

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”

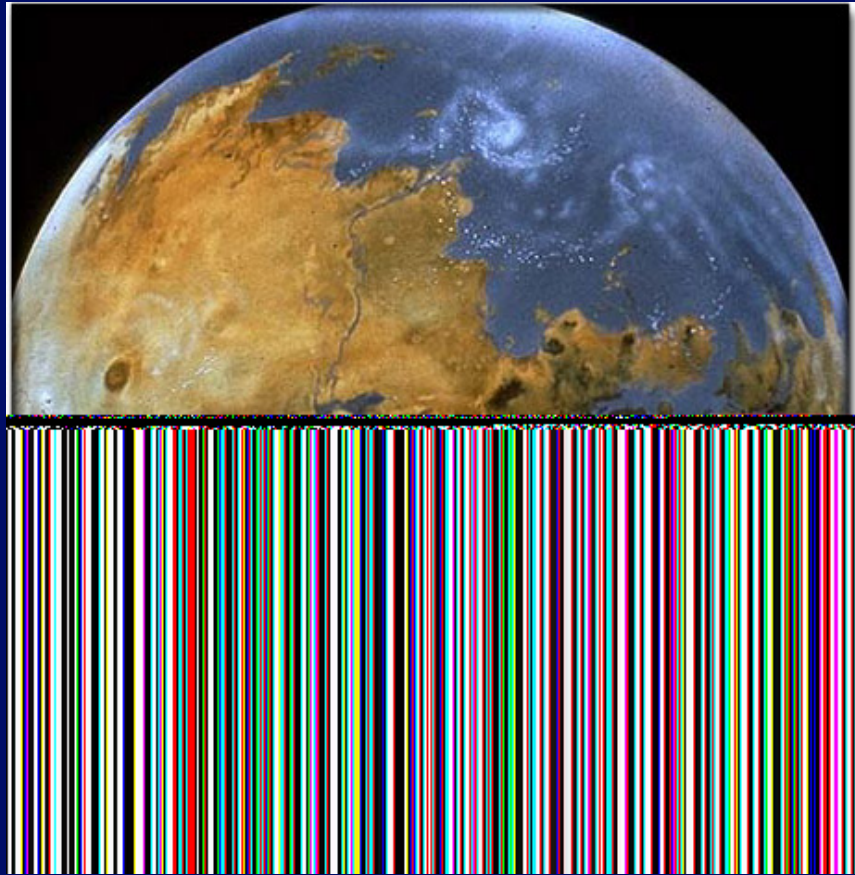
These make the planet more habitable for humans

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)

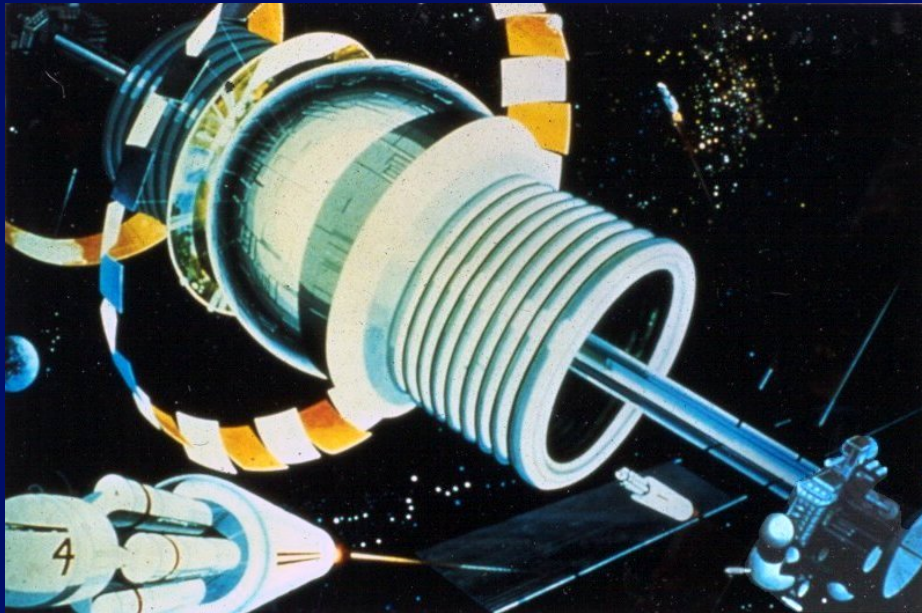
2500 to 10000 years to build up atm. pressure, get liquid water

Terraformed Mars

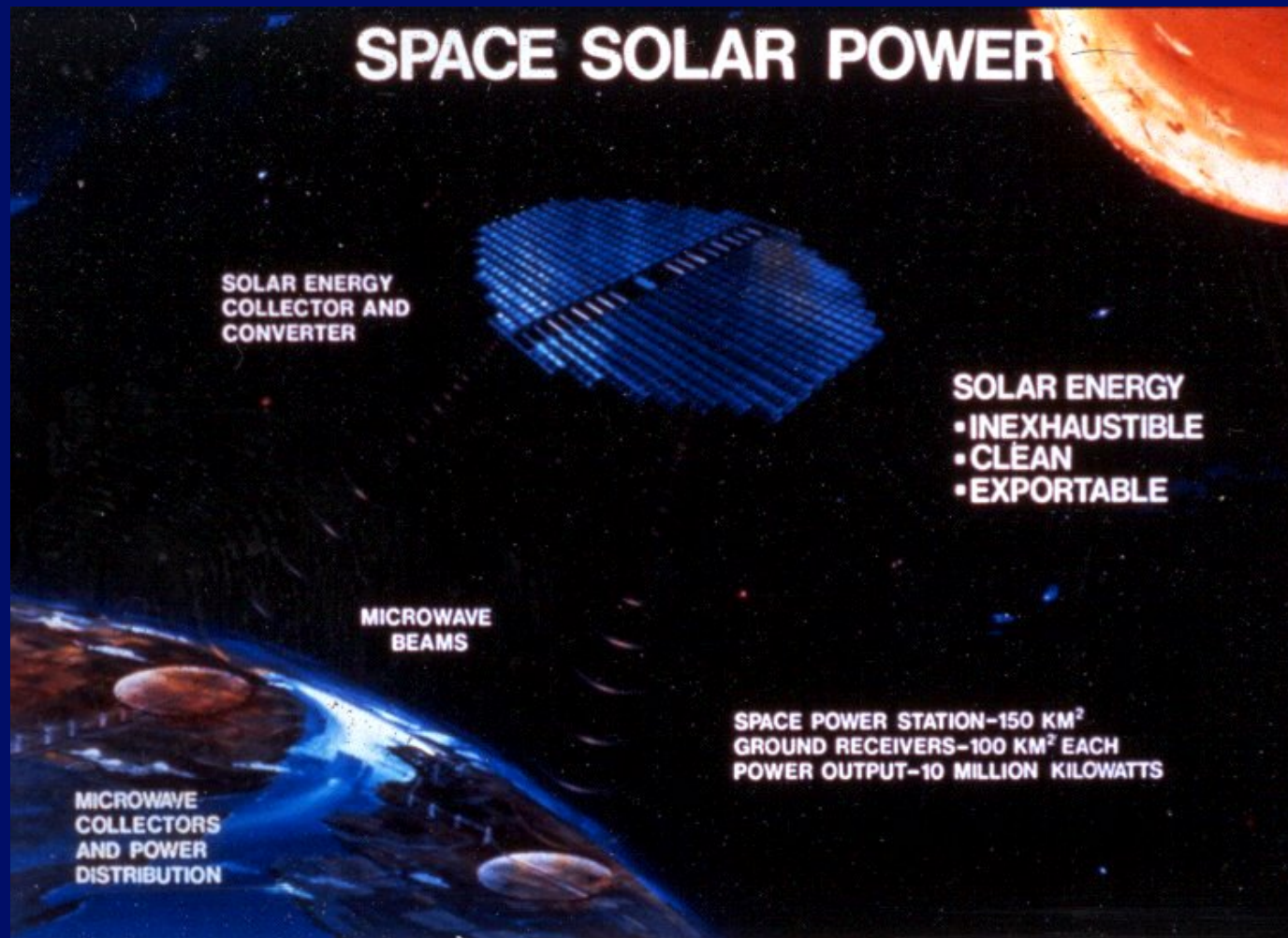


Ocean in northern lowlands covers
25% of planet

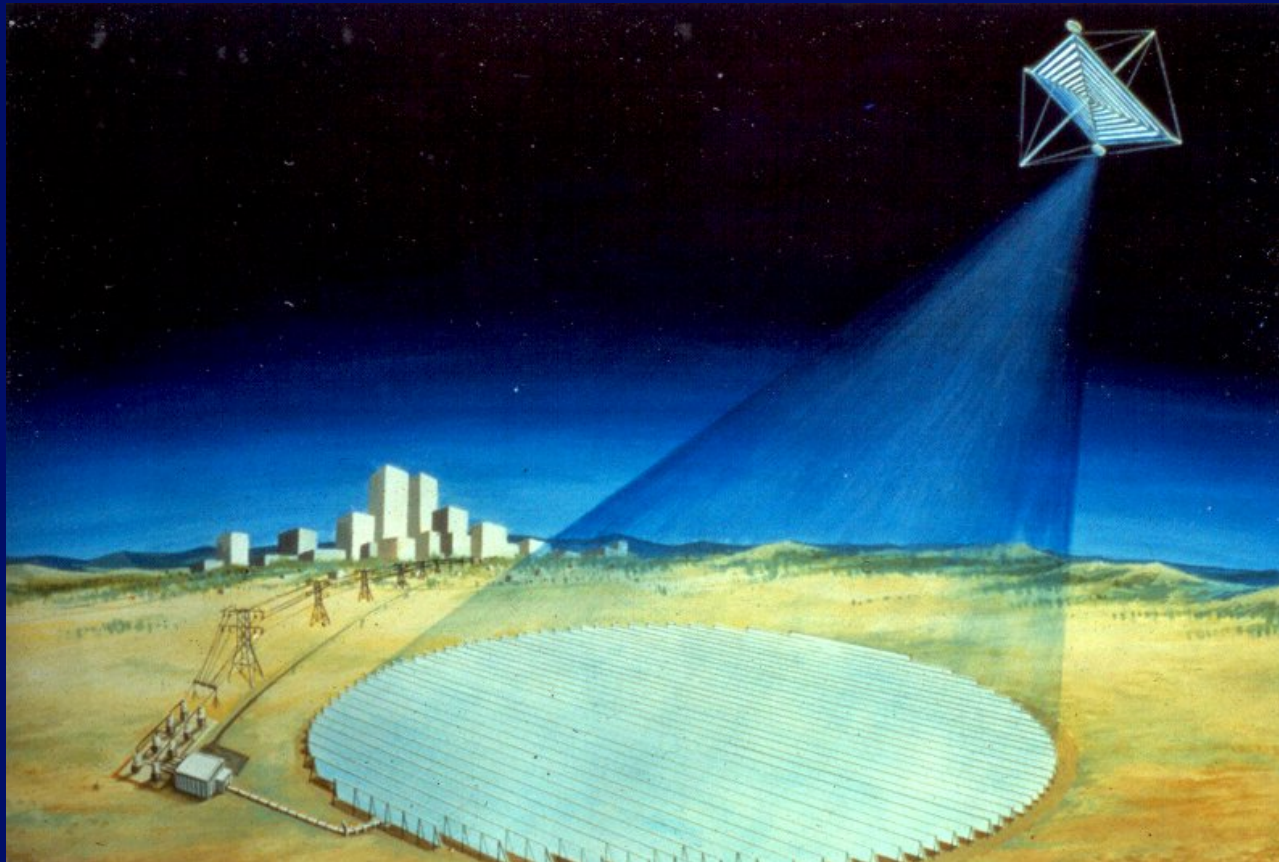
Space Colony (Island One)



Solar Power Satellites



Solar Power Satellite



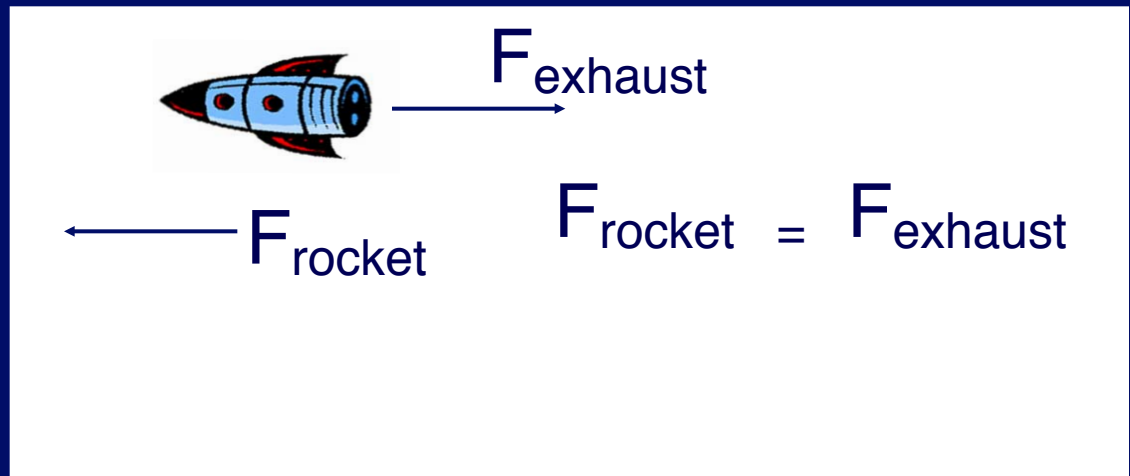
Dyson Spheres

- 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



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

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

Recall Newton's second law:

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

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.)

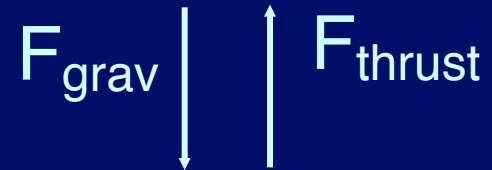
$$\frac{\text{Thrust}}{\text{Rate of Fuel Use}} \quad \left(\begin{array}{l} \text{Newtons/kg/sec,} \\ \text{Pounds/Pounds/sec} = \text{"sec"} \end{array} \right)$$

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 = 2×10^6 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. = 1.5×10^6 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