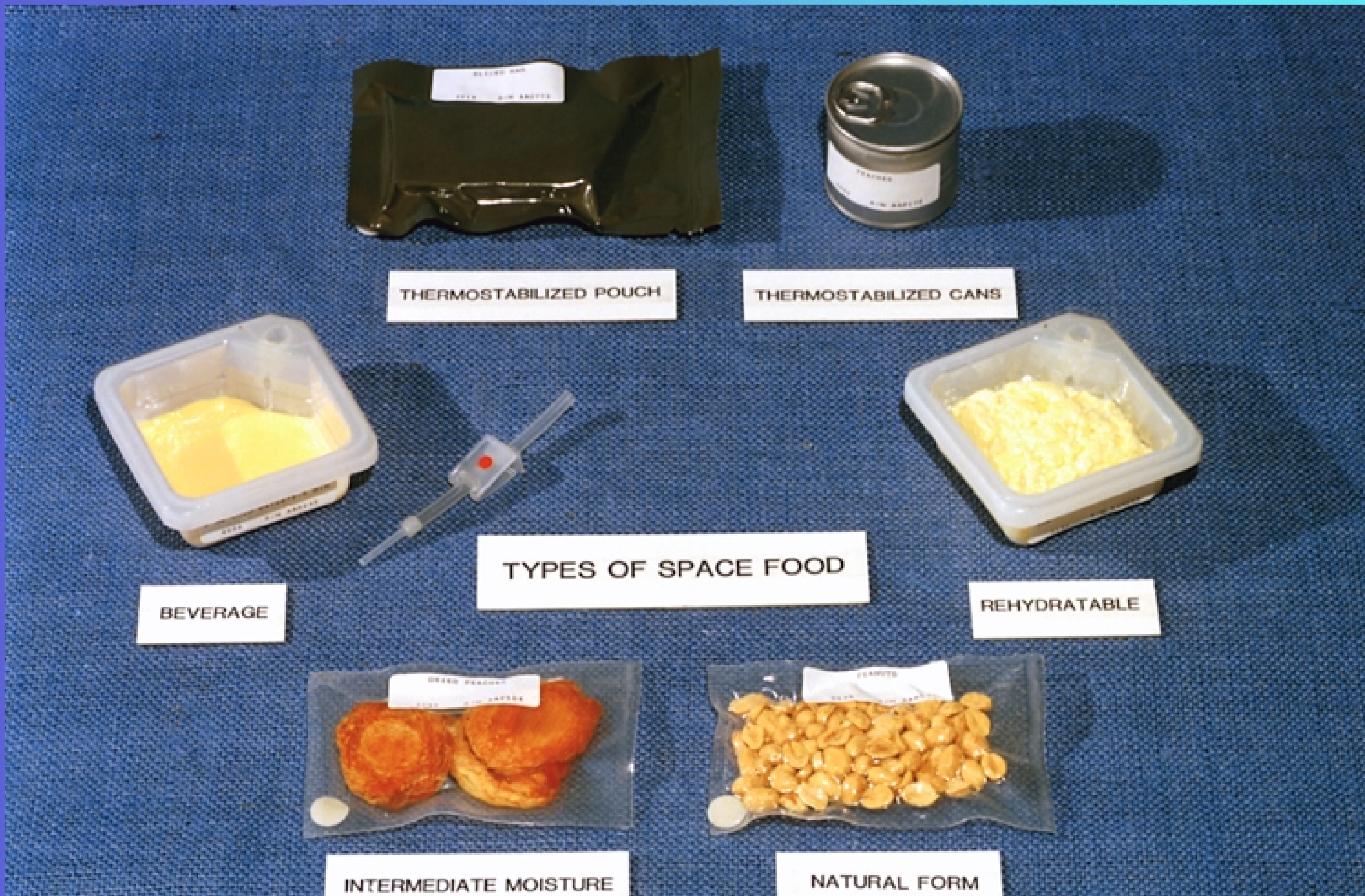
Space Shuttle 1981-present

- No refrigerator or freezer
- Fuel cell water
- Galley with rehydration station and convection oven
- 50% dehydrated food
- Commercial off the shelf food where available.
- Choice: dehydrated, thermostabilized, intermediate moisture, natural, snack
- Increased choice, personal preference with dietary constraints

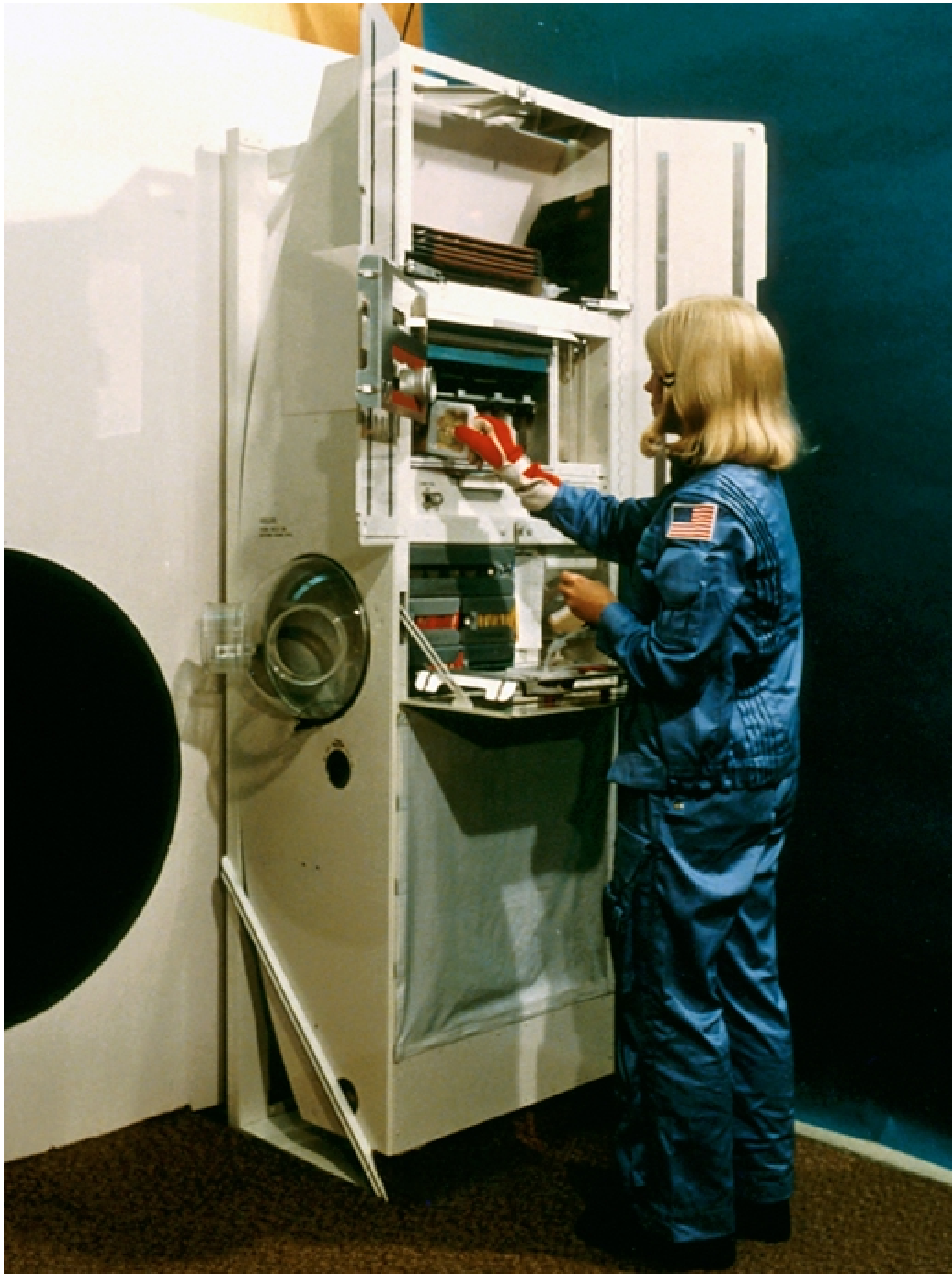
Early Space Shuttle era drink container components

Was rehydrated at the galley by injecting water with a syringe needle. The system can dispense either hot or cold water

Some foods currently available on Space Shuttle flights

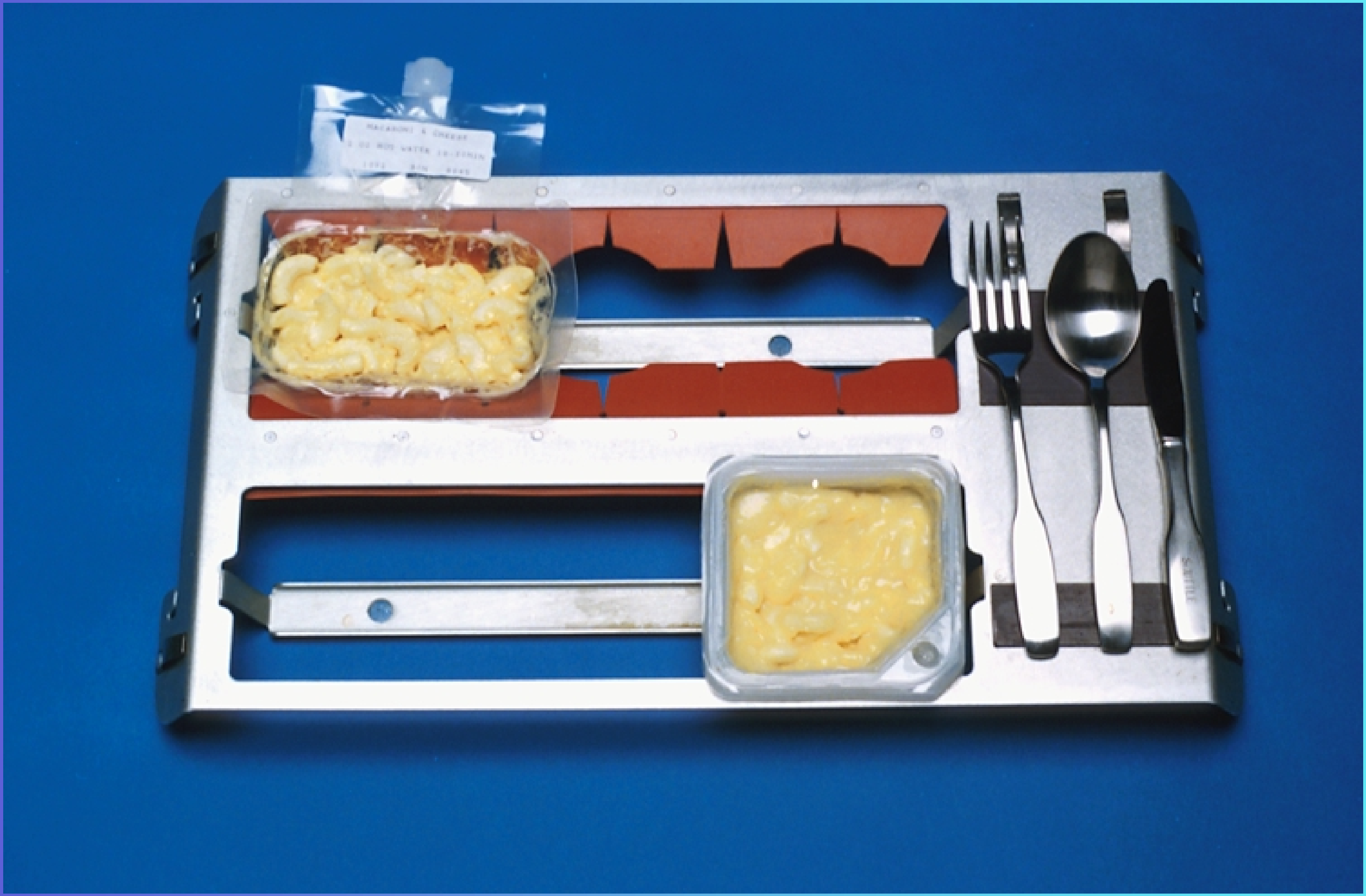


Space Shuttle flour tortilla with bean dip



Shuttle Astronaut
Dr. Rhea Seddon
preparing a meal
in the Space Shuttle
galley

Early Space Shuttle food tray with menu items and utensils



International Cooperation in Space

- Cultural differences in dietary choices
- On ISS: American, Canadian, European, Russian and Japanese crewmembers

Shuttle MIR 1995-1998

- Longer missions 111-184 days
- Mix of Russian and American food items provided increased variety
- Galley includes heating and rehydration facilities
- Partially recycled water
- Food stored in MIR food containers 6 rations/container American or Russian

Shuttle-MIR 1995-1998 (continued)

- General approach: open a container then all members eat until the container is empty
- Choice: dehydrated, thermostabilized, intermediate moisture, natural, snacks
- 3000 kcal/day provided
- Fresh foods following re-supply by Russian Progress space vehicle or Space Shuttle

French thermostabilized food item for Space Shuttle

French thermostabilized food item for Space Shuttle

Rabbit

French thermostabilized food item for Space Shuttle

Irradiation to Preserve Space Food

IRRADIATED PRODUCTS USED ON THE FIRST 24 SHUTTLE FLIGHTS

(1981 TO 1986, APPROXIMATELY 805 MAN-DAYS)

	SERVINGS	
MEAT PRODUCTS	**TOTAL SENT**	**TOTAL USED**
BEEF STEAK	231	164
CORNED BEEF	41	11
SMOKED TURKEY	104	53
TOTAL MEAT	376	228
BAKERY PRODUCTS		
BREAD (SEEDLESS RYE)	172	64
BREAKFAST ROLLS	81	57
TOTAL BAKERY	253	121

ADVANTAGES OF IRRADIATED BAKERY PRODUCTS IN SPACE

- NO REFRIGERATION REQUIRED
- EXTENDED SHELF LIFE
- ELIMINATES POTENTIAL PATHOGENS

ADVANTAGES OF IRRADIATED MEAT IN SPACE

- NO REFRIGERATION REQUIRED
- CAN CONTROL EXCESS LIQUID
- CAN CONTROL DONENESS (NOT OVERCOOKED)
- POPULAR WITH ASTRONAUTS
- DEMONSTRATE NEW TECHNOLOGY

IRRADIATION PROCESS FOR BEEF STEAKS AND TURKEY

1. COOK

2. PACKAGE AND SEAL

3. FREEZE

4. IRRADIATE WHILE FROZEN (-40° C) MINIMUM ABSORBED DOSE 44KGY

5. STORE AT AMBIENT TEMPERATURE

ISS Habitation Module

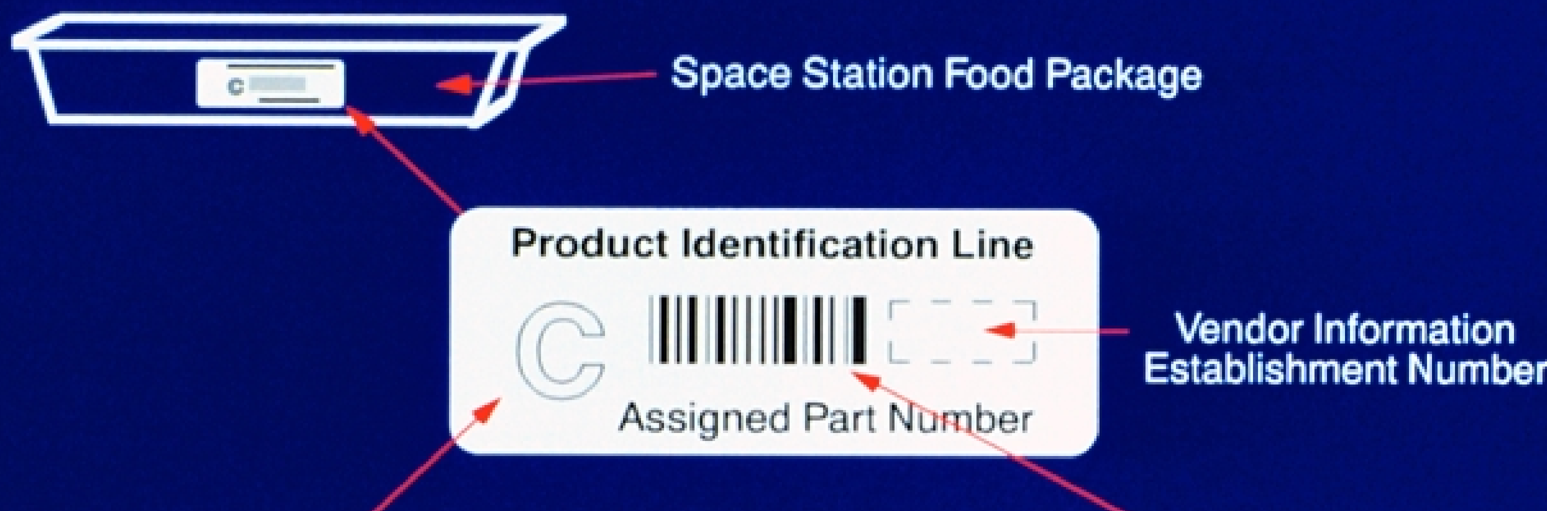
International Space Station 2000 - future

- From 2000-2004 the ISS will use the Shuttle-MIR system
- Complete assembly currently scheduled for 2004
- Will have freezers, refrigerators and ambient food storage
- Microwave/convection oven

International Space Station 2000 - future (continued)

- Significant water recycling
- 30 day repeating menu
- Extended shelf life products in refrigerator: fruits, vegetables some dairy products
- Make diet as Earth like as possible with great variety

SPACE STATION FOOD SYSTEM PACKAGE LABELS



Cook Control Code

- Manually Input Code to Oven for PreprogrammedTime/Temperature Setting
- Easily Identified on Label
- Provides for Ease of Product Preparation

Barcode

- Inventory Tracking
- Read Electronically with Scanner

Food System Mass and Volumes

STOWAGE ITEM	90 DAY		14 DAY	
	CU FT	WT LBS	CU FT	WT LBS
Daily food, frozen	104	2167	16	339
Daily food, refrig'd	35	774	7	120
Daily food, ambient	44	928	6	145
TOTAL	**183**	**3869**	**29**	**604**

For a crew of six

Drink containers currently being used on the **Space Shuttle** and to be used on **International Space Station**. They are empty or contain powdered flavors, i.e. tea, lemonade, orange drink.

Possible International Space Station meal.
Fresh salad would only be available following re-supply

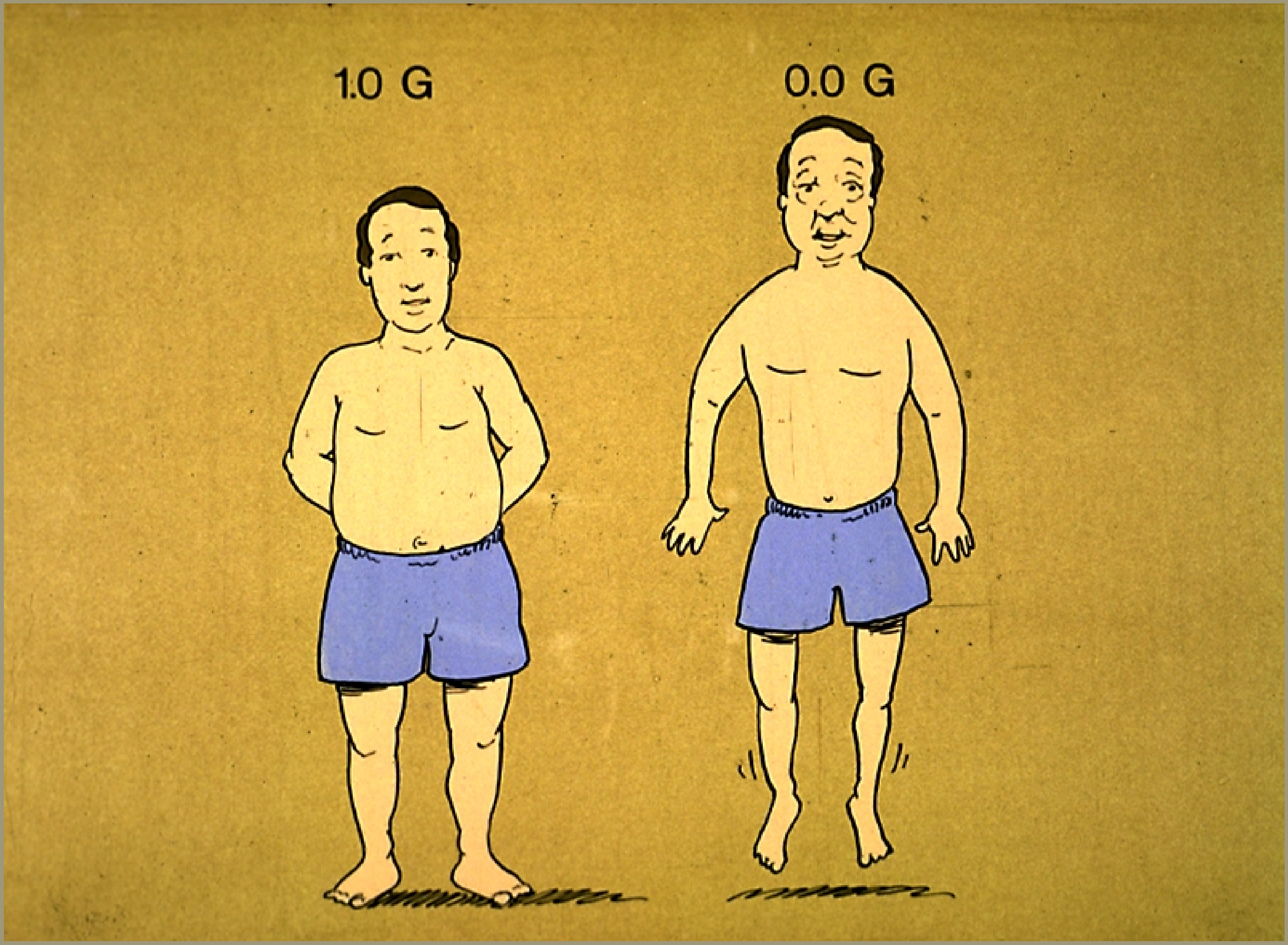
Physiological Effects of Spaceflight

- Weight Loss
- Fluid Shift
- Dehydration
- Constipation
- Electrolyte Imbalance
- Calcium Loss
- Potassium Loss
- Decreased Red Blood Cell Mass
- Space Motion Sickness

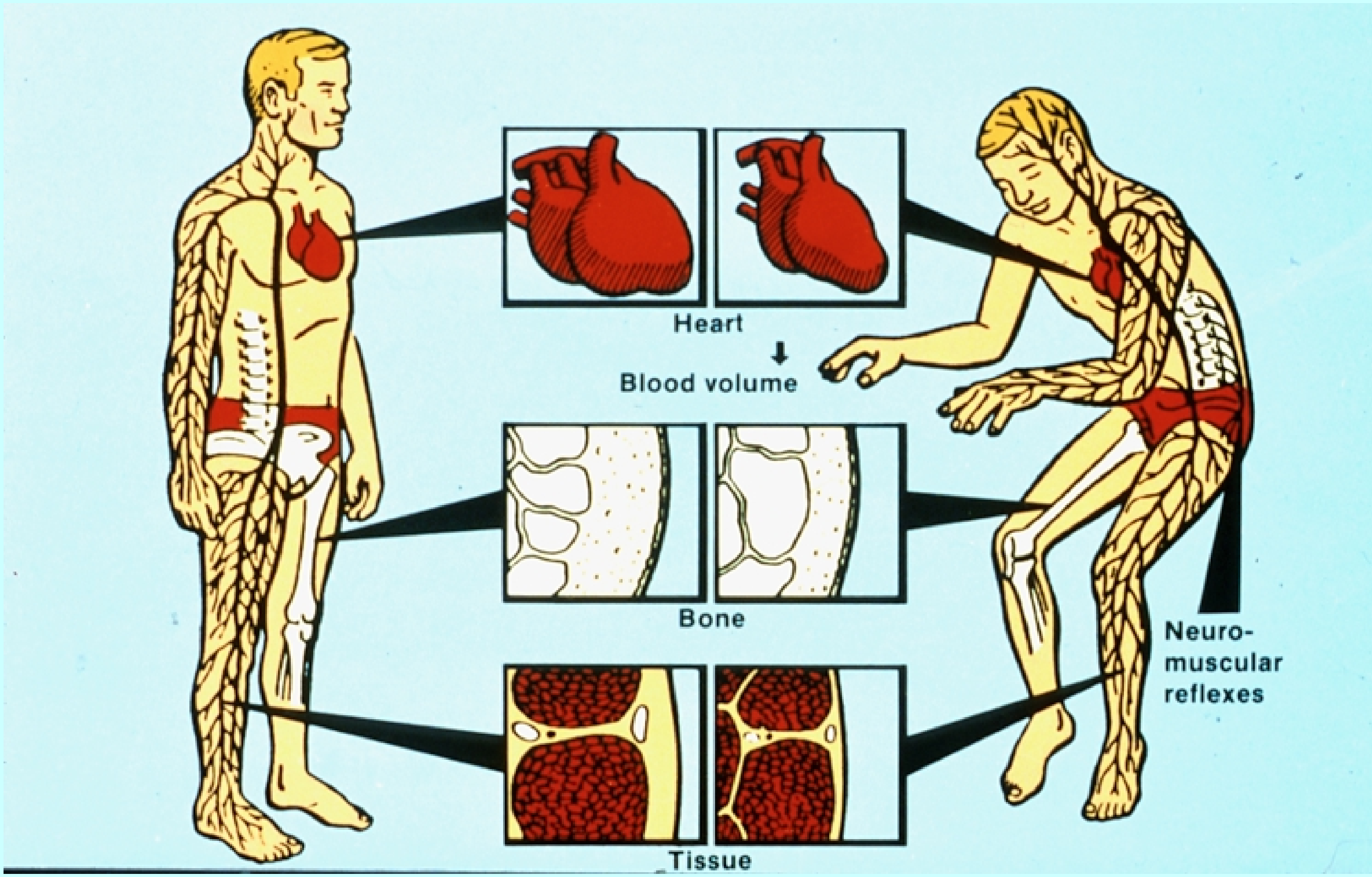
Body Mass Measuring Device (BMMD)

Measures mass based on period of oscillation

Physiological Effects of Spaceflight



Adaptive Changes in Weightlessness



Space Diets

- Tend to have decreased fat and increased protein
- Tend to have less fiber
- Protein content similar to Earth diets

Approval criteria for space foods

- Acceptable regarding taste and texture
- No microbiological hazards
- Easy to consume in microgravity, i.e. no crumbs
- Compatible with oven, trays and storage, minimal waste following meal
- Nutritional adequacy, considering rest of menu

Factors Affecting Intake

- Resting metabolic rate similar in space and on Earth
- Exercises that work against gravity on Earth have ↓ energy requirement in space
- Energy for EVA higher in space
- Total energy expenditure ↑ with larger spaceships
- Increased exercise requirement necessitates increased energy intake

Fluids and Electrolytes

- Little or no change in total body water in space
- Plasma water is ↓ by 10-15%
- Sodium may ↑ calcium loss
- Current sodium intake recommendation is less than 3500 mg/day

Proteins in Space

- Consistent loss of muscle protein
- Negative nitrogen balance
- Nitrogen losses tend to ↓ on long missions
- Protein loss is diminished with exercise
- Most space diets provide excess protein over requirement
- Post-flight supplementation helps regain lost protein

Factors Affecting Protein Loss

- Inadequate energy intake
- muscle “remodeling” due to microgravity
- Metabolic stress with increased turnover rate
- Decreased protein synthesis

Vitamin D Requirements in Space

- Need ↑ increased vitamin D due to lack of UV activation of precursors
- Should consider dietary vitamin D a sole source
- Current dietary lack of dairy products limits supplementation

Effects of Microgravity on Bone

- Skeletal unloading due to:
  - a) ↓ muscle strength
  - b) ↓ in weight bearing

- Bone formation no change or ↓
- Bone resorption ↑ and exceeds formation

- ↑ urinary calcium excretion
- No current effective chemical or physical countermeasures to bone loss

Dietary Calcium in Space

- ↑ calcium in diet may cause renal stones

- ↓ calcium in diet may increase rate of calcium loss

Iron in Space

- Roughly 2/3 of body iron in red blood cells
- Roughly 1/3 of body iron in storage proteins (ferritin)
- Very little iron lost from body/day

Iron in Space (continued)

- Decreased erythropoietin and increased storage of iron in space due to decreased # of red blood cells
- Low dietary requirements 10mg/day
- May need iron supplementation following long term spaceflight

Micronutrients

- Zinc principally in bone and muscle, as they decrease will diminish body stores
- Iodine added to drinking water, therefore iodine toxicity more likely than deficiency
- B-vitamins: no evidence that requirements in space are different than on Earth

Space Radiation and Nutrition

- Ionizing radiation much higher in space than on Earth
- Radiation forms reactive oxygen species in the body
- These oxidants can damage:
  - a) lipids causing peroxidation
  - b) proteins causing dysfunction
  - c) DNA causing mutations

Space Radiation and Nutrition
(continued)

- Antioxidant defense primarily nutritional;
  - vitamin A and beta carotene
  - vitamin C (ascorbic acid)
  - vitamin E (tocopherols)
  - trace elements copper, iron, manganese, selenium and zinc
- Radiation for food preservation can destroy B-vitamins and deplete natural antioxidants

Antioxidants and Space Nutrition

- Pretreatment with antioxidants can decrease radiation damage
- In general oral antioxidants have minimal toxicity
- Radiation for food preservation can destroy antioxidants
- Currently no opportunity for in depth studies of space radiation on foods and antioxidants

Extended Missions: Mars

- Two to three year human Mars trip will require:
  - More shelf stable foods
  - Wide variety of foods to prevent food boredom and enhance intake
  - Preservation of antioxidants

Hypothetical artists concept of **Martian base.**

Would include:
food and nutrient recycling facilities that would also generate oxygen and potable water and an advanced closed circuit advanced life support system or ALS.

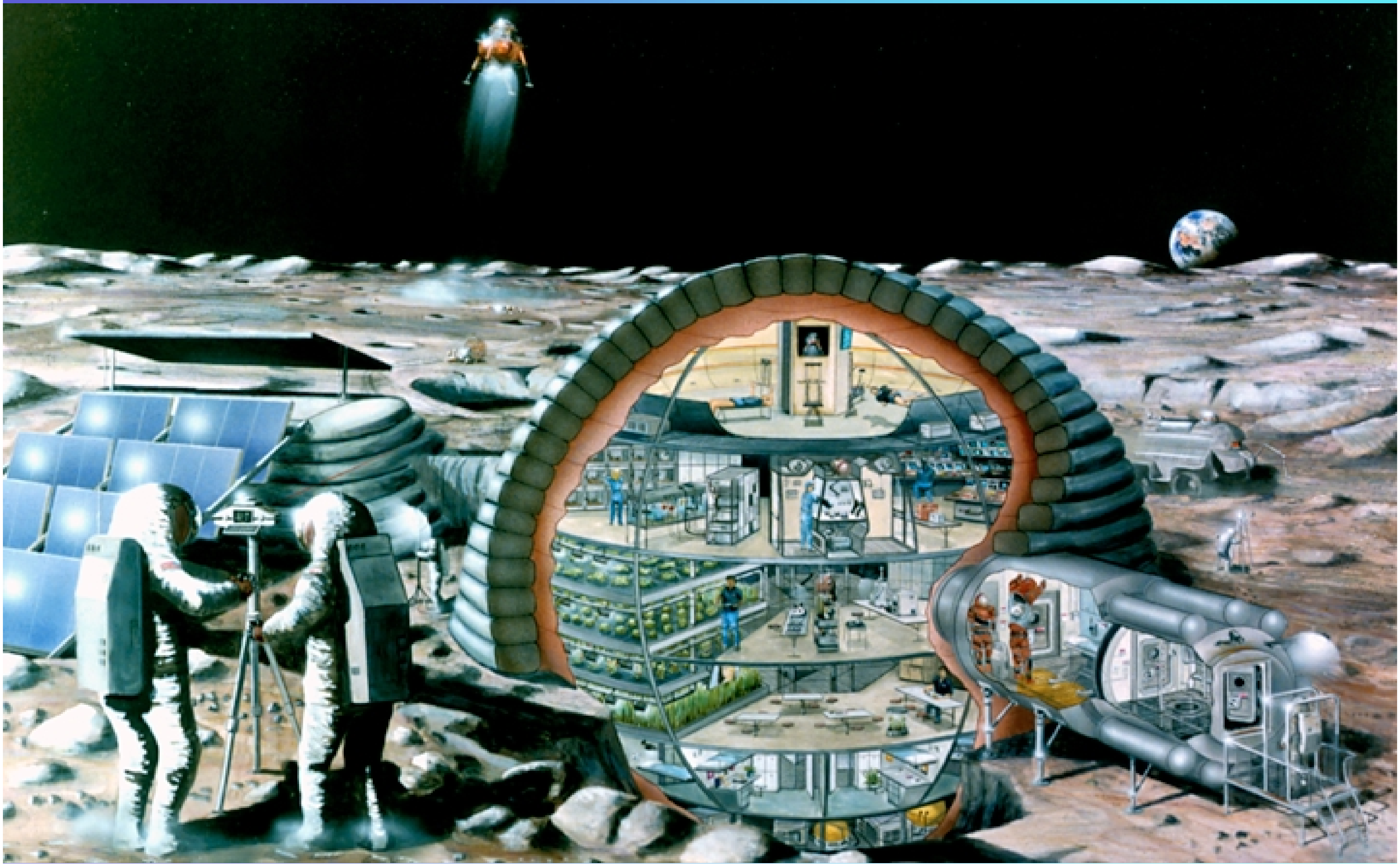
Extended Missions: Moon or Mars Base

- Heavy reliance on Advanced Life Support to grow foods and replenish oxygen
- Will require a closed loop system to recycle carbon, hydrogen, oxygen, nitrogen and water

Extended Missions: Moon or Mars Base (continued)

- A number of plants are under consideration as food crops, some factors:
  - dependable yield
  - high edible biomass yield
  - small size
  - dietary variety
  - nutritionally complete
  - may be genetically modified to increase nutrient content

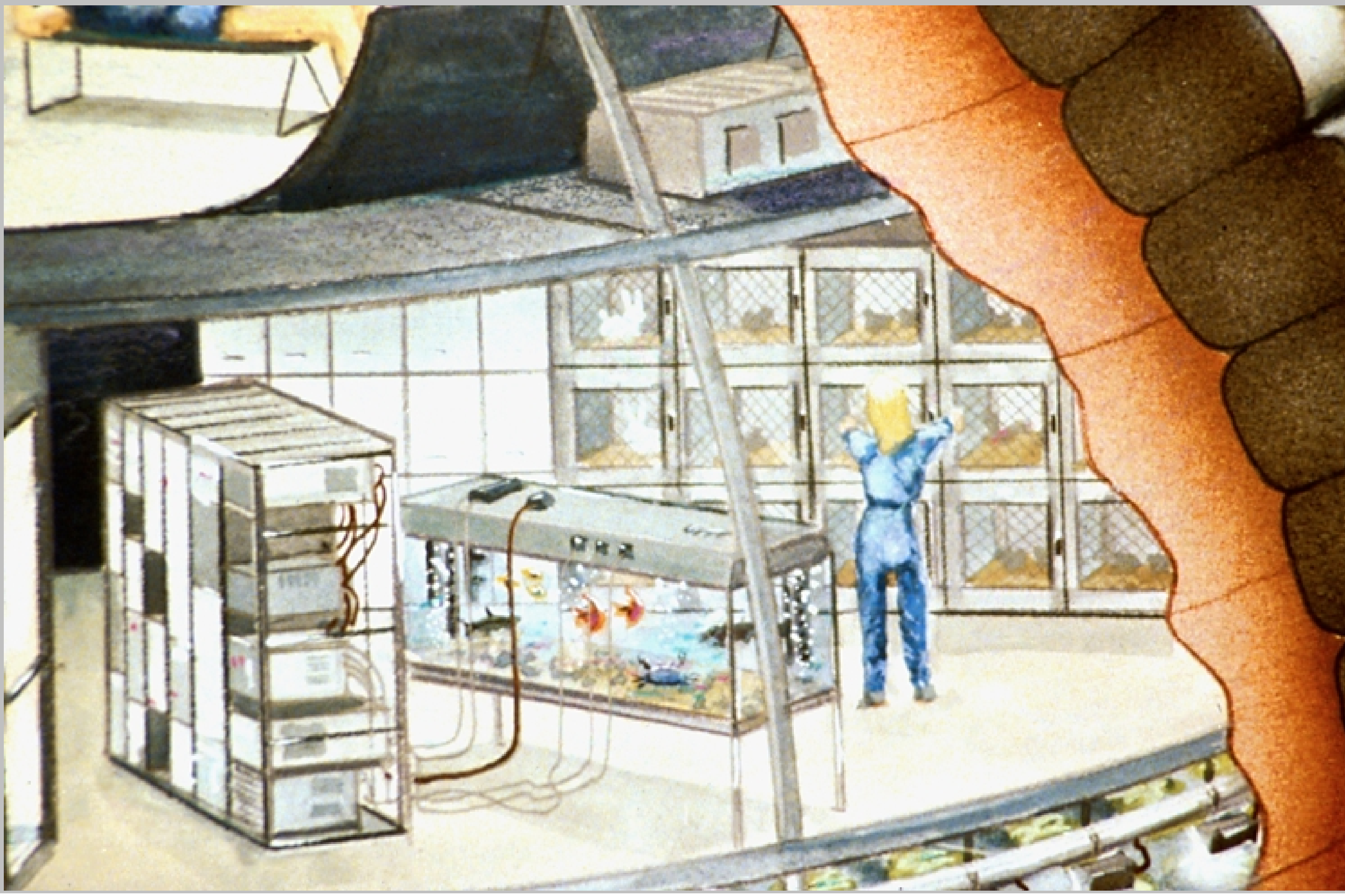
Artist’s concept of a **lunar outpost facility** that includes several levels of the structure devoted to food crop growth including animal protein production and oxygen and water recycling



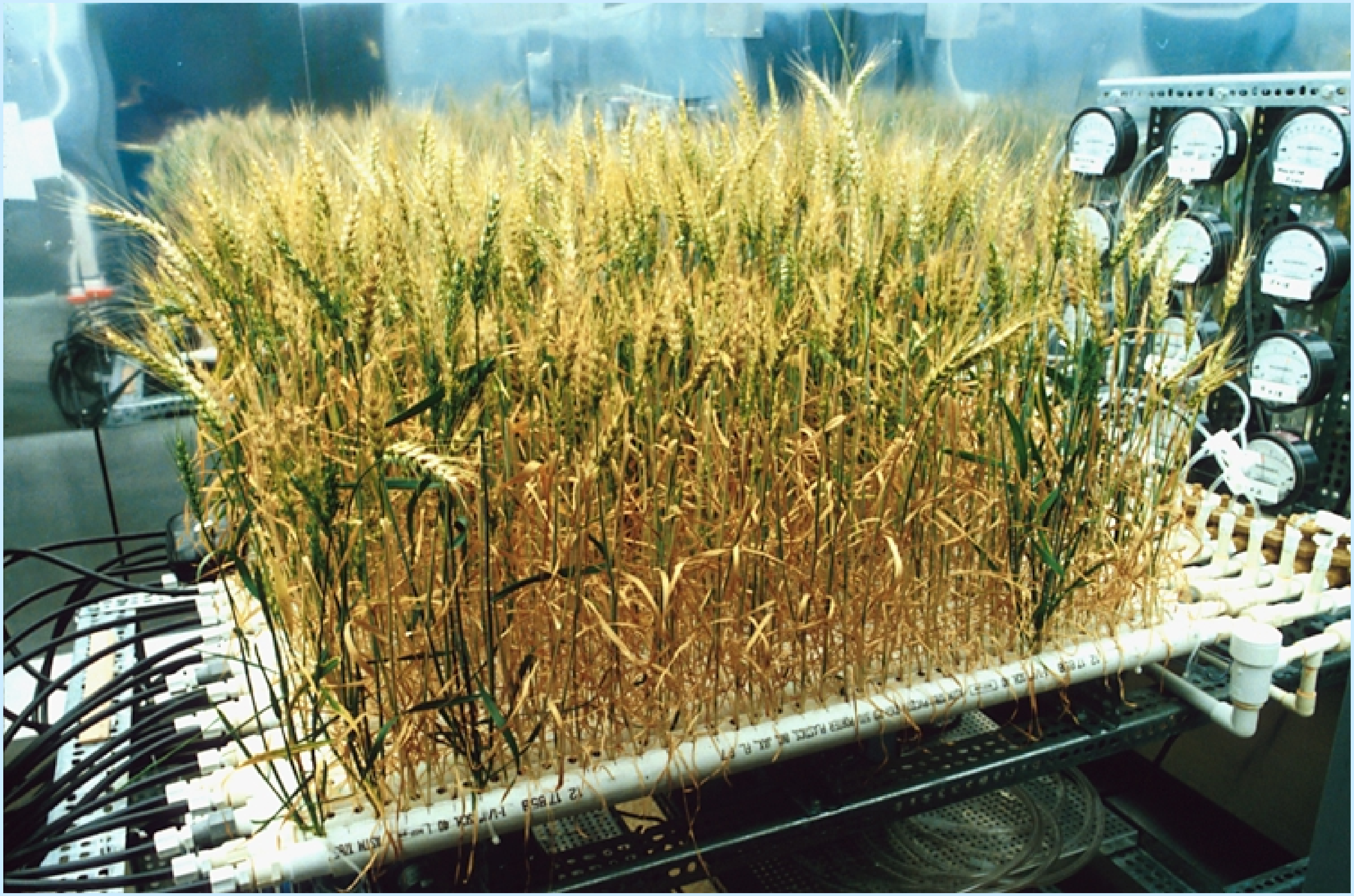
Food Processing on Moon or Mars Base

- Little consideration has been given to processing raw foods i.e. soybeans, wheat or rice
- Need to have crops that are easily processed into numerous edible products
- Need to develop nutritionally effective and appetizing utilization of cellulose and lignin
- Heavy reliance on spices and flavors carried from Earth to increase taste variety

Artist's concept of an advanced food production system at a **lunar site**. Animal protein is being produced by fish, rabbits and poultry.



Intensive wheat growth in the **Environmental Chamber** at Kennedy Space Center. Optimum conditions of light, temperature, carbon dioxide concentration, water and nutrient availability can be monitored and changed to determine what optimal growing conditions will be under very intensive and closed circuit cultivation as would be necessary on a lunar or Martian settlement.



A container of ripe intensively grown wheat using hydroponics at Kennedy Space Center