Astronomy 330

This class (Lecture 23):
Communication

Next Class:
Communication

HW11 is due Sunday. Fun one, but still not multiple choice.

Music: *Aliens Exist*– Blink 182

Online ICES

- ICES forms are available online.
- I appreciate you filling them out!
- Please make sure to leave written comments. I find these comments the most useful, and typically that's where I make the most changes to the course.
- So far 22/97, so fill them out!

Outline

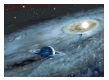
- How to communicate with aliens.
- Radio?
- If detected how to decode?
- Important factors for detection.

Drake Equation

That's 39,700 advanced civs!

Frank Drake








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

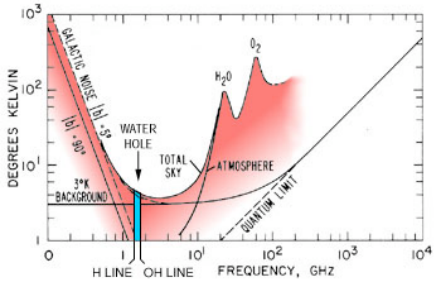
N	R_*	f_p	n_e	f_l	f_i	f_c	L
# of advanced civilizations we can contact in our Galaxy today	Star formation rate	Fraction of stars with planets	# of Earthlike planets per system	Fraction on which life arises	Fraction that evolve intelligence	Fraction that commun-icate	Lifetime of advanced civilizations
	20 stars/ yr	0.12 systems/ star	1.25 x 0.12 = 0.15 planets/ system	0.4 life/ planet	0.23 intel./ life	.5 comm./ intel.	240,000 yrs/ comm.

How to Communicate?

Radio is probably best.

1. Dust extinction is reduced.
2. Lower frequency means less energy/photon, so cheaper.
3. There is a natural dip from about 1 to 10 GHz in the radio where the atmosphere and the galaxy are the quietest.

http://setiathome.ssl.berkeley.edu/about_seti/radio_search_2.html



Decoder Ring

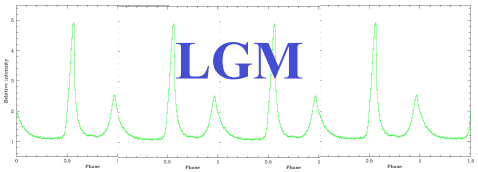
- After receiving and amplifying the signals, one has to decode the signals.
- Naturally created signals do not usually vary with time and are unpolarized.

http://theimaginaryworld.com/box678.jpg

Decoder Ring

- Normally, artificial signals encode data:
  - FM : frequency modulation (frequency varies with time)
  - AM : amplitude modulation (brightness varies with time)
    - Usually analog, but digital is more robust
    - Can turn on/off to signify 1 or 0 (most likely for ET)
- Note, most astronomers do not look for fast varying signals, but weak non-varying signals.

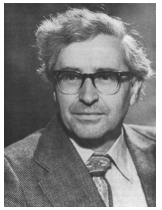
http://theimaginaryworld.com/box678.jpg



LGM

- But, astronomers studying the short variations in the interstellar medium did look at fast varying signals.
- Jocelyn Bell noticed a regularly repeating signal.
- Perfect timing, but no real encoding.
- Jokingly called LGMs, then Pulsars.
- Eventually realized to be from neutron stars.
- The lighthouse beam from the rapid rotator sometimes intersecting the Earth.

Jocelyn Bell Burnell



Anthony Hewish

http://www.radiosky.com/rspplsr.html

Built to be Decoded

- If a signal is found, how do we decode it?
- Most coding is meant to hide the signal, but in this case we want it to be decoded by any intelligence.
- Obviously this is not trivial.
- Many suggestions that revolve around mathematics have been made.
- To date there has only been one serious message sent from Earth.

The Arecibo Message

- On November 16, 1974 Carl Sagan and Frank Drake sent a message for 3 minutes
- Frequency used was 2380 MHz, with frequency modulation (10 Hz)
- Used the Arecibo telescope with a large transmitter– 100 kw beamed or 20 trillion watts of power if omni-directional.
- Strongest man-made signal ever sent.

Can you Figure it out?

See if you can decode anything.

By frequency modulation, they sent 1679 bits of 1/on and 0/off.

1679 is the product of 2 prime numbers– 23 and 73.

ET should be able to try arranging them into a picture.

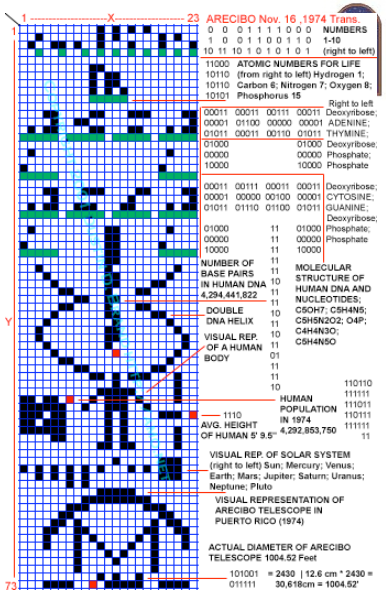
We attempted Contact

- Now, we wait.
- Sent toward the globular cluster M13 which is 21,000 lyrs away.
- If they're looking, any SETI experiment will detect this.
- But do we expect anyone?

Decode what?

- An amazing amount of information in 1679 bits.
- But human experts had trouble decoding it.

http://antwrp.gsfc.nasa.gov/apod/ap970717.html



http://amo.net/Contact/

Question

In 21,000 years, when the Drake message gets to M13

a) The aliens will be able to decode it, and enjoy images and sounds of the people of Earth.

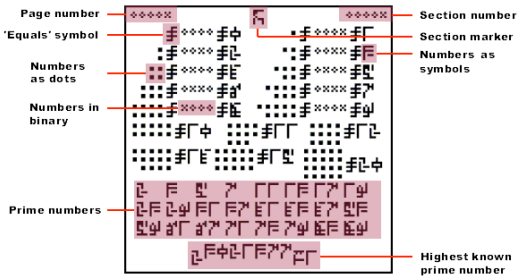
b) The aliens may not be able to decode it.

c) The aliens will not be able to decode it, but with the additional hints sent afterwards, they will figure it out.

d) The aliens will be able to decode it and build their own telescope with the knowledge.

Encounter Messages

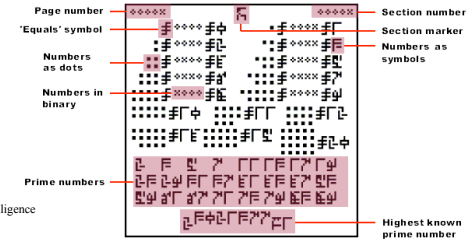
- Sent by commercial company based in Houston, Texas using the Evpatoriya Deep Space Center radio telescope in Ukraine to 5 nearby stars less than 50 lyrs.
- Drake's message had 1,679 bits of information. This has 300,000 bits, with built-in redundancy. If some bits are lost to noise en route, ET might be able to decode.
- Astronomers derived code: Dutil & Dumas
- Included names and address of 2000 donors and personal messages.



http://www.ibiblio.org/astrobiology/index.php?page=interview01

Encounter Messages

Name	Designation HD	Constellation	Date sent	Arrival date	Message
16 Cyg A	HD 186408	Cygnus	May 24 , 1999	November 2069	Cosmic Call 1
15 Sge	HD 190406	Sagitta	June 30 , 1999	February 2057	Cosmic Call 1
	HD 178428	Sagitta	June 30 , 1999	October 2067	Cosmic Call 1
Gl 777	HD 190360	Cygnus	July 1 , 1999	April 2051	Cosmic Call 1
	Hip 4872	Cassiopeia	July 6 , 2003	April 2036	Cosmic Call 2
	HD 245409	Orion	July 6 , 2003	August 2040	Cosmic Call 2
55 Cnc	HD 75732	Cancer	July 6 , 2003	May 2044	Cosmic Call 2
	HD 10307	Andromeda	July 6 , 2003	September 2044	Cosmic Call 2
47 UMa	HD 95128	Ursa Major	July 6 , 2003	May 2049	Cosmic Call 2



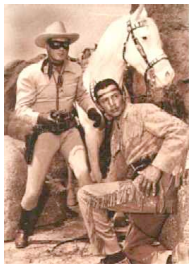
http://en.wikipedia.org/wiki/Communication_with_Extraterrestrial_Intelligence

Contacting Us

- What does an advanced civilization that wants to contact us do?
- Could set-up radio beacons
  - Broadcast in all directions.
  - Broadcast at several frequencies.
  - Would require enormous energy sources.
- Would be much better if they could use directional messages.
- Existing transmitters on Arecibo are strong enough to communicate across the galaxy with similar telescopes, but with a very small beam.
- The problem is where to look or to transmit.

Does ET Love Lucy?

- One solution is to look for unintentional leakage signals.
- Leakage, as it "leaks" from the planet's ionosphere.
- We can not currently detect this, but maybe other civilizations can.
- This is the scenario explored in the novel *Contact* by Carl Sagan and the movie based on the novel.
- What leakage do we have? TV, FM Radio, radar
- Television transmission exceeds 10^7 watts (10 MW).



http://www.time.com/time/time100/scientist/profile/farnsworth.html

Contact

http://www.youtube.com/watch?v=kht_rJs38Y4

"If humans were the only life in the Universe it would be a terrible waste of space."

Vega calls us back, but how can we be sure that we're listening?

Our leakage radiation is actually decreasing with cable, fiber optics, direct satellite, etc. Civilizations may not spend much time in that phase.

http://www.youtube.com/watch?v=R14lfb3QnM0&feature=related

Does ET Love Lucy?

- ET would be unable to really distinguish individual stations due to the rotation of the Earth.
- To detect early carrier signals at 50 lyrs, need 3000 acres of antenna.
- To watch the TV show, need antenna the size of Colorado. It is possible?

http://www.space.com/searchforlife/seti_shostak_aliens_031023.html

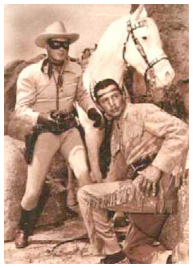
Does ET Love Lucy?

- Still Earth would produce a regular 24 hour pattern for the last 60 years.
- Military radar is more promising. Highly focused and powerful.
- Only requires a 1000 foot antenna.

http://www.space.com/searchforlife/seti_shostak_aliens_031023.html

Does ET Love Lucy?

- As radio travels at speed of light, our leakage signals have reached the nearest 5000 stars!
- Still, this is way too few for our estimate.
- It is unlikely that a civilization is within 50 lyrs. → $N_{required} = 10^7$
- So probably ET does not love Lucy, at least yet.



Problems…Problems

- Assume that an advanced civilization is broadcasting either in all directions or toward us.
- Where and when do we listen?
- Which frequency?
- Which channel?
- Which polarization?
- What is the code?

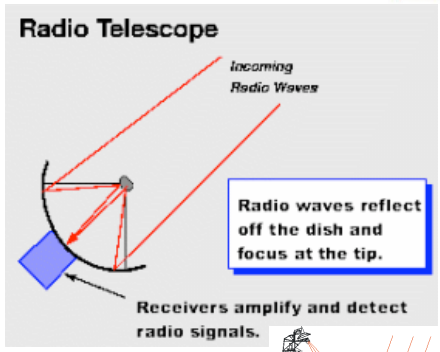
Problems…Problems

- The problem is worse than searching for a needle in a haystack.
- We have to assume that they are constantly broadcasting, or the problem is impossible.
- Have to make the needle bigger!

http://nl.ijs.si/et/talks/essIli02/metadata_files/Haystack-FINALb.jpg

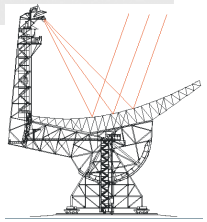
Sky Dishes

- Radio telescopes are similar to optical telescopes.
- Most radio telescopes are Parabolic Cassegrains.
- Radio telescopes measure the source intensity.
- The bigger the dish, the more sensitive.
- So a big dish is best, right?



http://www.nrao.edu/whatisra/radiotel.shtml

Unblocked Aperture



Haystack: Sensitivity

- Sensitivity of a radio telescope:
- We have to detect a weak signal in the presence of noise.
- So, ideally look in a fixed direction for a long time– better sensitivity to weak signals.
- But it may be the wrong direction.
- And a big dish is best, right?

Channel size — time

$$S \propto D^2 \sqrt{\Delta\upsilon \times t}$$

Dish diameter

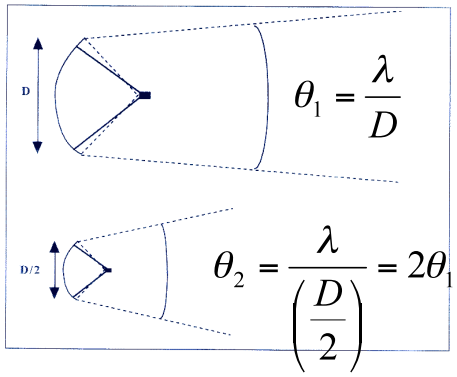
Question

What makes a telescope more sensitive?

a) Double the size
b) Double the channel width
c) Double the observing time
d) Double the voltage
e) Double the trouble

Haystack: Direction

- We can not *a priori* know which direction to look, so we must look in many directions.
- Tradeoff: The most sensitive radio telescope has the largest diameter but the smallest field of view.
- Beam size decreases as the diameter increases.
- The number of times you have to point to cover a certain area of the sky increases as diameter squared.



$$\theta_1 = \frac{\lambda}{D}$$

$$\theta_2 = \frac{\lambda}{\left(\frac{D}{2}\right)} = 2\theta_1$$

θ is in radians.

Dish Decision

- If ET signals are a few strong signals, we can use a small telescope and listen for a short time in any direction. The small diameter dish covers more area.
- If ET signal is many weak signals, we can use a bigger telescope and observe in a single direction for a long time. A weak signal requires a big dish.

http://www.noao.edu/staff/mighell/sacpeak/jpina/VLA%20in%20dish%204.jpg

Question

In any SETI experiment, it is best

a) To use the biggest radio telescope available.
b) To use a big radio telescope and sit on one star for a long time.
c) To use a combination of small and large telescopes.
d) To look for UFOs directly.

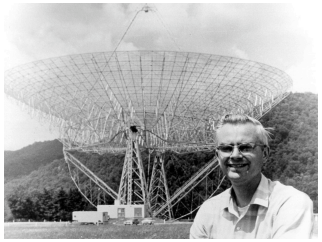
Haystack: Frequency

- Would the signal be concentrated in a small range of freqs?
- What size should a channel be?
- Could argue that the best choice is around 1 Hz.
- Then in the 1-10 GHz band there are 9×10^9 channels!
- With modern electronics we can survey large numbers of channels, but not that many.
- What's the history of SETI?

Project Ozma

- The first look for ET radio signals by Frank Drake in 1960.
- Used a 26 meter telescope in W.V. using the H atom frequency band of 1.42 GHz.
- Targeted search of 2 nearby stars (11 lyrs) that are the same age as our Sun
- 200 hours over 3 months.
- A single 100 Hz channel scanned 400 kHz.
- 1 false alarm due to a secret military experiment.
- Nothing else detected

http://www.angelfire.com/pa/maryanne/images/ozma.jpg



http://216.120.234.103/setiprime/setiprime/images/images-2003.html

Ozma II

- Ben Zuckerman and Pat Palmer used the 91m telescope in W.V. to survey the 670 nearest “suitable” stars.
- Targeted Search of stars with low mass and binaries that allowed stable planet orbits.
- Also observed at 1.42 GHz with 192 channels of 4 kHz and 192 channels of 52 kHz.
- Could have detected a 40 MW transmitter on a 100m telescope.
- Observed for 500 hours.
- No detection at a sensitivity 10 times better than Ozma

Ohio State Survey

- In 1973 by F. Dixon and D. Cole.
- Used Ohio State radio telescope for a continuous survey of sky.
- Not steerable– sort of like Arecibo, so cuts a swath through the sky: A Sky Survey
- Searched overhead for signals.

http://www.bigear.org

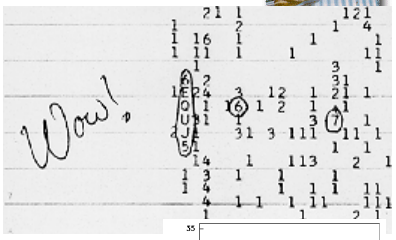
Ohio State

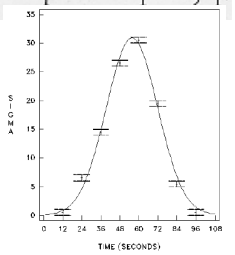
- 1.42 GHz with 50 channels of 10 kHz.
- Modest sensitivity— 100 times worse than Ozma II
- But not just looking at stars.
- Could only detect extremely strong transmissions.
- Land was sold to a golf course development.

http://www.bigear.org

The Wow Signal

- Aug. 15, 1977, Jerry Ehman was looking through the data when he recorded the Wow! signal.
- A major signal in the telescope– 30σ detection!
- Stayed around for >72 seconds.
- Unlikely to be noise, but never seen again.
- "Even if it were intelligent beings sending a signal, they'd do it far more than once."
- Used in X-Files



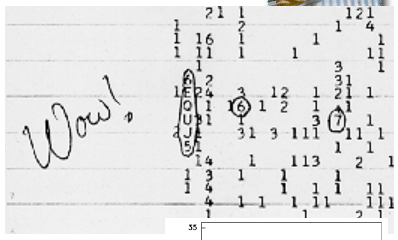


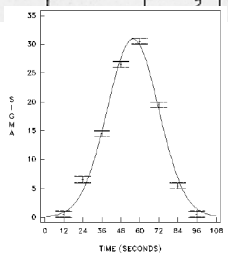
http://www.bigear.org/wow.htm

Gray & Marvel 2001, ApJ 546, 1171

The Wow Signal: Facts

- Narrowband signal: < 10 kHz wide (one channel only)
- Signal observed in only one (of two) horns
- Signal observed only once ("Big Ear" or other observatories)
- Within each 10-second observing interval, the average signal strength remained constant.
- For the entire observing interval of 6 data points lasting 72 seconds, the average signal strength remained constant (because the 6 data values follow the antenna pattern to better than a 99% accuracy).
- Modulation (signal strength variation) on a time scale less than 10 seconds could not be measured.





http://www.bigear.org/Wow30th/wow30th.htm#otheranal

http://www.bigear.org/wow.htm

Gray & Marvel 2001, ApJ 546, 1171

Paul Horowitz Searches 1.42 GHz

- Paul Horowitz moved from a small number of channels to many many many channels.
- 1983 Sentinel: 128,000 channels covering 6 kHz each
- 1985 META: 8 million channels with 400 kHz bandwidth.
- 1993: Horowitz and Sagan reported 8 unexplained signals that did not repeat.
- 1995 BETA: Nearly a billion channels (2.5×10^8) covering 2 GHz, 10 kHz channels. Windstorm blew the telescope over in late 1990s.
- Overall, Paul has found 37 signals that did not repeat, and did not have any other known source.

The NASA Search

The most ambitious search was planned by NASA on the 500th anniversary of the *Discovery* of America– Oct 12, 1992.

http://www.teslasociety.com/exposition2.jpg
http://www.sailtexas.com/columbusships.html

The NASA Plan

- 2 prong approach using both Targeted Search and Sky Survey
- Sky Survey:
  - NASA's 34 m tracking telescopes in CA and Australia.
  - 6 year plan covering 1-10 GHz with 16 million channels of 20 Hz each and 30 different settings.
  - Would only detect very strong signals.
- Targeted Search:
  - Cover 800 suitable stars within 75 lyrs.
  - 16 million channels with 1 Hz bandwidth
  - 1-3 GHz range and very good sensitivity!

The NASA Search

- “In 1993, Nevada Senator Richard Bryan successfully introduced an amendment that eliminated all funding for the NASA SETI program.
- The cost of the program was less than 0.1% of NASA's annual budget, amounting to about a nickel per taxpayer per year. The Senator cited budget pressures as his reason for ending NASA’s involvement with SETI.”

http://www.planetary.org/html/UPDATES/seti/history/History12.htm
http://www.seti.org/about_us/faq.html

The NASA Search

- “The Great Martian Chase may finally come to an end. As of today millions have been spent and we have yet to bag a single little green fellow. Not a single Martian has said take me to your leader, and not a single flying saucer has applied for FAA approval."

http://www.planetary.org/html/UPDATES/seti/history/History12.htm
http://www.seti.org/about_us/faq.html

The SETI Institute

- An independent institute that was working with NASA on their SETI project.
- Once NASA cut funding, they went ahead with a more modest version of the Targeted Search– Project Phoenix.
- Now funded by private donors.
- Initially a search of 200 stars within 150 ly younger than 3 x 10^9 yrs using an Australian 63 m telescope for 5 minutes on each target.
- Scanned 28 million channels each 1 Hz wide, used multiple settings to scan 1.2 to 13.0 GHz

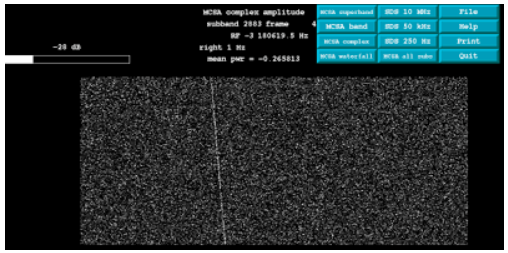
http://www.seti.org/seti/our_projects/project_phoenix/oveview/overview.html

Project Phoenix

- Just finished up in 2004. (http://www.seti.org/seti/projects/project-phoenix/faq.php).
- About 2-3 weeks a year of telescope time to scan a total of 800 stars (out to 240 lyrs) for a total of 11,000 hours.
- Best survey to date, but no ET signals.

Project Phoenix

- Proof of concept was shown by tracking the Pioneer 10 spacecraft (launched in 1973) that is 6 billion miles away and broadcasting with a few Watts of power.
- The signal was detected.
- As the Earth and object are moving, there is a small Doppler shift in the frequency of the light received over time.



Allen Telescope Array

- At the BIMA site, UC Berkeley and the SETI Institute, with majority of funding from Paul Allen, are building the ATA.
- 350 antennas that are 6.1 m in diameter, planned.
- Area comparison: Arecibo (70,650 m^2) & ATA (10,200 m^2) but still > 100 m single dish.

Allen Telescope Array

- And small dishes– larger field of view.
- But LOTS of them.. planned
- With advanced electronics it will cover 1-10 GHz with many channels.
- Can image a few stars per field.

Allen Telescope Array

- 100% SETI (with science on for the ride)
- Will increase search to 100,000 or 1 Million stars.
- Current status is 42 dishes.
- Is now observing!
- http://www.seti.org/ata/

Allen Telescope Array

See the telescope in action:

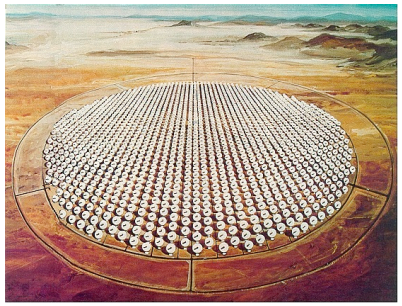
http://atacam.seti.org/maincam-index.html

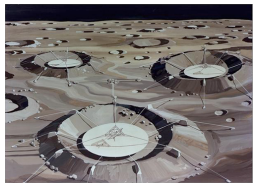
End All

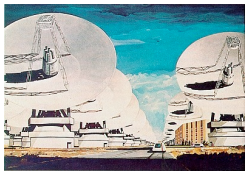
- The modern SETI searches are really expanding the frequency range in which we search, but we are still sensitivity limited.
- In any SETI experiment, what does a null result mean?

The Future?

- Cyclops – 1000 telescopes each 100 m in diameter.
- Resembles a giant eye.
- Could detect leakage transmission at 100 ly.
- Could detect a 1000 MW transmission at 1000 lyrs.
- Bucco Bucks– $50B and 10-20 yrs to build.



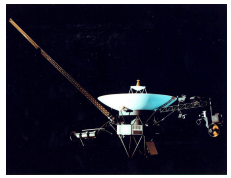




http://www.astrosurf.com/lombry/ovni-bioastronomie-et.htm

Interstellar Travel

- The distances are freaky huge!
- Nearest star is 4.3 ly away or around 4 x 10^{13} km!
- **40,000,000,000,000 km! 40 TRILLION km!!!**
  - **Voyager (our fastest spacecraft to date) would take** 100,000 years



Interstellar Travel

- But, what if all communication with ET fails?
  - Wrong frequencies.
  - Everyone is listening and no one is broadcasting.
  - We fail to recognize the signal.
- We can go visit them or the microbes. "To boldly go…"
- Human colonization of the Galaxy has to start somewhere. Our own backyard!

Humans Spreading Out

If we assume that no life is found in our solar system, we have multiple options.

- Seed other planets with genetically engineered life or terraform the planet for terrestrial life.
- Colonize the planets or asteroids.
- Send robots to exploit solar system resources.

GELFs

- Genetic engineering techniques might allow us to develop organisms suitable for life on Mars, in the clouds of Venus, or the upper atmosphere of Jupiter.
- But the most likely organism would be those that are part of a larger plan to transform an environment into one suitable for human colonization.
- Terraforming– forming a planet or moon into something like the Earth conditions.

Spider genes being injected into a goat egg. Goat produces spider silk protein in milk– Biosteel.

http://science.howstuffworks.com/designer-children3.htm

http://www.nexiabiotech.com

Terraforming Mars

- Mostly envision Mars for terraforming.
- Comparison:

Mars:		Earth:	
– 95.3%	carbon dioxide	– 78.1%	nitrogen
– 2.7%	nitrogen	– 20.9%	oxygen
– 1.6%	argon	– 0.1%	carbon dioxide + trace
– 0.2%	oxygen		

- Why terraform?
  - In 1-2 x 10^9 yrs, Earth will get hot.
  - Other economical possibilities.
- What are the essential ingredients?
  - Water, Oxygen, and Ozone.
- The bacteria that can build up oxygen need the water.