

Probability For Life On Earth

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By Dr. Hugh Ross

Probability Estimate for Attaining the Necessary Characteristics for a Life Support Body

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Notes: Estimate of dependency and longevity factors are accounted for at the end of the list. References to relevant science research papers and books also follow the list. The definition used here for a planet is broad enough to include a large satellite orbiting another planet. For reasons why satellites in general and starless planets are not suitable candidates for a life-support body see [Lights in the Sky and Little Green Men](#) by Hugh Ross, Kenneth Samples, and Mark Clark (Colorado Springs, CO: NavPress, 2002), pp. 39-41.

Parameter	Probability that feature will fall in the required range for physical life
local abundance and distribution of dark matter	0.1
relative abundances of different exotic mass particles	0.01
decay rates of different exotic mass particles	0.05
density of quasars	0.1
density of giant galaxies in the early universe	0.1
galaxy cluster size	0.1
galaxy cluster density	0.1
galaxy cluster location	0.1
galaxy size	0.1
galaxy type	0.1
galaxy mass distribution	0.2
size of galactic central bulge	0.2
galaxy location	0.1
variability of local dwarf galaxy absorption rate	0.1
quantity of galactic dust	0.1
giant star density in galaxy	0.1
frequency of gamma ray bursts in galaxy	0.05
star location relative to galactic center	0.2
star distance from corotation circle of galaxy	0.005
ratio of inner dark halo mass to stellar mass for galaxy	0.1
star distance from closest spiral arm	0.1

z-axis extremes of star's orbit	0.02
proximity of solar nebula to a normal type I supernova eruption	0.01
timing of solar nebula formation relative to a normal type I supernova eruption	0.01
proximity of solar nebula to a type II supernova eruption	0.01
timing of solar nebula formation relative to type II supernova eruption	0.01
timing of hypernovae eruptions	0.2
number of hypernovae eruptions	0.1
masses of stars that become hypernovae	0.1
flux of cosmic ray protons	0.1
variability of cosmic ray proton flux	0.1
gas dispersal rate by companion stars, shock waves, and molecular cloud expansion in the Sun's birthing star cluster	0.1
number of stars in birthing cluster	0.01
star formation rate in parent star vicinity during history of that star	0.1
variation in star formation rate in parent star vicinity during history of that star	0.1
birth date of the star-planetary system	0.01
number of stars in system	0.7
number and timing of close encounters by nearby stars	0.01
proximity of close stellar encounters	0.1
masses of close stellar encounters	0.1
density of brown dwarfs	0.1
distance from nearest black hole	0.2
absorption rate of planets and planetismals by parent star	0.1
star age	0.4
star metallicity	0.05
ratio of ^{40}K , $^{235,238}\text{U}$, ^{232}Th to iron in star-planetary system	0.02
star orbital eccentricity	0.1
star mass	0.001
star luminosity change relative to speciation types & rates	0.00001
star color	0.4
star rotation rate	0.3
rate of change in star rotation rate	0.3
star magnetic field	0.1
star magnetic field variability	0.1
stellar wind strength and variability	0.1
short period variation in parent star diameter	0.1

star's carbon to oxygen ratio	0.01
star's space velocity relative to Local Standard of Rest	0.05
star's short term luminosity variability	0.05
star's long term luminosity variability	0.05
amplitude and duration of star spot cycle	0.1
number & timing of solar system encounters with interstellar gas clouds and cloudlets	0.1
galactic tidal forces on planetary system	0.2
H ₃ ⁺ production	0.1
supernovae rates & locations	0.01
white dwarf binary types, rates, & locations	0.01
structure of comet cloud surrounding planetary system	0.3
planetary distance from star	0.001
inclination of planetary orbit	0.5
axis tilt of planet	0.3
rate of change of axial tilt	0.01
period and size of axis tilt variation	0.1
planetary rotation period	0.1
rate of change in planetary rotation period	0.05
planetary revolution period	0.2
planetary orbit eccentricity	0.3
rate of change of planetary orbital eccentricity	0.1
rate of change of planetary inclination	0.5
period and size of eccentricity variation	0.1
period and size of inclination variation	0.1
precession in planet's rotation	0.3
rate of change in planet's precession	0.3
polycyclic aromatic hydrocarbon abundance in solar nebula	0.1
number of moons	0.2
mass and distance of moon	0.01
surface gravity (escape velocity)	0.001
tidal force from sun and moon	0.1
magnetic field	0.01
rate of change & character of change in magnetic field	0.1
albedo (planet reflectivity)	0.1
density	0.1
density of interstellar and interplanetary dust particles in vicinity of life-support planet	0.3
reducing strength of planet's primordial mantle	0.3
thickness of crust	0.01
timing of birth of continent formation	0.1
oceans-to-continent ratio	0.2
rate of change in oceans to continent ratio	0.1

global distribution of continents	0.3
frequency, timing, & extent of ice ages	0.1
frequency, timing, & extent of global snowball events	0.1
silicate dust annealing by nebular shocks	0.02
asteroidal & cometary collision rate	0.1
change in asteroidal & cometary collision rates	0.1
rate of change in asteroidal & cometary collision rates	0.1
mass of body colliding with primordial Earth	0.002
timing of body colliding with primordial Earth	0.05
location of body's collision with primordial Earth	0.05
position & mass of Jupiter relative to Earth	0.01
major planet eccentricities	0.05
major planet orbital instabilities	0.05
drift and rate of drift in major planet distances	0.05
number & distribution of planets	0.001
distance of gas giant planets from mean motion resonances	0.02
orbital separation distances among inner planets	0.01
mass of Neptune	0.1
total mass of Kuiper Belt asteroids	0.1
mass distribution of Kuiper Belt asteroids	0.2
average rainfall precipitation	0.01
variation and timing of average rainfall precipitation	0.01
atmospheric transparency	0.01
atmospheric pressure	0.01
atmospheric viscosity	0.1
atmospheric electric discharge rate	0.01
atmospheric temperature gradient	0.01
carbon dioxide level in atmosphere	0.01
rates of change in carbon dioxide levels in atmosphere throughout the planet's history	0.001
rates of change in water vapor levels in atmosphere throughout the planet's history	0.01
rate of change in methane level in early atmosphere	0.01
oxygen quantity in atmosphere	0.01
nitrogen quantity in atmosphere	0.01
carbon monoxide quantity in atmosphere	0.1
chlorine quantity in atmosphere	0.1
aerosol particle density emitted from forests	0.05
cobalt quantity in crust	0.1
arsenic quantity in crust	0.1
copper quantity in crust	0.1
boron quantity in crust	0.1
cadmium quantity in crust	0.1

calcium quantity in crust	0.4
fluorine quantity in crust	0.1
iodine quantity in crust	0.1
magnesium in crust	0.4
manganese quantity in crust	0.1
nickel quantity in crust	0.1
phosphorus quantity in crust	0.1
potassium quantity in crust	0.4
tin quantity in crust	0.1
zinc quantity in crust	0.1
molybdenum quantity in crust	0.05
vanadium quantity in crust	0.1
chromium quantity in crust	0.1
selenium quantity in crust	0.1
iron quantity in oceans	0.1
tropospheric ozone quantity	0.01
stratospheric ozone quantity	0.01
mesospheric ozone quantity	0.01
water vapor level in atmosphere	0.01
oxygen to nitrogen ratio in atmosphere	0.1
quantity of greenhouse gases in atmosphere	0.01
rate of change in greenhouse gases in atmosphere	0.01
poleward heat transport in atmosphere by mid-latitude storms	0.2
quantity of forest & grass fires	0.01
quantity of sea salt aerosols in troposphere	0.1
soil mineralization	0.1
quantity of anaerobic bacteria in the oceans	0.01
quantity of aerobic bacteria in the oceans	0.01
quantity of anaerobic nitrogen-fixing bacteria in the early oceans	0.01
quantity, variety, and timing of sulfate-reducing bacteria	0.00001
quantity of geobacteraceae	0.01
quantity of aerobic photoheterotrophic bacteria	0.01
quantity of decomposer bacteria in soil	0.01
quantity of mycorrhizal fungi in soil	0.01
quantity of nitrifying microbes in soil	0.01
quantity & timing of vascular plant introductions	0.001
quantity, timing, & placement of carbonate-producing animals	0.00001
quantity, timing, & placement of methanogens	0.00001
phosphorus and iron absorption by banded iron formations	0.01
quantity of soil sulfur	0.1

ratio of electrically conducting inner core radius to radius of the adjacent turbulent fluid shell	0.2
ratio of core to shell (see above) magnetic diffusivity	0.2
magnetic Reynold's number of the shell (see above)	0.2
elasticity of iron in the inner core	0.2
electromagnetic Maxwell shear stresses in the inner core	0.2
core precession frequency for planet	0.1
rate of interior heat loss for planet	0.1
quantity of sulfur in the planet's core	0.1
quantity of silicon in the planet's core	0.1
quantity of water at subduction zones in the crust	0.01
quantity of high pressure ice in subducting crustal slabs	0.1
hydration rate of subducted minerals	0.1
water absorption capacity of planet's lower mantle	0.1
tectonic activity	0.05
rate of decline in tectonic activity	0.1
volcanic activity	0.1
rate of decline in volcanic activity	0.1
location of volcanic eruptions	0.1
continental relief	0.1
viscosity at Earth core boundaries	0.01
viscosity of lithosphere	0.2
thickness of mid-mantle boundary	0.1
rate of sedimentary loading at crustal subduction zones	0.1
biomass to comet infall ratio	0.01
regularity of cometary infall	0.1
number, intensity, and location of hurricanes	0.02
intensity of primordial cosmic superwinds	0.05
number of smoking quasars	0.05
formation of large terrestrial planet in the presence of two or more gas giant planets	0.1
orbital stability of large terrestrial planet in the presence of two or more gas giant planets	0.01
total mass of Oort Cloud objects	0.2
mass distribution of Oort Cloud objects	0.2
air turbulence in troposphere	0.1
quantity of sulfate aerosols in troposphere	0.1
quantity of actinide bioreducing bacteria	0.01
quantity of phytoplankton	0.001
hydrothermal alteration of ancient oceanic basalts	0.01
quantity of iodocarbon-emitting marine organisms	0.01
location of dislocation creep relative to diffusion creep in and near the crust-mantle boundary (determines mantle convection dynamics)	0.1

size of oxygen sinks in the planet's crust	0.2
size of oxygen sinks in the planet's mantle	0.2
mantle plume production	0.1
number and mass of planets in system suffering significant drift	0.2
mass of the galaxy's central black hole	0.3
timing of the growth of the galaxy's central black hole	0.5
rate of in-spiraling gas into galaxy's central black hole during life epoch	0.05
distance from nearest giant galaxy	0.5
distance from nearest Seyfert galaxy	0.9
amount of mass loss by star in its youth	0.1
rate of mass loss of star in its youth	0.3
rate of mass loss by star during its middle age	0.3
quantity of magnetars (proto-neutron stars with very strong magnetic fields) produced during galaxy's history	0.05
variation in coverage of star's surface by faculae	0.5
ratio of galaxy's dark halo mass to its baryonic mass	0.2
ratio of galaxy's dark halo mass to its dark halo core mass	0.2
galaxy cluster formation rate	0.1
proximity of supernovae and hypernovae throughout history of planet and planetary system	0.1
tidal heating from neighboring galaxies	0.5
tidal heating from dark galactic and galaxy cluster halos	0.5
intensity and duration of galactic winds	0.3
density of dwarf galaxies in vicinity of home galaxy	0.1
amount of photoevaporation during planetary formation from parent star and other nearby stars	0.2
orbital inclinations of companion planets in system	0.1
variation of orbital inclinations of companion planets	0.2
inclinations and eccentricities of nearby terrestrial planets	0.3
in-spiral rate of stars into black holes within parent galaxy	0.7
strength of magnetocentrifugally launched wind of parent star during its protostar era	0.2
degree to which the atmospheric composition of the planet departs from thermodynamic equilibrium	0.01
delivery rate of volatiles to planet from asteroid-comet belts during epoch of planet formation	0.1
amount of outward migration of Neptune	0.1
amount of outward migration of Uranus	0.1
Q-value (rigidity) of planet during its early history	0.2
variation in Q-value of planet during its early history	0.3

injection efficiency of shock wave material from nearby supernovae into collapsing molecular cloud that forms star and planetary system	0.1
number of giant galaxies in galaxy cluster	0.2
number of large galaxies in galaxy cluster	0.2
number of dwarf galaxies in galaxy cluster	0.2
number and sizes of planets and planetesimals consumed by star	0.3
distance of galaxy's corotation circle from center of galaxy	0.1
rate of diffusion of heavy elements from galactic center out to the galaxy's corotation circle	0.2
outward migration of star relative to galactic center	0.3
degree to which exotic matter self interacts	0.01
migration of planet during its formation in the protoplanetary disk	0.1
viscosity gradient in protoplanetary disk	0.1
variations in star's diameter	0.1
average quantity of gas infused into the universe's first star clusters	0.1
frequency of late impacts by large asteroids and comets	0.1
level of supersonic turbulence in the infant universe	0.05
number and sizes of intergalactic hydrogen gas clouds in galaxy's vicinity	0.1
average longevity of intergalactic hydrogen gas clouds in galaxy's vicinity	0.2
minimization of chloromethane production by rotting plants and fungi that are exposed to the atmosphere (life's survival demands very efficient burial mechanisms and relatively low temperatures)	..01
avoidance of apsidal phase locking in the orbits of planets in the planetary system	0.03
number density of the first metal-free stars to form in the universe	0.02
epoch during which the first metal-free stars form in cosmic history	0.1
level of spot production on star's surface	0.2
variability of spot production on star's surface	0.2
size of the carbon sink in the deep mantle of the planet	0.05
average circumstellar medium density for white dwarf red giant pairs	0.2
number densities of metal-poor and extremely metal-poor galaxies	0.1
rate of growth of central spheroid for the galaxy	0.05

amount of gas infalling into the central core of the galaxy	0.1
level of cooling of gas infalling into the central core of the galaxy	0.1
ratio of dual water molecules, (H ₂ O) ₂ , to single water molecules, H ₂ O, in the troposphere	0.03
heavy element abundance in the intracluster medium for the early universe	0.1
quantity of volatiles on and in Earth-sized planet in the habitable zone	0.001
rate of infall of intergalactic gas into emerging and growing galaxies during first five billion years of cosmic history	0.1
pressure of the intra-galaxy-cluster medium	0.1
proximity of solar nebula to a type I supernova whose core underwent significant gravitational collapse before carbon deflagration	0.01
timing of solar nebula formation relative to a type I supernova whose core underwent significant gravitational collapse before carbon deflagration	0.01
sizes of largest cosmic structures in the universe	0.01
level of spiral substructure in spiral galaxy	0.2
mass of outer gas giant planet relative to inner gas giant planet	0.05
Kozai oscillation level in planetary system	0.7
triggering of El Nino events by explosive volcanic eruptions	0.1
time window between the peak of kerogen production and the appearance of intelligent life	0.1
time window between the production of cisterns in the planet's crust that can effectively collect and store petroleum and natural gas and the appearance of intelligent life	0.1
reduction of Kuiper Belt mass during planetary system's early history	0.1
efficiency of stellar mass loss during final stages of stellar burning	0.3
efficiency of flows of silicate melt, hypersaline hydrothermal fluids, and hydrothermal vapors in the upper crust	0.2
supernova eruption rate when galaxy is young	0.2
range of rotation rates for stars are on the verge of becoming supernovae	0.2
quantity of dust formed in the ejecta of Population III supernovae	0.1

chemical composition of dust ejected by Population III stars	0.3
time in cosmic history when the merging of galaxies peaks	0.2
efficiency of ocean pumps that return nutrients to ocean surfaces	0.1
sulfur and sulfate content of oceans	0.3
density of extragalactic intruder stars in solar neighborhood	0.4
density of dust-exporting stars in solar neighborhood	0.3
average rate of increase in galaxy sizes	0.1
change in average rate of increase in galaxy sizes throughout cosmic history	0.1
proximity of solar nebula to asymptotic giant branch stars	0.05
timing of solar nebula formation relative to its close approach to asymptotic giant branch stars	0.05
orientation of continents relative to prevailing winds	0.3
quantity and proximity of gamma-ray burst events relative to emerging solar nebula	0.01
proximity of superbubbles to planetary system during life epoch of life-support planet	0.03
proximity of strong ultraviolet emitting stars to planetary system during life epoch of life-support planet	0.02
number, mass, and distance from star of gas giant planets in addition to planets of the mass and distance of Jupiter and Saturn	0.01
quantity and proximity of galactic gamma-ray burst events relative to time window for intelligent life	0.1
infall of buckminsterfullerenes from interplanetary and interstellar space upon surface of planet	0.3
quantity of silicic acid in the oceans	0.1
heat flow through the planet's mantle from radiometric decay in planet's core	0.002
water absorption by planet's mantle	0.01
timing of star formation peak for the universe	0.2
timing of star formation peak for the galaxy	0.2

Probability for occurrence of all 322 parameters $\approx 10^{-388}$

dependency factors estimate $\approx 10^{-96}$

longevity requirements estimate $\approx 10^{14}$

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