

Interplanetary communications

Jump to: navigation, search

Contents

- 1 Laser communication
- 2 Deep space network
- 3 Starlink
- 4 Future Mars settlement
- 5 See also
- 6 References

Laser communication

Interplanetary communications are limited by two basic theoretical factors:

$$\theta = \frac{\lambda}{\pi w}, \text{ (Beam divergence (https://en.wikipedia.org/wiki/Beam_divergence))}$$

and

$$C = B \log_2 \left(1 + \frac{S}{N} \right) \text{ (The Shannon Hartley theorem (https://en.wikipedia.org/wiki/Shannon\%E2\%80\%93Hartley_theorem))}$$

The first dictates how large a beam spreads over space, in this case λ is the wavelength (https://en.wikipedia.org/wiki/Wavelength), which is on the order of centimeters for radio waves and nanometers for laser communications.

The second is the bandwidth, with $\frac{S}{N}$ being the signal to noise ratio, or how much energy from the transmitter the receiver picks up compared to energy from background noise.

As such very high frequency communications (such as UV lasers) that can be easily distinguished from background radiation (such as lasers through a Monochromatic filter (https://en.wikipedia.org/wiki/Monochromatic_filter)) will allow for significantly higher bandwidth than standard radio wave based communication. A drawback is that the laser link is point to point, and requires relative physical positioning to be maintained as both sender and receiver move throughout their orbits. Another drawback for using lasers for Martian communication is that the sun is both opaque and very bright. This then means that a relay station must be placed elsewhere, such as at L4/L5 (https://en.wikipedia.org/wiki/Lagrangian_point) in order to ensure that Earth/Mars communications are uninterrupted. Ultra long range laser communication technology is also currently unproven (https://www.nasa.gov/directorates/heo/scan/engineering/technology/txt_accordion1.html) compared to radio communications, and so needs to be tested in space. These tests are currently planned through NASA's Space Optical Communications (https://en.wikipedia.org/wiki/Deep_Space_Optical_Communications%7CDeep) network and commercially through the laser intersatellite communications grid planned in the Starlink constellation^[1].

Deep space network

Interplanetary communications between the Earth and Mars will be required for a Martian settlement.

As of 2019, The Deep Space Network (DSN) provides the infrastructure for interplanetary communication between the Earth and Mars. The network is composed of Antennas on Earth, orbiters in Mars orbit and landers and rovers on the surface (plus all the other vehicles in space under the supervision of NASA). For example, the Curiosity Rover can communicate with the Mars Reconnaissance Orbiter at a rate of up to 2 million bits per second (Mbps), or directly to the DSN at a rate of 500 to 32 000 bps depending on conditions.

The Mars reconnaissance Orbiter can communicate with the DSN at a rate of 6 Mbps using 32 GHz on the K_a band. The amplifier required for the K_a band has 35 W of power. However, this capacity is not used and the spacecraft rather uses a 100 W amplifier in the K band at 8 GHz and about 2 Mbps^[2].

In the future, the communication requirements will grow tremendously and the DSN will need to be upgraded or replaced.

Starlink

SpaceX is planning on using Starlink as an interplanetary communication system, possibly by using the ion drives of the satellites to move them to Mars, or by sending a large contingent using Starship. Starlink satellites might also coordinate their actions to serve as a large receiver for Martian transmissions. Starlink satellites are provided with laser communications between the satellites of the network.

Future Mars settlement

A single typical compressed HDTV (1920 x 1080) signal may require 40 Mbps. The 2017 Viasat-2 geostationary communication satellite can handle data rates up to 300 Gbps, or practically ten thousand HDTV signals. A similar satellite in Martian areostationary orbit, with larger solar panels to take into account the reduced solar power available at Mars, could probably satisfy the communication requirements for a while. The solar array on the Viasat 2 has a power of 18 kW and the Viasat 2 masses 6418 kg.

The Interplanetary Internet could be used over the Mars settlement communication link to help synchronize the content of Earth's Internet with a reduced subset of the Internet on Mars. A large number of problems with software and communication systems would need to be solved, as most interactive software cannot handle the long communication delays between Earth and Mars.

So the Interplanetary Internet would need to be supported on Mars by an Information infrastructure and local Communication systems to create an Internet on Mars. This would include local servers, large memory stores and wireless as well as optical fibers and wire based communication systems.

Resources such as Wikipedia, movie databases and numerous information data bases could be copied to Mars servers. These servers would also serve to gather information for the many Mars projects going on at the same time, and feed the Interplanetary communication network with information to return to Earth.

A base communication tower at the martian settlement would be able to communicate with the areostationary satellite, that would communicate back to Earth. It might be helpful to use the capacity of the Mars Transportation System to set up a dedicated geostationary satellite, that could serve as a relay to Earth based stations. To complete the system, a relay satellite would be required in a Mars or Earth leading orbit to transmit between the planets when the direct line of sight is blocked by the Sun.

See also

Laser communications

Laser communication systems

References

1. <https://en.wikipedia.org/wiki/Starlink>
2. MRO on Wikipedia
https://en.wikipedia.org/wiki/Mars_Reconnaissance_Orbiter#Telecommunications_system

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