Future of Life in the Solar System

Future of Life in Solar System

Terraform other planets (Mars most likely)

Space Colonies

Solar Power from space

Dyson spheres

Robots

Von Neumann Devices

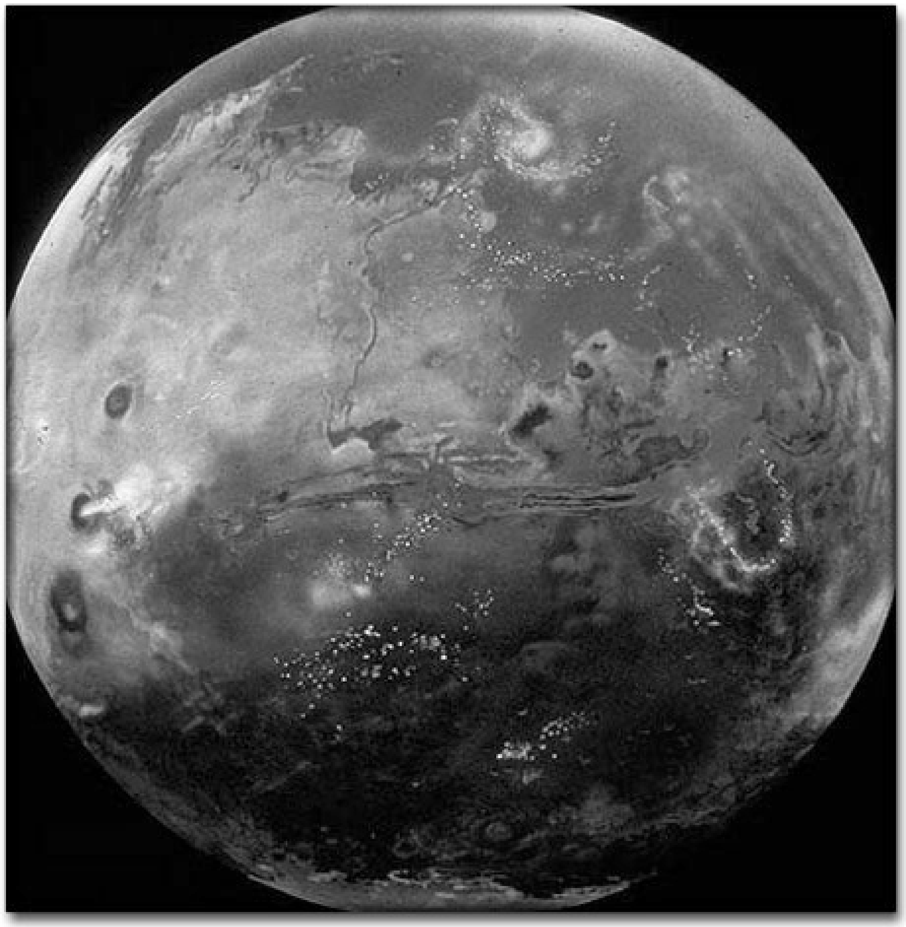
Future of Life in the Solar System

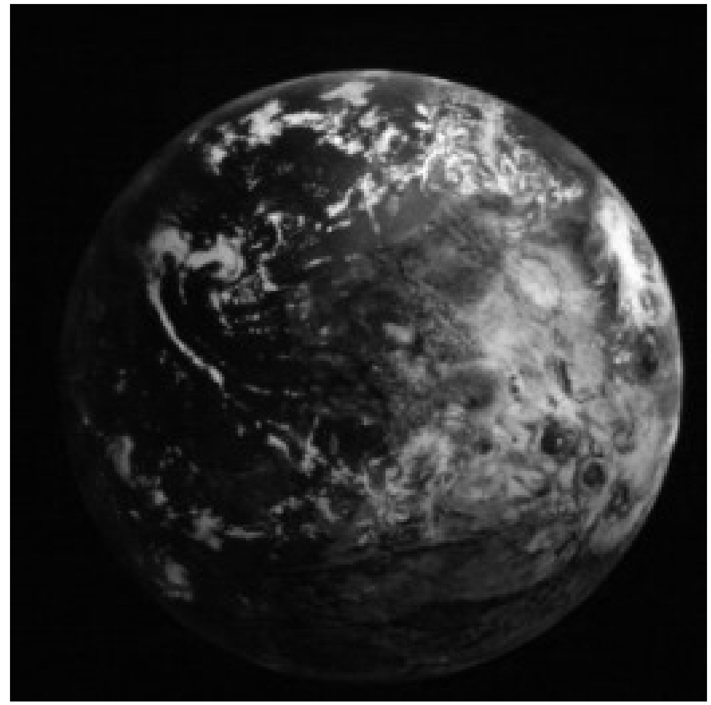
Seed other planets with
"bio-engineered organisms"

Use these to make more habitable for humans

Terraform (need H_2O, O_2, O_3)
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

Living in Space to Robots…

Space colonies

Solar Power satellites

↓

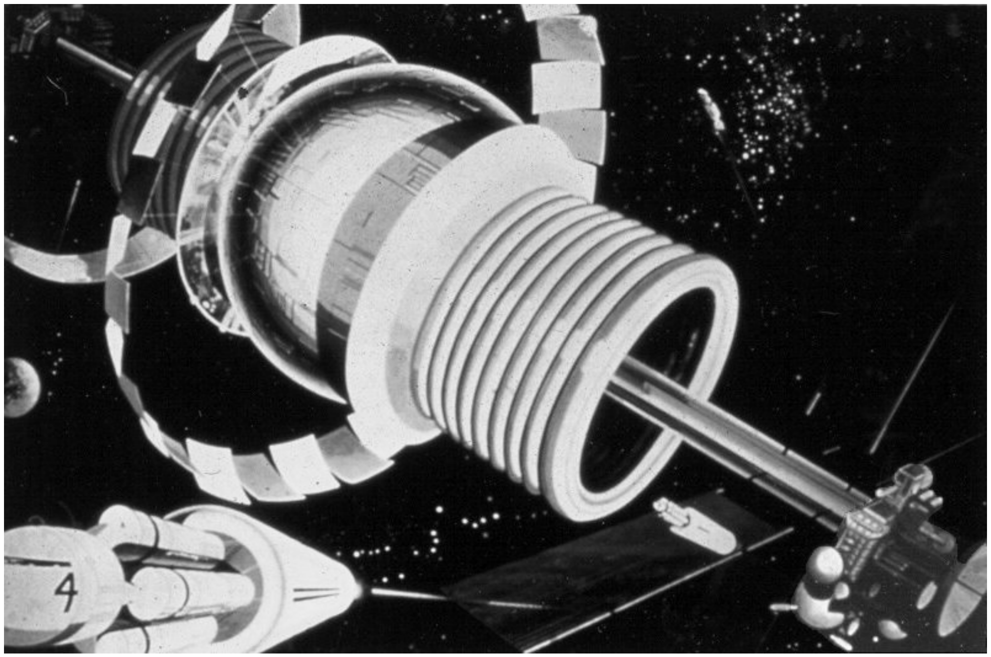
Dyson sphere (Type II Civilization)

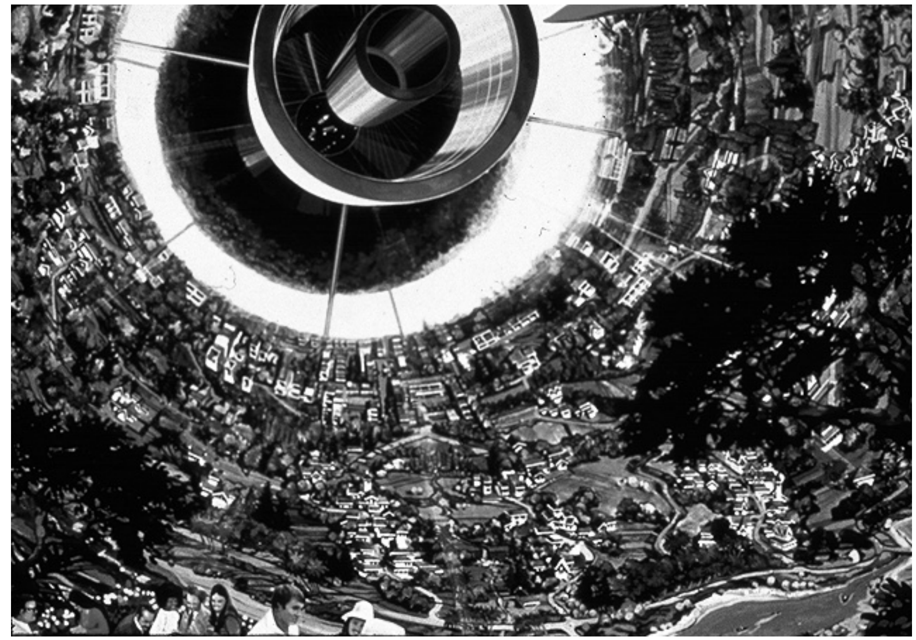
Role of Robots

↓

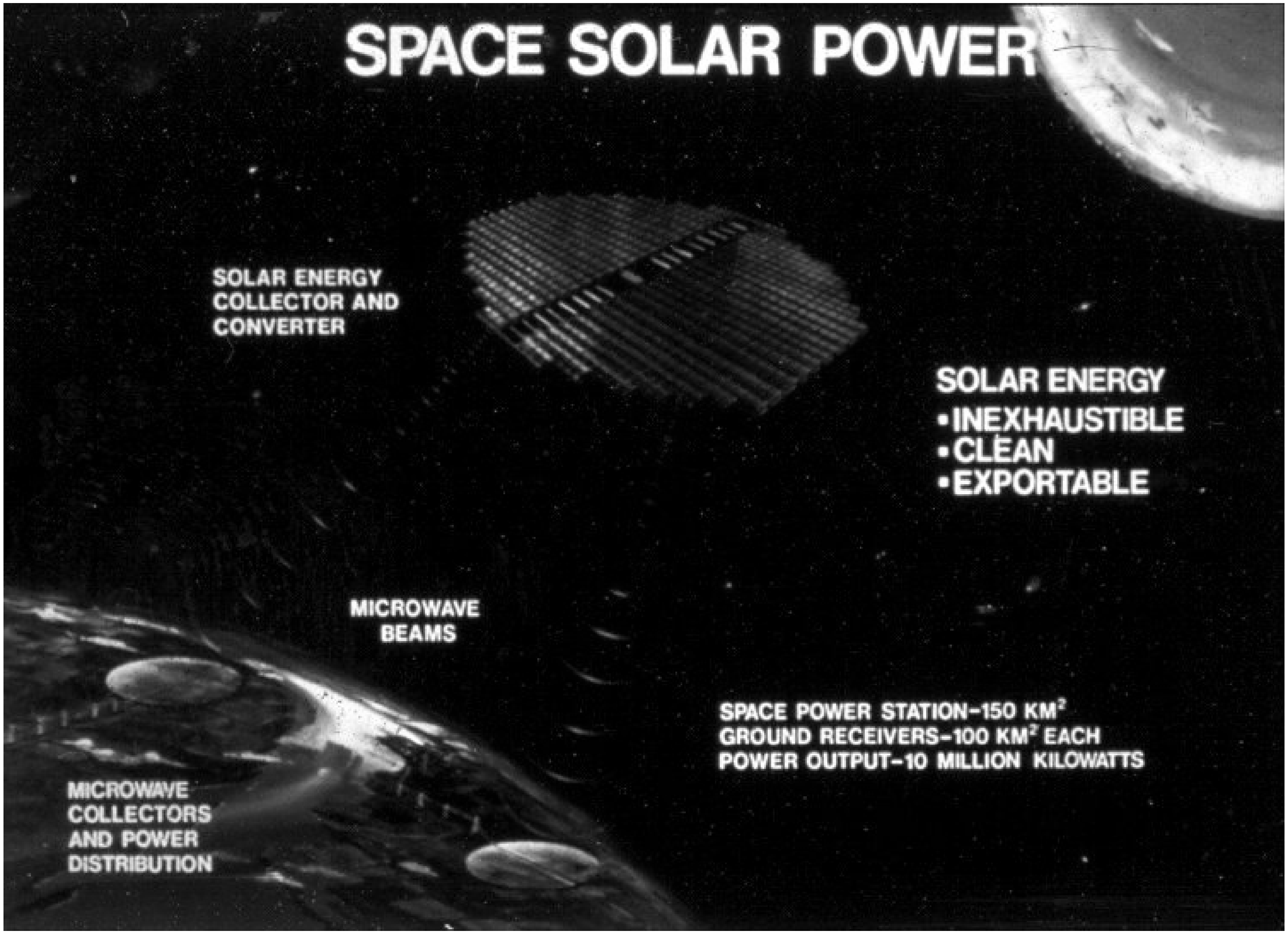
Von Neumann device

Space Colony (Island One)

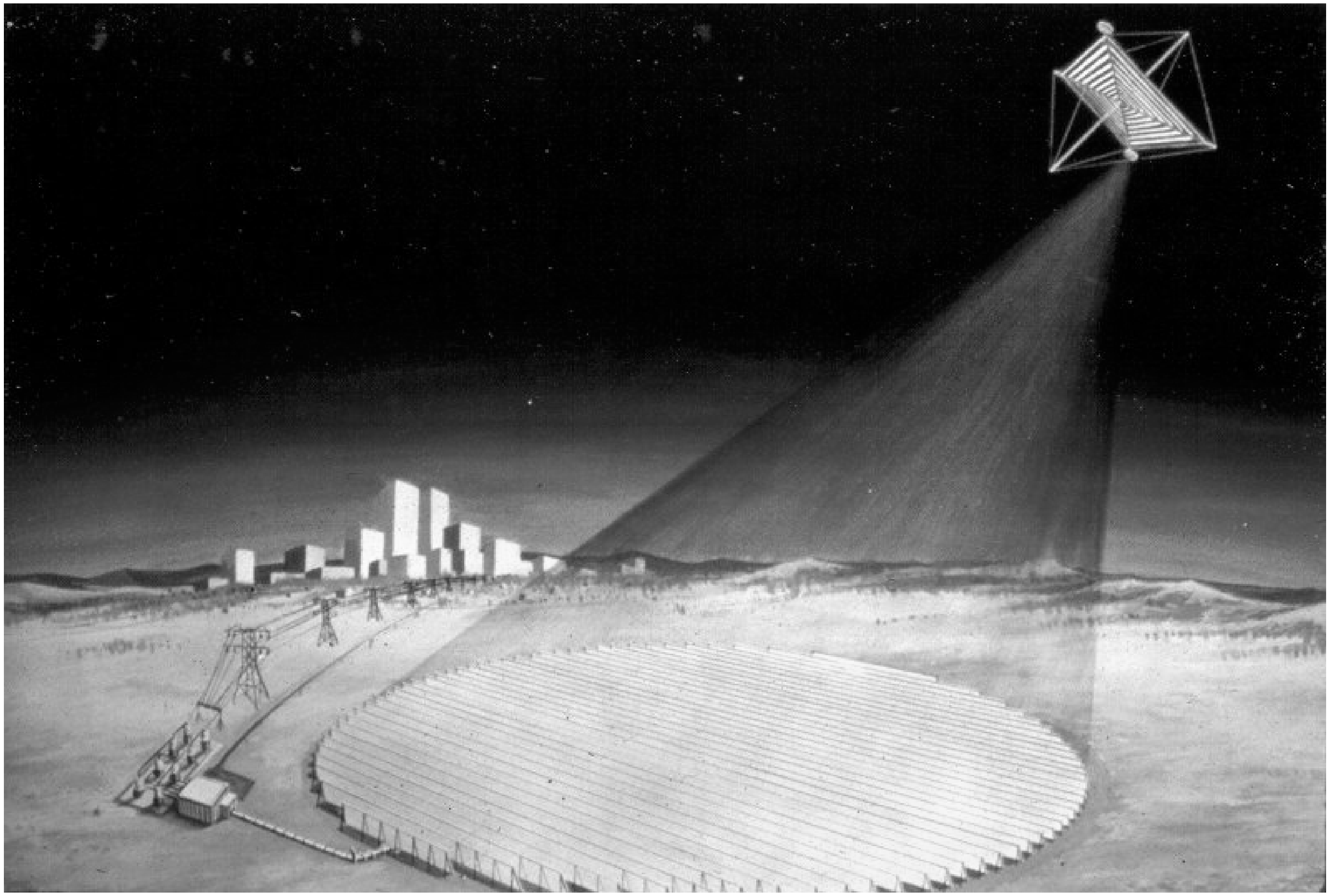




Solar Power Satellites

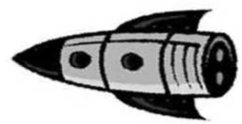


Solar Power Satellite



Rockets

Principle: Newton's Third Law



$F_{exhaust}$ →

← F_{rocket}

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

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

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

2. Thrust (Force) $F = \mathring{M} \; V_e$

(Newtons, Pounds)

($\mathring{M}$ = rate of mass ejected)

3. Mass ratio

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

4. Specific impulse (s.i.)

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

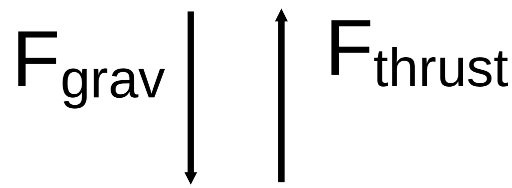
(Newtons/kg/sec,

Pounds/Pounds/sec = “sec”)

A measure of efficiency.

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

Rockets



To take off: Thrust > Weight

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

(7 miles/sec)

Rockets

Multi-stage Rockets

Space Shuttle: Mass = 2×10^6 kg

$F_{thrust} = 29 \times 10^6$ Newtons $R_M = 68$

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 principle, more likely to get 20,000 sec)

Current Initiative

- Human mission to Mars
- Several attempts to get started in past
- Exploration Vision in 2004
  - First return to Moon
  - Then Mars
  - Long-term program needed
  - http://www.nasa.gov/missions/solarsystem/explore_main.html

Evaluating your Drake Equation

Basic Ideas

- Number of Civilizations in our Galaxy
  - Product of rate of emergence and L
    - Running product gives rate for each step
    - Until L, we have rates
    - Through f_c, we get “communicable” civilizations
  - Multiplying by L gives the number (N)
    - Assumes “steady state” between birth and death of civilizations

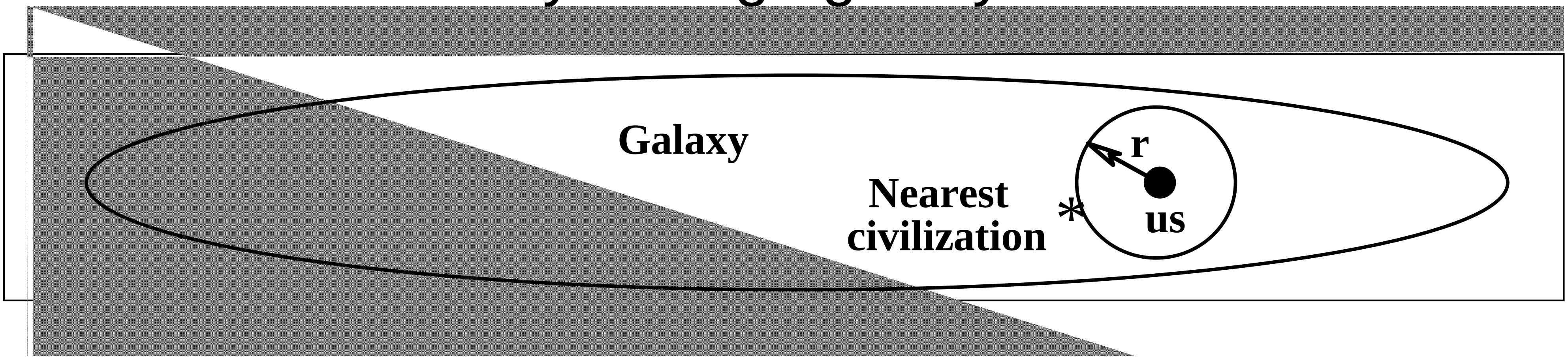
Drake Equation:

$$N = R_* f_p n_e f_l f_i f_c L$$

N	=	number of communicable civilizations in our galaxy
R_*	=	Rate at which stars form
f_p	=	Fraction of stars which have planetary systems
n_e	=	Number of planets, per planetary system, which are suitable for life
f_l	=	Fraction of life bearing planets where intelligence develops
f_c	=	Fraction of planets with intelligent life which develop a technological phase during which there is a capacity for and interest in interstellar communication
L	=	Average of lifetime of communicable civilizations
r	=	Average distance to nearest civilization

Distance to Nearest Neighbor

1. Assume civilizations spread uniformly but randomly through galaxy

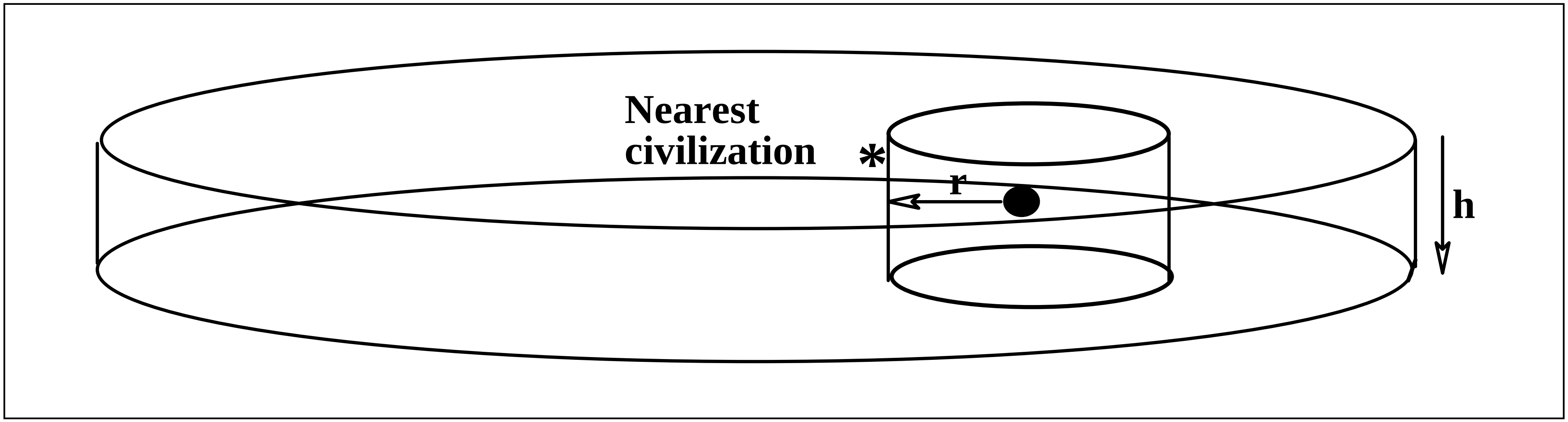


r = radius of imaginary sphere centered on us that touches nearest civilizaztion

search vol $\propto$ r^3

$$\Rightarrow \quad r = \frac{10^4 \text{ ly}}{N^{1/3}}$$

Distance to Nearest Neighbor



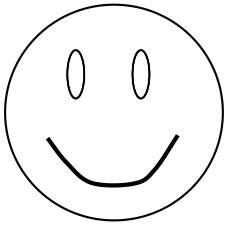
If N < 8000, r from previous formula is 500 ly

About equal to thickness of Galaxy

Use cylinder for search vol $\propto r^2 h$

so $r = \dfrac{5 \times 10^4 \text{ ly}}{N^{1/2}}$

Happy Feller



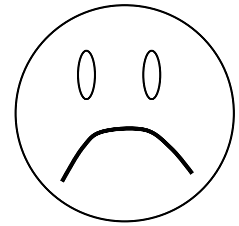
	R	f_p	n_e	f_l	f_i	f_c	L	N	r
Estimate	50	1	1	1	1	1	5×10^9	2.5×10^{11}	1.6 ly
Birthrate	50	50	50	50	50	50			

↑ 2.5 out of 4 stars

If N > 8000, $r = \frac{10^4 \text{ light years}}{N^{1/3}}$

If N <8000, $r = \frac{5 \times 10^4 \text{ light years}}{N^{1/2}}$

Angela Angst



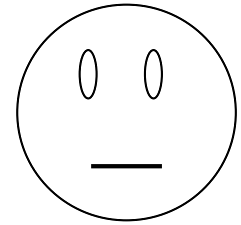
	R	f_p	n_e	f_l	f_i	f_c	L	N	r
Estimate	5	0.1	0.1	0.01	0.01	0.01	100	5×10^{-6}	---
Birthrate	5	0.5	0.05	5×10^{-4}	5×10^{-6}	5×10^{-8}			

Never two civilizations at same time

If $N > 8000$, $$r = \frac{10^4 \text{ light years}}{N^{1/3}}$$

If $N < 8000$, $$r = \frac{5 \times 10^4 \text{ light years}}{N^{1/2}}$$

Mr. Average Guy



	R	f_p	n_e	f_l	f_i	f_c	L	N	r
Estimate	10	0.5	0.89	0.5	0.7	0.6	1×10^6	9.4×10^5	100
Birthrate	10	5	4.45	2.23	1.56	0.94			

1 out of 4×10^5 stars

$10 \times 10^5 = 10^6$

If $N > 8000$, $$r = \frac{10^4 \text{ light years}}{N^{1/3}}$$

If $N < 8000$, $$r = \frac{5 \times 10^4 \text{ light years}}{N^{1/2}}$$

Evaluating YOUR Drake Equation

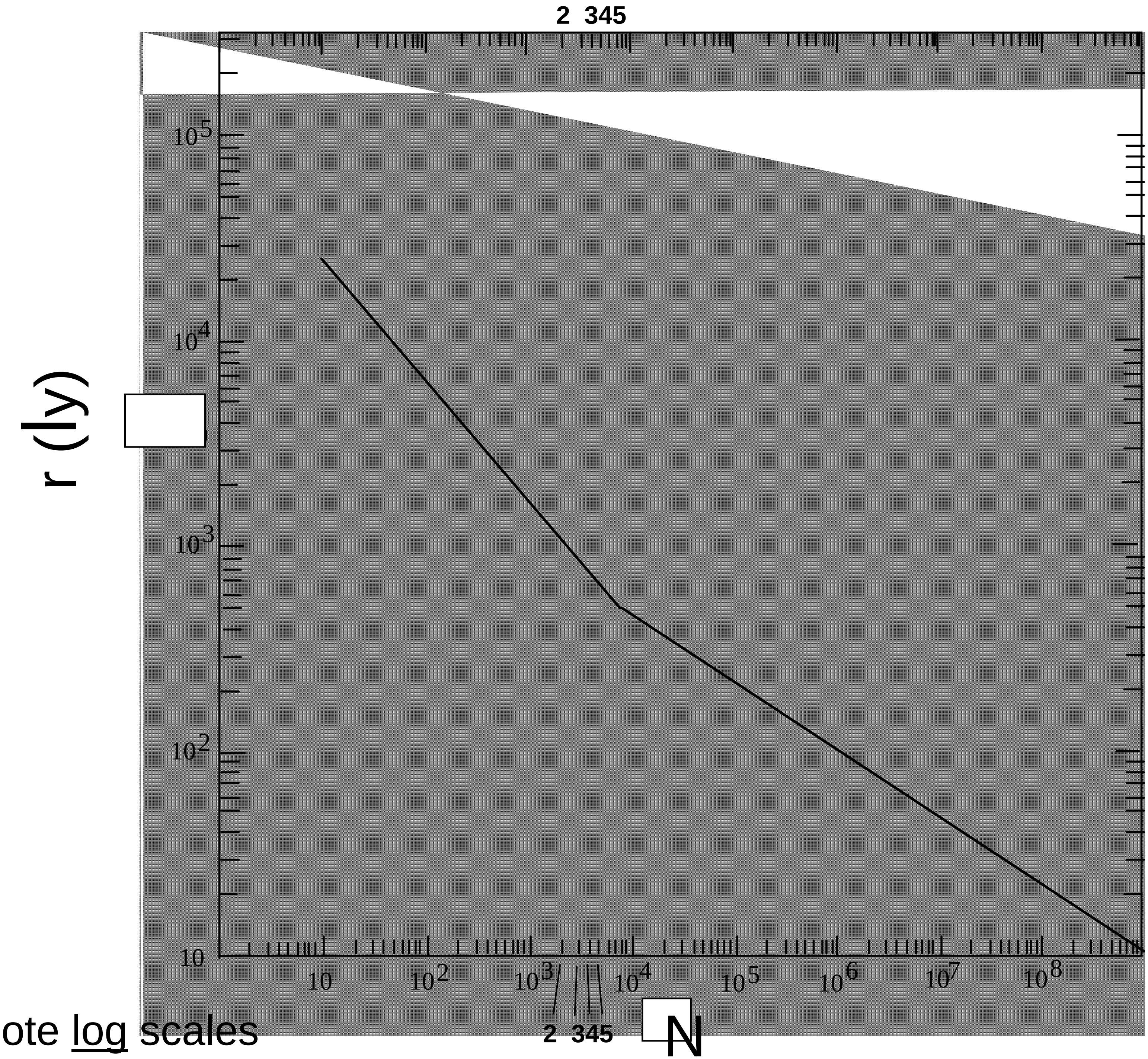
- Almost no answers are wrong
  - It must be possible for us to exist
  - N must be no greater than the number of stars in the Galaxy
    - May imply limit on L
- Ways to evaluate:
  - Plug into equations
  - Use calculator on web
    - http://www.as.utexas.edu/astronomy/education/drake/drake.html
  - Ask us for help

Your Drake Equation

	R	f_p	n_e	f_l	f_i	f_c	L	N	r
Estimate									
Birthrate									

If $N > 8000$, $$r = \frac{10^4 \text{ light years}}{N^{1/3}}$$

If $N < 8000$, $$r = \frac{5 \times 10^4 \text{ light years}}{N^{1/2}}$$



Note <u>log</u> scales

Points to bear in mind

- r is based on assuming spread uniformly
  - Could be less in closer to center of MW
- r is based on averages
  - Could be closer but unlikely
- r is less uncertain than N
- Since signals travel at c, time = distance in ly
- If $L < 2r$, no two way messages