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

Robots

Von Neumann Devices

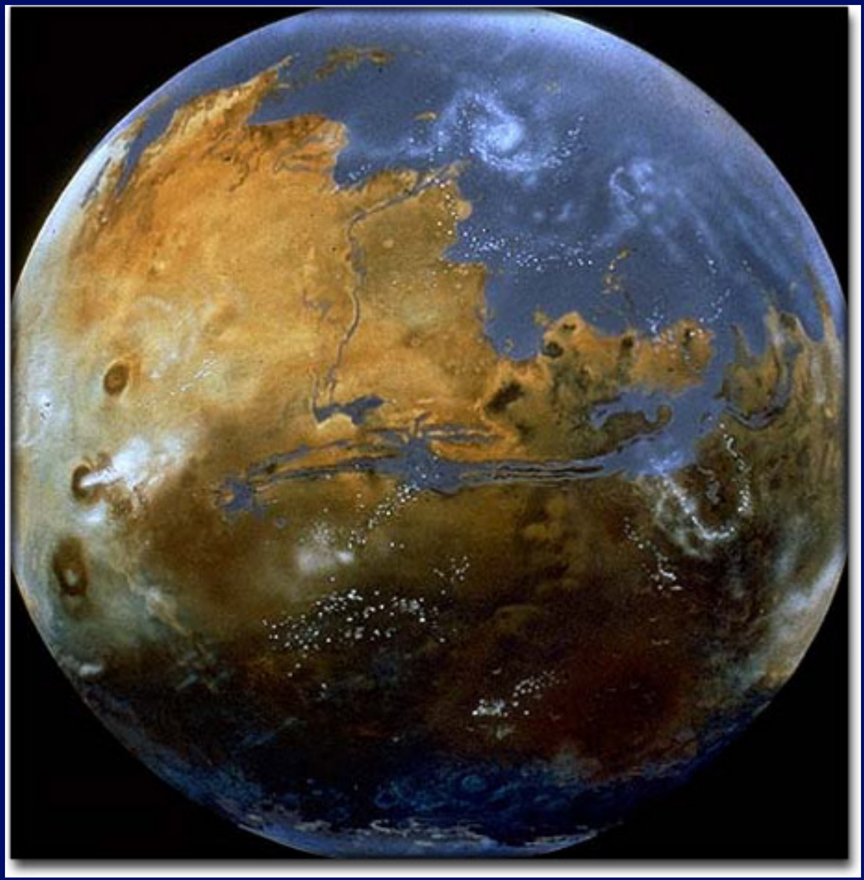
Terraforming Planets

Seed other planets with
"bio-engineered organisms"

These make the planet more habitable for humans

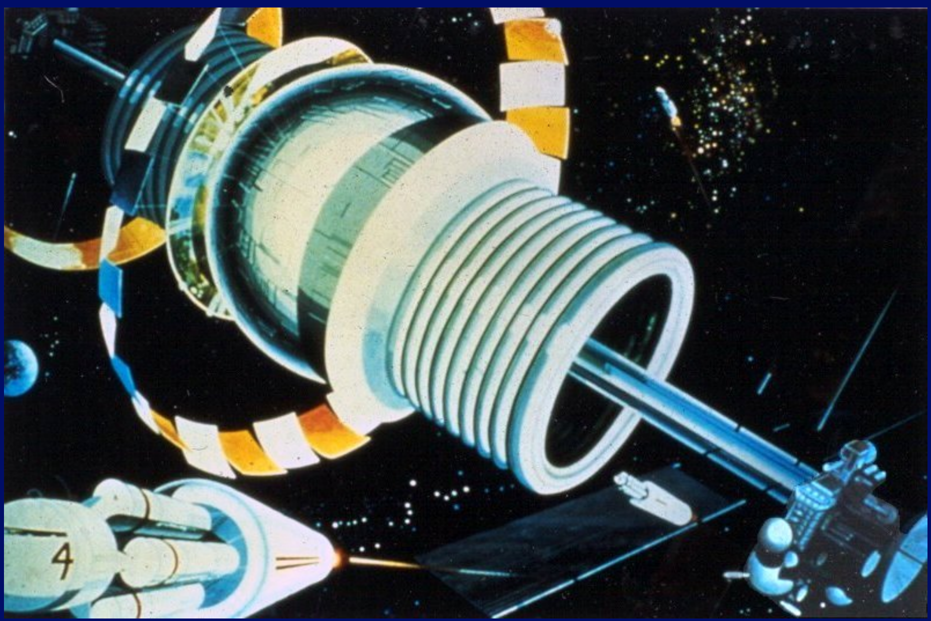
To terraform (need H_2O, O_2, O_3 in order of priority)
e.g., Melt polar caps on Mars (10^{14} tons of ice)
2500 to 10000 years to build up atm. pressure, get liquid water

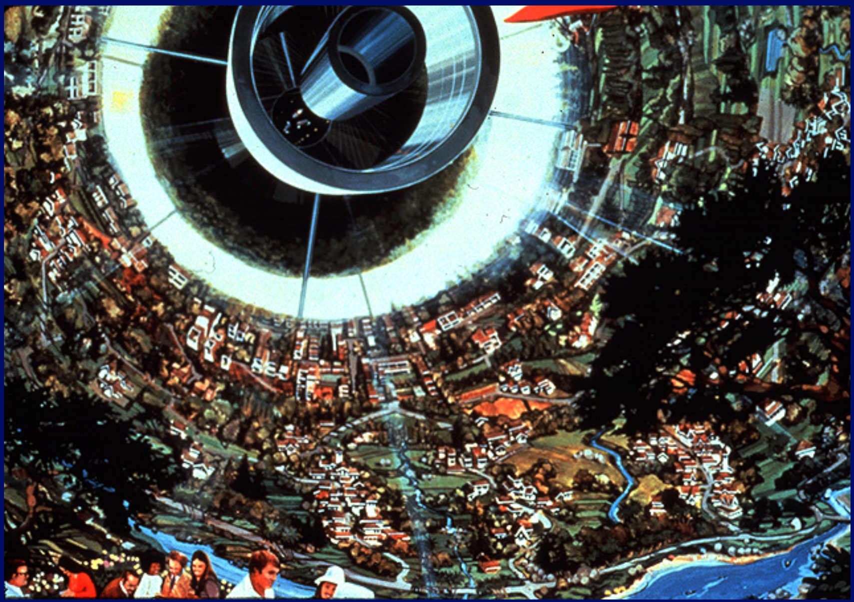
Terraformed Mars



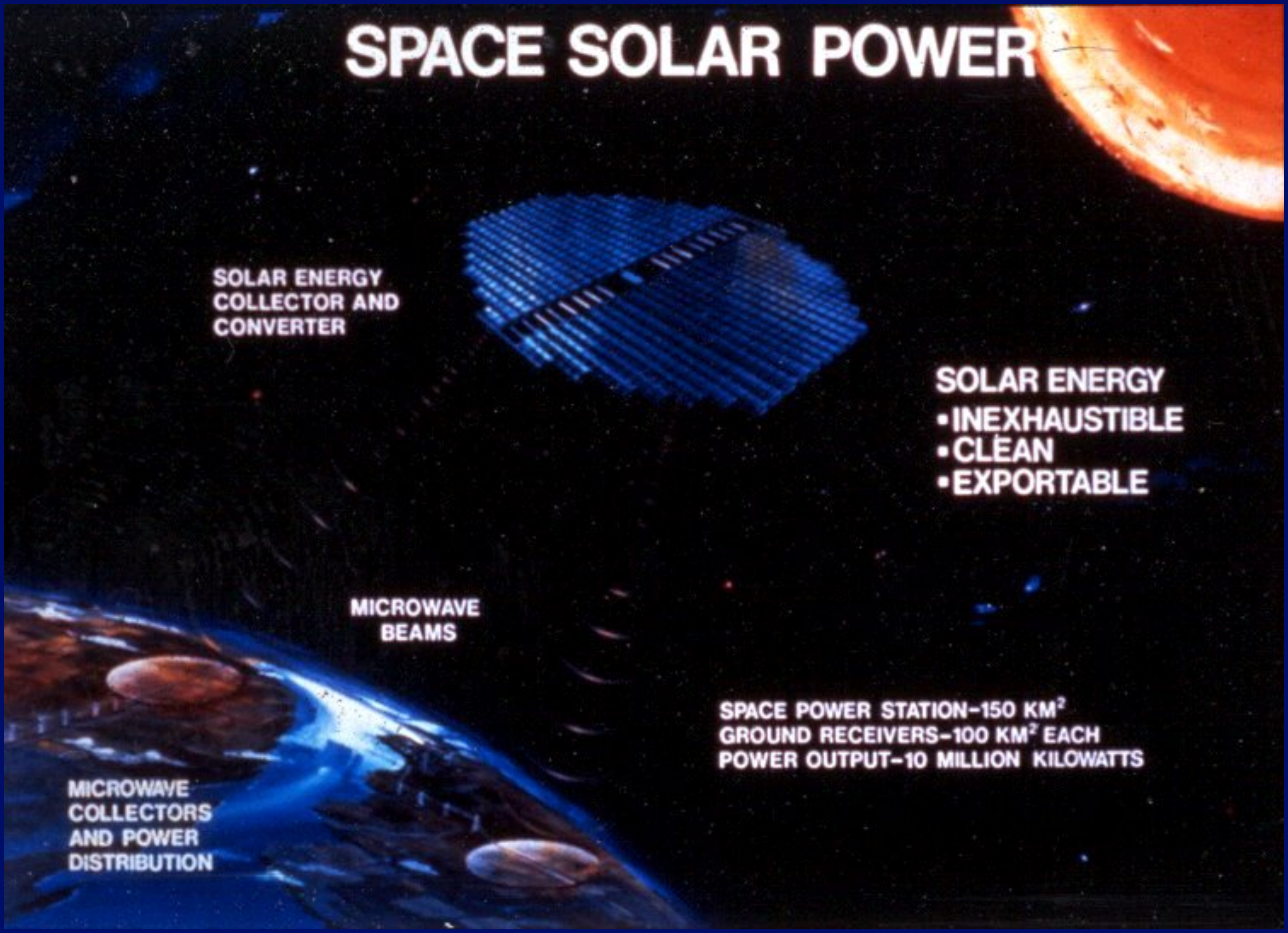
Ocean in northern lowlands covers 25% of planet

Space Colony (Island One)





Solar Power Satellites



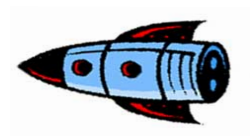
Solar Power Satellite

Dyson Spheres

- Ultimate version of solar power satellites
- Surround the sun with collectors
- Have access to nearly all of solar luminosity
  - 2×10^{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



$F_{exhaust}$

F_{rocket}

$$F_{rocket} = F_{exhaust}$$

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

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

Recall Newton's second law:

$F = (dp/dt) = m\ (dv/dt) = m\ a$, if m 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.)

$$\frac{\text{Thrust}}{\text{Rate of Fuel Use}}$$

(Newtons/kg/sec,
Pounds/Pounds/sec = “sec”)

A measure of efficiency.

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

Can the Rocket take off?

F_{grav} F_{thrust}

To take off: Thrust > Weight

To escape gravity $v > v_{esc} = 11.2 \text{ km s}^{-1}$

(7 miles/sec)

This is very difficult for the gravity of the Earth

So we use Multi-stage Rockets

An Example

Space Shuttle: Mass = 2×10^6 kg

$F_{thrust} = 29 \times 10^6$ 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. = 1.5×10^6 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
  – Return to Moon, travel to Mars essentially put on hold for now

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 (Ares V)
  - 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