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

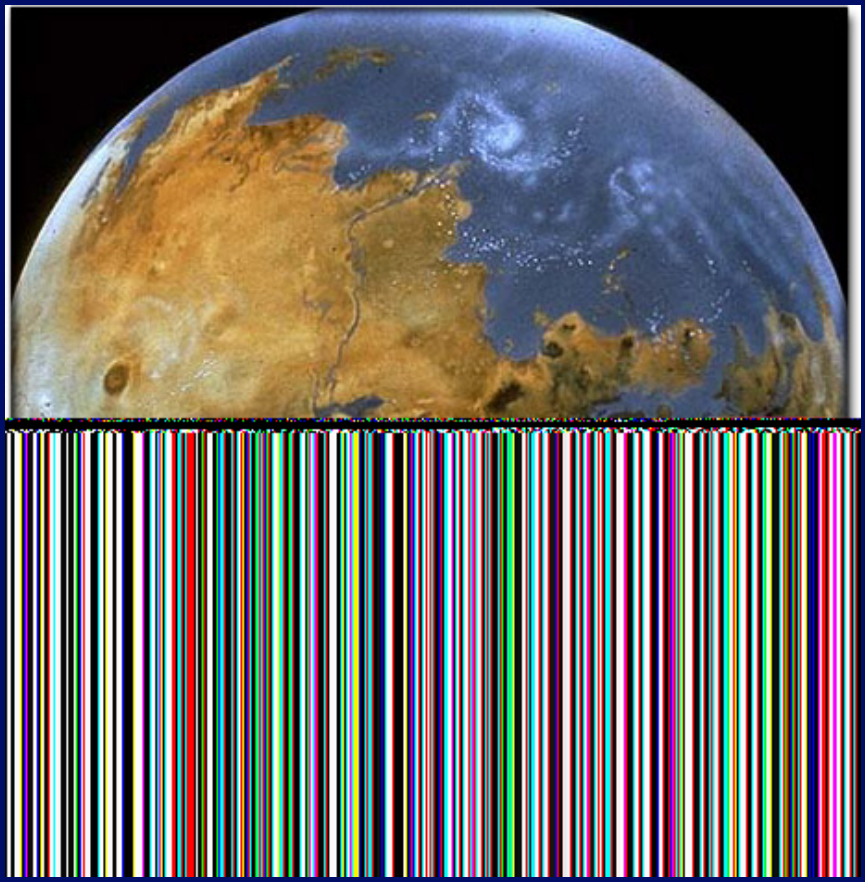
Terraforming Planets

Seed other planets with
“bio-engineered organisms”

These make the planet more habitable for humans

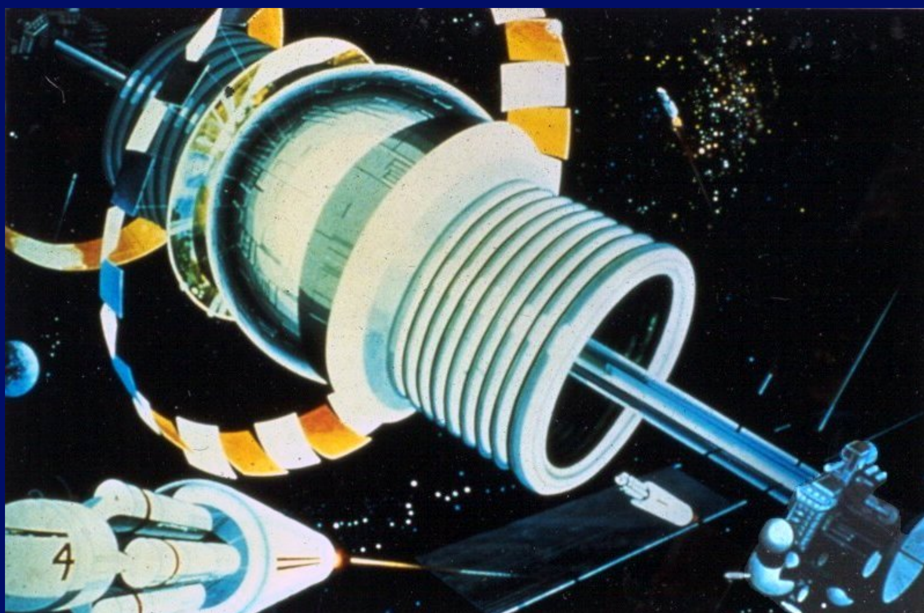
To terraform (need H_2O, O_2, O_3 in order of priority)
e.g., Melt polar caps on Mars (10^{14} tons of ice)
2500 to 10000 years to build up atm. pressure, get liquid water

Terraformed Mars

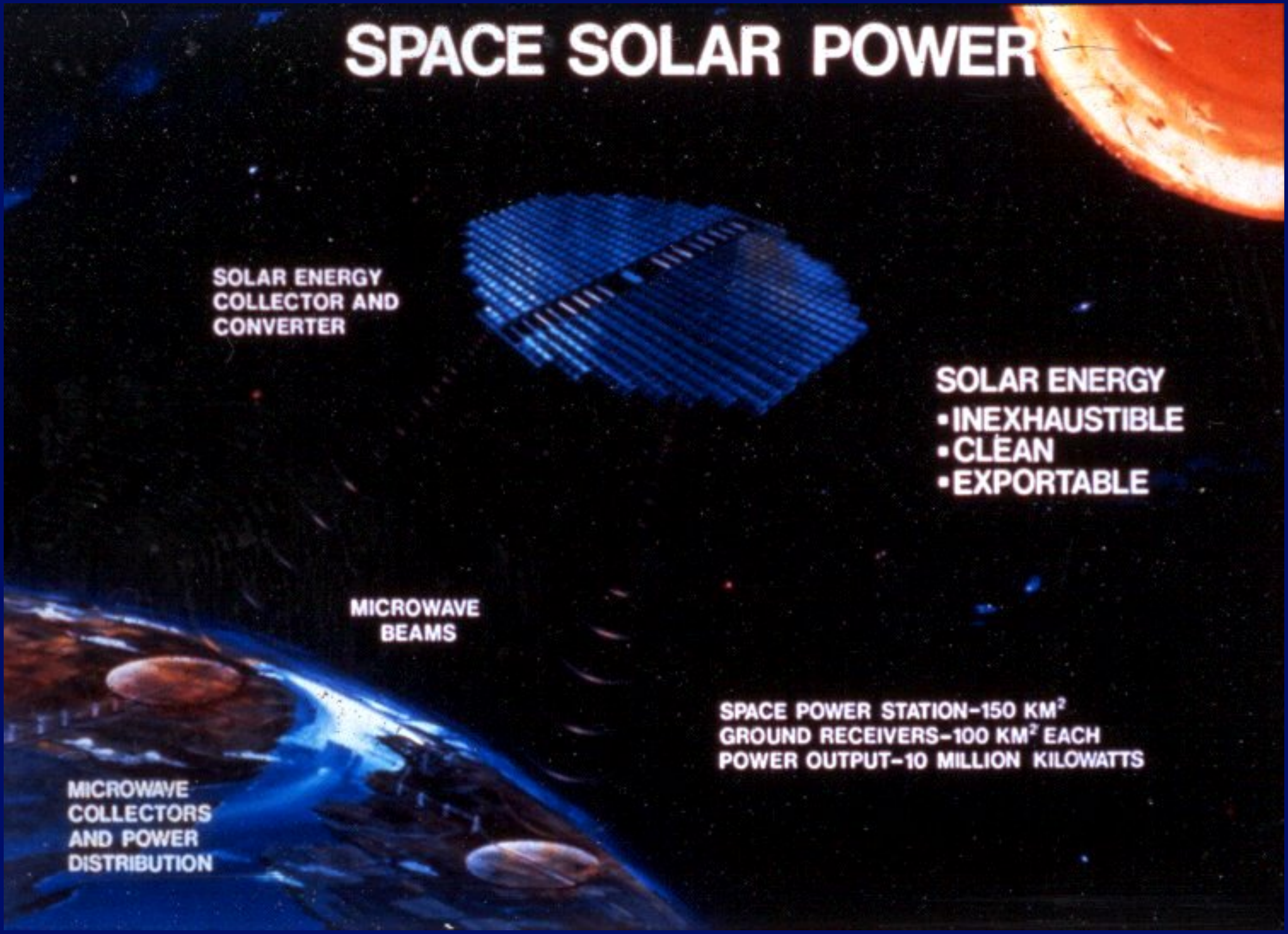


Ocean in northern lowlands covers
25% of plant

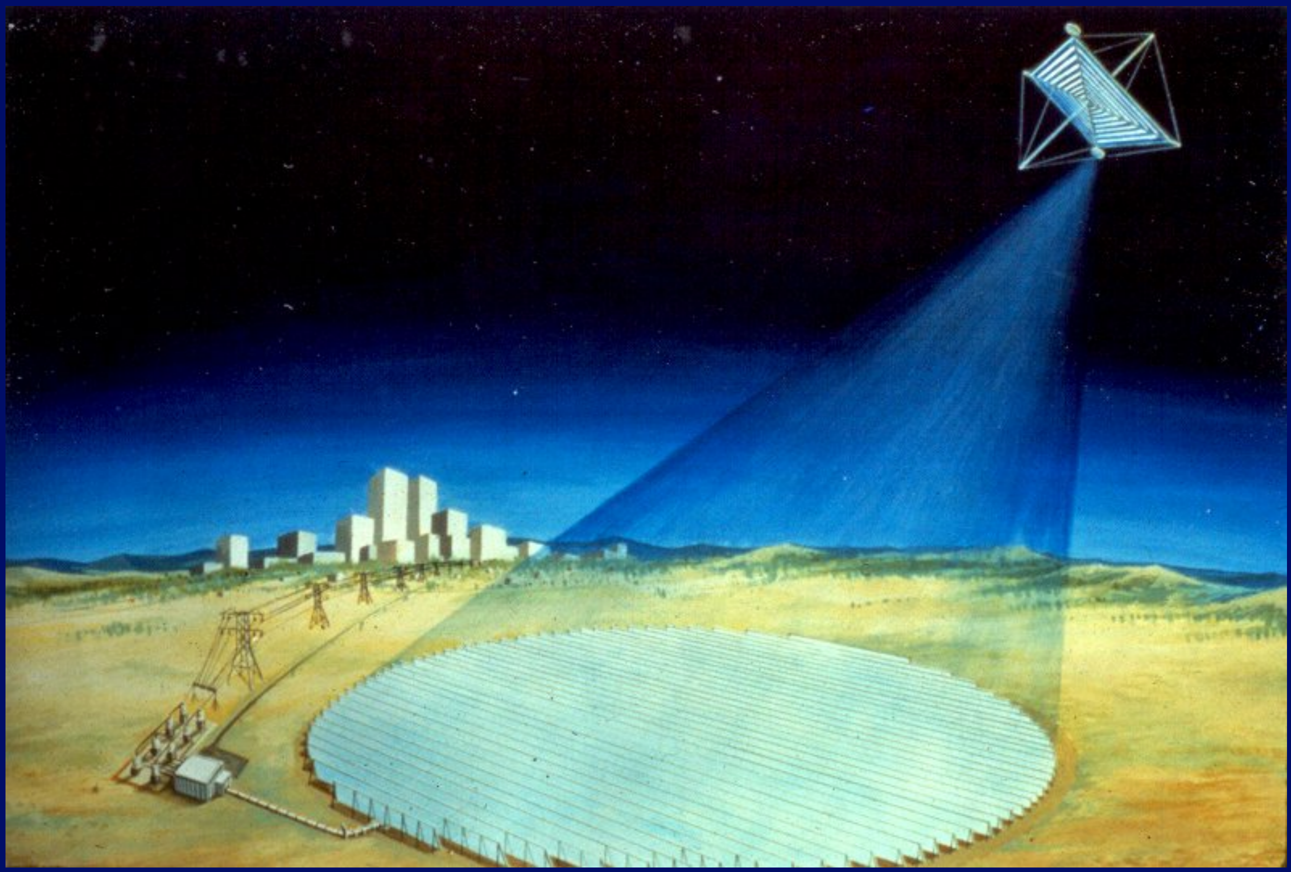
Space Colony (Island One)



Solar Power Satellites



Solar Power Satellite

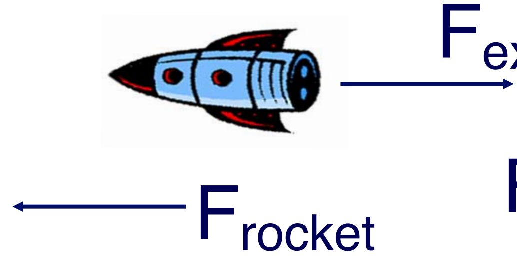


Dyson Spheres

- 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



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

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 $v > v_{esc} = 11.2$ 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