

# Future of Life in the Solar System

# Long-term Thinking

- Most of our current problems and challenges arise from short-term thinking
- How do we foster the long view?
  - The ten-thousand year clock
    - <http://www.longnow.org/projects/clock/>
    - Why 10,000 years?
      - Millions? Billions?
- What could we do on long time-scales?

# Future of Life in Solar System

Terraform other planets (Mars most likely)

Space Colonies

Solar Power from space, Dyson spheres

Rockets: Principles and 4 quantities

Robots, Von Neumann Devices

# Terraforming Planets

Seed other planets with  
“bio-engineered organisms”

These make the planet more habitable for humans

To terraform (need H<sub>2</sub>O, O<sub>2</sub>, O<sub>3</sub> in order of priority)

e.g., Melt polar caps on Mars (10<sup>14</sup> tons of ice)

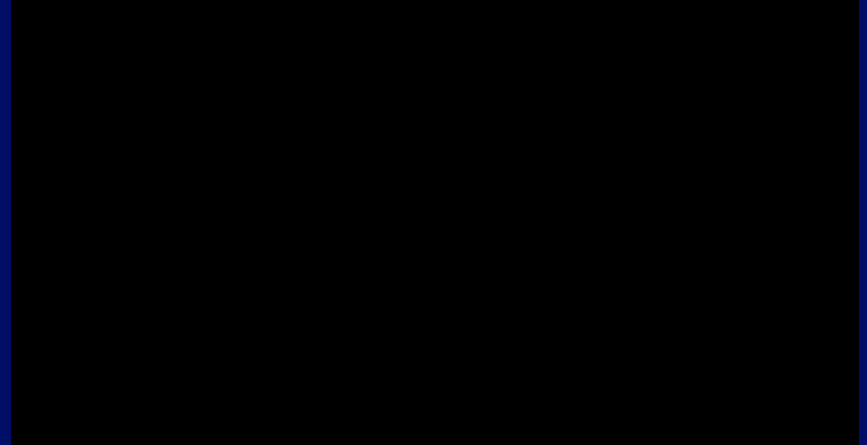
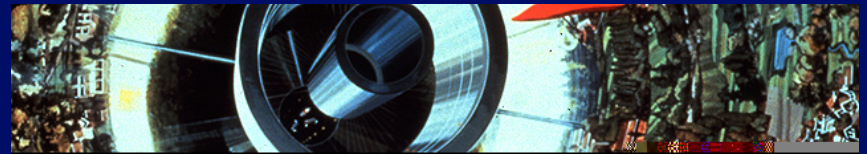
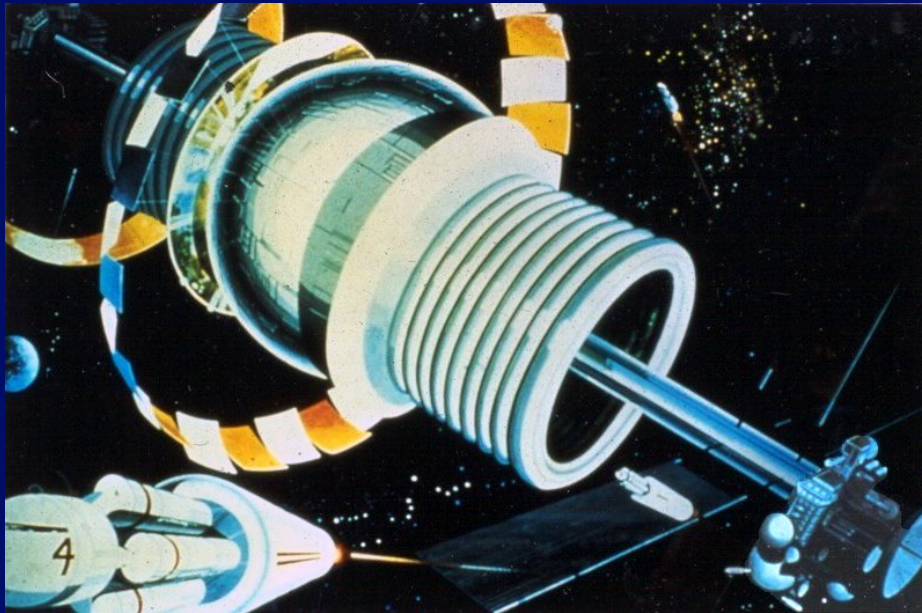
2500 to 10000 years to build up atm. pressure, get liquid water

# Terraformed Mars

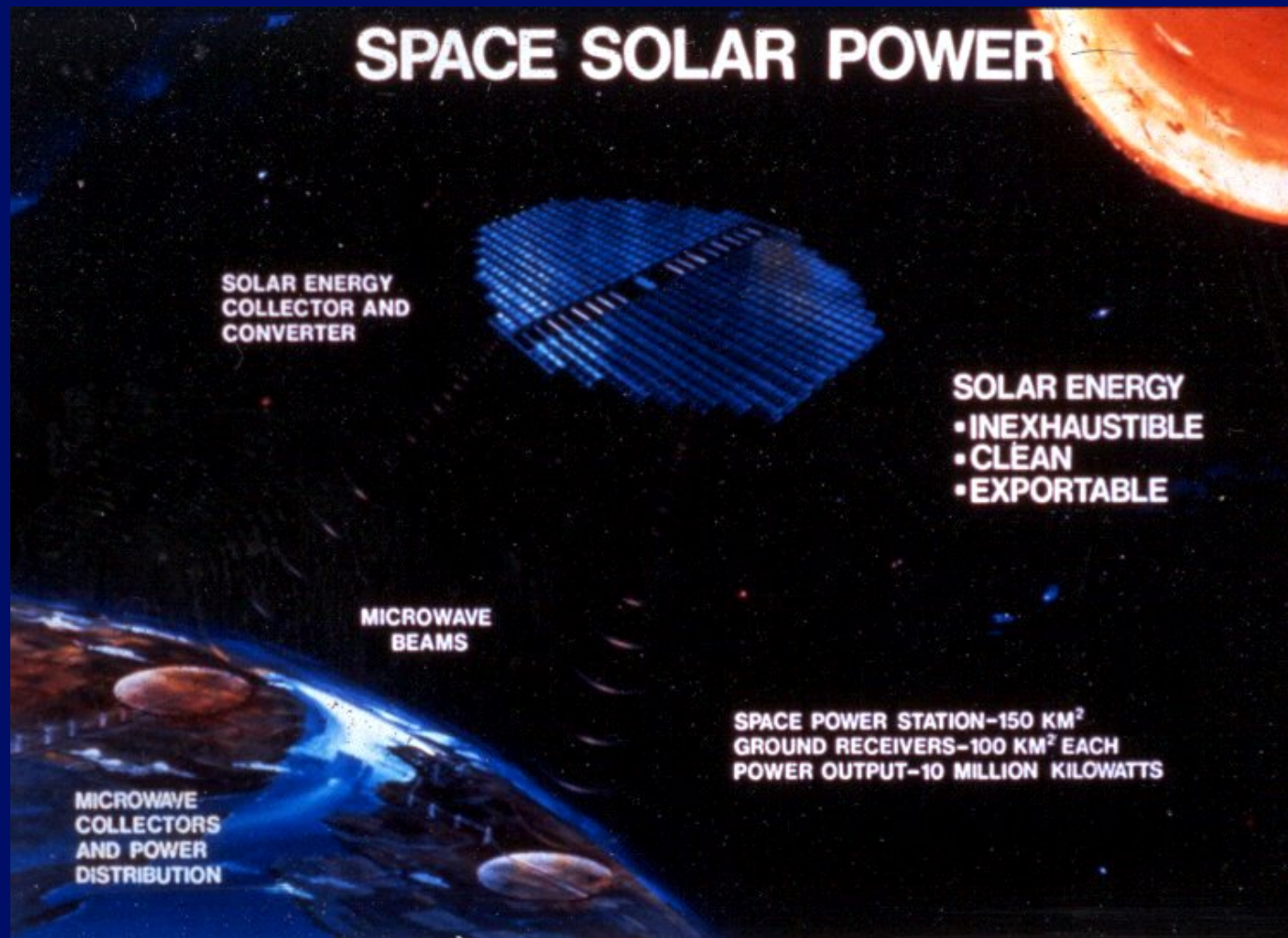


Ocean in northern lowlands covers  
25% of planet

# Space Colony (Island One)



# Solar Power Satellites





# Solar Power Satellite





Word of the Day: Dyson sphere

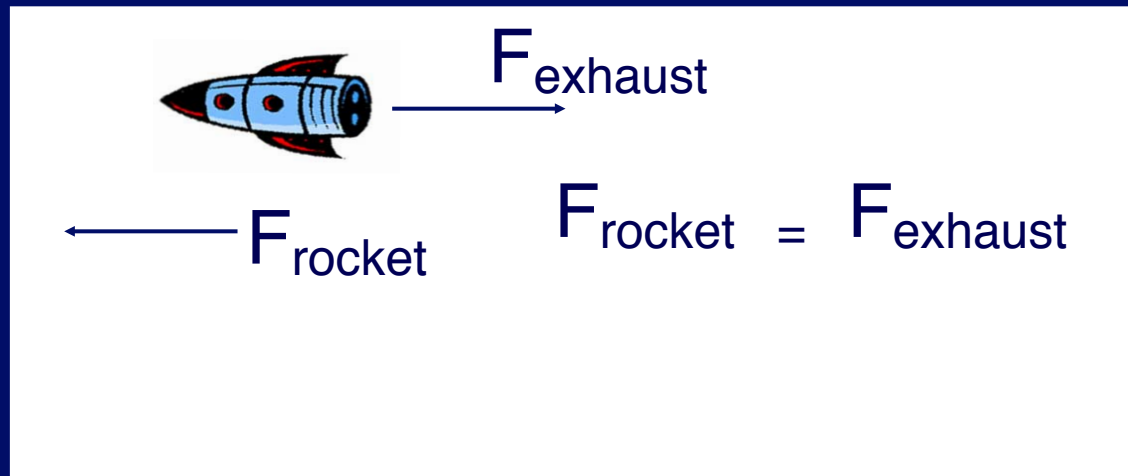
# Dyson Spheres

- Ultimate version of solar power satellites
- Surround the sun with collectors
- Have access to nearly all of solar luminosity
  - $2 \times 10^{26}$  Watts
- What if another civilization did this?
  - Dyson's idea, so called Dyson spheres
  - It would look like an infrared source
  - Hard to distinguish from young or old stars surrounded by dust

# Rockets

Principle:

Newton's Third Law



1. Exhaust velocity  $V_e$  ( $\text{km s}^{-1}$ )

$$V_e \propto \sqrt{\frac{T}{M}}$$

Recall Newton's second law:

$$F = (dp/dt) = m (dv/dt) = m a, \text{ if } m \text{ constant}$$

If  $v$  constant, but  $m$  is not,

$$F = (dm/dt) v$$

2. Thrust (Force)  $F = (dM/dt) V_e$   
(Newtons, Pounds)

$dM/dt$  = rate at which mass is ejected

3. Mass ratio

$$R_M = \frac{\text{Total Mass at Takeoff}}{\text{Mass After Fuel Used Up}}$$

High mass ratios mean you need a lot of fuel to get a certain payload accelerated to a certain speed

#### 4. Specific impulse (s.i.)

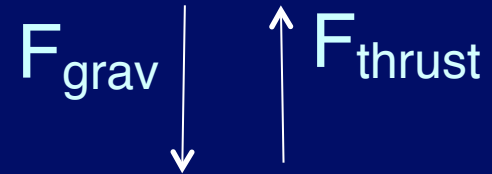
$$\frac{\text{Thrust}}{\text{Rate of Fuel Use}} \quad (\text{Newtons/kg/sec, Pounds/Pounds/sec} = \text{“sec”})$$

A measure of efficiency.

Highest possible s.i. with chemical fuels is  $< 500$

## Can the Rocket take off?

To take off: Thrust  $>$  Weight



To escape gravity  $v > v_{\text{esc}} = 11.2 \text{ km s}^{-1}$   
(7 miles/sec)

This is very difficult for the gravity of the Earth  
So we use Multi-stage Rockets



## An Example

Space Shuttle: Mass =  $2 \times 10^6$  kg

$F_{\text{thrust}} = 29 \times 10^6$  Newtons

$R_M = 68$  for actual payload

s.i. = 455 sec. ~ best possible with  
chemical fuel

For more adventurous exploitation of Solar System

Probably want Nuclear Propulsion

Fission could give s.i. =  $1.5 \times 10^6$  sec

(in practice, more likely to get 20,000 sec)

# Future of Humans in Space

## Exploration Vision in 2004

- First return to Moon, then Mars
- Under-funded, side-effects on other programs
- Fundamental Redirection in 2011
  - [http://www.nasa.gov/missions/solarsystem/explore\\_main.html](http://www.nasa.gov/missions/solarsystem/explore_main.html)
  - Return to Moon, travel to Mars essentially put on hold for now
  - But rocket development continues

# New Vehicles

- Space shuttle has been retired
- Look to commercial ventures for access to space station
- Go “back” to Apollo-like capsules (Orion) on big rockets (Space Launch Systems)
  - Twice the volume of Apollo (4-6 crew)
  - New technology, more flexible, automation
  - Launch-abort system
    - Saves crew if problem during launch
  - Solar panels for long term power

# Robots

- Martian landers and rovers
- Likely to use for most solar system exploration
- Ultimate is Von Neumann device
  - Self-repairing, self-replicating robot
  - A kind of life?
- Human-machine hybrids
  - Artificial body parts increasingly common

## Future of solar system

- Think about the long term future of solar system
- Will we colonize other planets?
- Mine asteroids for metals?
  - Could we detect an ET civilization doing this?
  - Forgan and Elvis 2011: hard to be sure
    - Look for chemical or other anomalies