Average Lifetime of Technological Civilization

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Average Lifetime of Technological Civilization

L = ?

- End of Communication Efforts (Civilization Survives) (Decades?)
- Civilization Evolves away from interest or capability (Post-technological Civilization) (Centuries - Millenia)

Natural Catastrophes $(> 10^5 \text{ yr for most})$

 Lulture)
 Resource Depletion

 Metals, Drinkable Water, Arable Land, ...

 Energy is most fundamental

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 ears)

 most)



World ~500 "Quads" Per year 1 Quad = 10^{15} BTU $\simeq 3 \times 10^{11}$ kw - H $\simeq 10^{18}$ Joules (one exajoule)

Average power is $17\times 10^6\,$ MW

U.S. uses ~20% of this

Energy per capita ~ 7.5 metric tonnes of oil equivalent $\sim 2 \times$ Europe

~4 \times World avg.









Side Effects

- General Pollution of Air, Water, Land Makes resources less usable Air pollution, respiratory problems Undrinkable water
 Desertification of farm-lands
- Ozone Layer Destruction
 ⇒ UV reaches surface
 Skin Cancer, Cataracts, ...
 Crop Damage

Caused by CFC's (refrigeration, styrofoam,...) other chemicals

Stratosphere is very sensitive and poorly understood

Catalytic reactions: One CFC molecule leads to the destruction of **many** ozone molecules $O_3 \longrightarrow O_2$

400-Total Ozone Ozone over (Dobson Units) South Pole 35 250 200 150-Has leveled off 100 in recent years 50-Monthly Averages for October o-1960 1965 1970 1975 1980 1985 1990 Year











Other factors

- New models include Sulfate
 emission leads to haze which leads to
 increase in albedo
- Cooling tends to balance warming from Greenhouse CO₂
 Less temperature rise in short term

Greenland ice cores Nature, 15 July 1993

Study temperature, climate... over 150,000 yr Last interglacial (Eemian) 115,000 - 130,000 yr ago

warmer

3 temp. states: like present colder

Very rapid switches (up to $10^{\circ}\,\text{C})$

Our current stable climate may not be typical of interglacials



Ice core analysis shows strong correlation of temperature and astronomical cycles - rotation axis, orbital variations, solar cycle

Also - we are still in last stages of "little ice age" In climate behavior, but not temperature

Population Explosion

(The revenge of Malthus?)

Agriculture - Population Growth - Disease Population Growth leads to more rapid depletion of resources More pollution More conflict?

 Two "events" (transitions)

 10,000 yrs ago
 Agriculture

 250 yrs ago
 Disease lessened (demographic transition)

Time	Total Pop.	Growth Rate (per thousand per year)
Before Agriculture	~ 8 × 10 ⁶ (??)	0.015
~ 8000 BCE - 1 CE	~ 3 × 10 ⁸	0.36
1 CE - 1750 CE	~ 8 × 10 ⁸	0.56
1750-1800	~ 1 × 10 ⁹	4.4
:		
1950 - 1975	4 × 10 ⁹	17.1
2000	6 × 10 ⁹	~ 18
2012	7 x 10 ⁹	

Population Mathematics

 $\begin{array}{l} \mbox{Rate of increase \propto Number \times (Birth - Death)$ leads to exponential growth if (Birth - Death) constant Pop (t) = Pop (Now) 2^{(t/t_d)}$ t_d = doubling time \simeq 61 years currently$ So doubles in 61 yrs$ Quadruples (2²) in 122 yrs, ... 1100 yr (18 t_d) Pop = 1.8 \times 10^{15}$ \sim fills land area$ 2810 yr (46 t_d) Mass > M_{(earth)} !$ 13,725 yr (225 t_d) Mass expands at c !!$ Current population growth is <u>NOT</u> sustainable$ } \end{array}$











The Example of China

- From 1990 to 2004, 400 million Chinese citizens escaped poverty (~1/3 of population)
- Population grew by about 120 million
- Growth rate about 1% per year
- Rate projected to decrease to 0.2% by 2025
- Population will be about 1.5 billion

Nuclear War

Total arsenal world-wide ~ 10,000 megatons

Global effects of all-out war

- Depletion of ozone
- Radioactive fallout
- Dust and smoke in atmosphere would block sunlight and lead to cooling of the Earth "Nuclear Winter"

Th	e World	's Nucle	ar Arse	enals	
	Country	Suspected Strategic Nuclear Weapons	Suspected Non- Strategic Nuclear Weapons	Suspected Total Nuclear Weapons	
*:	China	250	120	400	
	France	350	0	350	
۲	India	60	?	60+	
\$	Israel	100-200	?	200+	
C	Pakistan	24-48	?	24-48	

(2011 update, Deployed)	Country	Suspected Strategic Nuclear Weapons	Suspected Non- Strategic Nuclear	Suspected Total Nuclear Weapons
			Weapons	
	Russia	~ 6,000	~ 4,000	~ 10,000
		(1900)		
	United	180	5	185
\sim	Kingdom	(160)		
\sim				
	United	8,646	2,010	10,656
	States	(1950)		

Nuclear Warheads being Deactivated

- US-Russia Agreement to deactivate warheads (START Agreement 1994)
 - Agreed to reduce to 6000 warheads each
 - Expired Dec 2009
 - Moscow Agreement (2002)
 - Decrease to 1700 2200 by 2012
- New Start

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- signed April 2010, into effect Feb. 2011
- Reduces deployed nuclear weapons to 1550 per side

Natural Catastrophes

Collisions Stars?

Negligible

Molecular Clouds? t ~ 10^8 yr Likely, but the effects are unclear

Less dense clouds? More common but effects are probably less

Asteroids and other debris (comets, meteoroids, ...)

Effect o e.g. 1/4 km radius	of Asteroid Impact:
V = 30 km s ⁻¹	(65,000 miles/hour)
$E_k = 1/2 \text{ Mv}^2 \simeq 7$	200 megatons of TNT all-out nuclear war
Crater ~ 10 km ac 10 ¹² tons of debris If covers globe, lea "asteroid winter"	ross, few km deep released into atmosphere ads to temperature drop and

How Often do	Large Asteroids Strike the Earth?		
1937 Hermes 1989FC 1991BA	~ 500,000 miles Similar 170,000 km (5 - 10 m diameter)		
How often might we expect global catastrophe? "Substantial" Impacts (1 km or larger) $t \sim 10^5$ yr - 10 ⁶ yr Major Extinctions $t \sim 30 \times 10^6$ yr Mass Extinctions $t \sim 100 \times 10^6$ yr ?			

More massive asteroids more destructive, but also more rare, so collisions are less likely

Preventable by advanced civilization?

1991 BA $\,\sim$ 40 kilotons TNT (3 $\,\times$ Hiroshima) 50 meter objects - once per century

April 1992 - proposal for project to search and identify - space watch underway







- Apophis (2004 MN4)
- d = 0.25 km, would release 400 Megatons
- 1/45000 chance of collision in 2036
- http://neo.jpl.nasa.gov/risk/
- · Has data base of Near Earth Objects

Solar variations

~ 10⁵ yr

1. Short term - cyclic variations in L, orbit of Earth -----> ice ages, climate change

~ 1-2 ×10⁹ yr 2. Sun increases in L

on main sequence -----> loss of oceans $UV + H_2O = 2H + O$ H lost to space

~ 5 ×10⁹ yr

3. Off main sequence leads to Red Giant -----> atmosphere evaporates

Could advanced civilization delay loss of oceans? (Decrease greenhouse, add dust) Move to Mars? Mars will be in HZ by end of Sun's main sequence lifetime. Red giants lose mass in winds: Earth's orbit moves out to 1.15 AU by 7.6 x 10^9 yr; but HZ is now 50-80 AU! Sun's atmosphere engulfs Earth and it spirals in. Other stars? Nearby star leads to Supernova $\sim 2 \times 10^9 \text{ yr}$ If within 30 *l*y, ozone is destroyed

Extreme supernova, gamma ray burst If within ~6000 ly, would affect ozone, Atmospheric chemistry

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If open, expands forever				
About 5 x 10 ⁹ years, Andromeda collides with MW				
10 ¹¹ local galaxies collapse into a supergalaxy, if acceleration continues, all other galaxies have disappeared				
10 ¹² - 10 ¹⁴	all stars die			
1017	planetary systems disrupted			
10 ¹⁸ - 10 ²⁰	galaxies "evaporate"			
10 ³² - 10 ³⁴	protons decay?			
10 ¹⁰⁰	Black holes evaporate			

What to choose for L?

• For number of civilizations now,

 $L \le 5 \times 10^9$ yrs -[age of galaxy – time to evolve]

Important to choose L consistent with what you think is the most likely way civilizations end.

Darkness

I had a dream, which was not all a dream. The bright sun was extinguish'd, and the stars Did wander darkling in the eternal space, Rayless, and pathless, and the icy earth Swung blind and blackening in the moonless air;

- Lord Byron, 1816

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