Communication and coverage analysis for a network of small satellites around Mars

Alessandra Babuscia (332H), Kar-Ming Cheung (332H), Charles Lee (332H), Thomas Choi (332H)
(Jet Propulsion Laboratory, California Institute of Technology)

Project Motivation

- COST and SCHEDULE: Small satellites and CubeSats can be designed and fabricated with considerable cost and time savings with respect to larger and more complex spacecraft.
- SCALABILITY: Multiple replica of the same small satellite or CubeSat can be used to design satellite constellations to support the exploration of different targets in the solar system, especially Mars.
- MARS EXPLORATION: The landing of the Mars Science Laboratory in 2013 and the current proposed Mars 2020 show that Mars is a target of great interest in the exploration of the solar system and that it will be likely explored by an increasing number of landers and rovers in the future.
- AUGMENT CURRENT MARS DATA RELAY: A network of satellites to facilitate data relay for mobile and fixed assets on the Mars surface is of paramount importance and the current satellites orbiting the planet are becoming old and exposed to potential failures.
- EMERGENCY COMMUNICATION AND TELEMETRY: A network of small satellites can provide “multiple access points/low data rate services” which can be useful for emergency communication.

Objectives

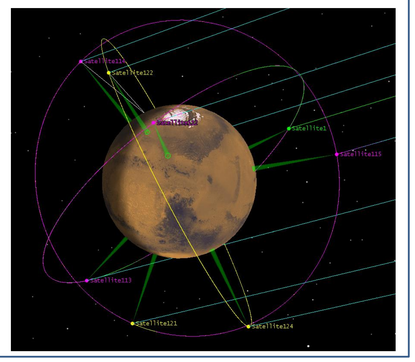
Develop a simulated study for a network of small satellites orbiting Mars to use as satellite relays for future Mars exploration

1. Identify suitable orbits and perform coverage analysis
2. Identify bandwidths and hardware components compatible with CubeSat technology
3. Develop link analysis study

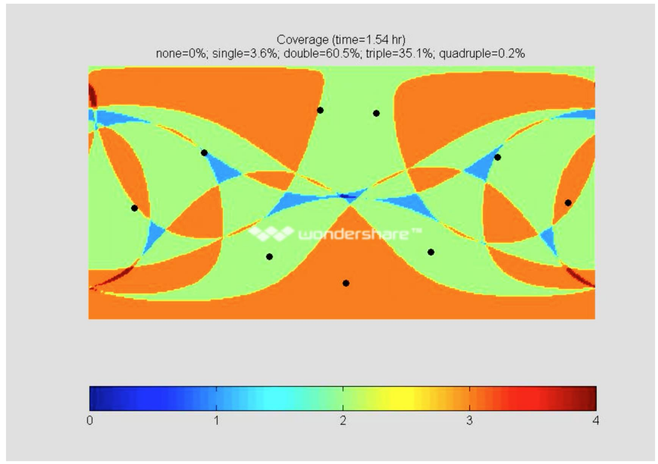
Selected Orbit

The simulation includes 9 satellites placed on high altitude polar orbits to maximize solar power collection and coverage.
Orbital parameters:

- H=3600 Km
- i=115.7
- RAAN=[0 120 240]
- W=[0 120 240; 40 160 280; 80 200 320]



Coverage Analysis

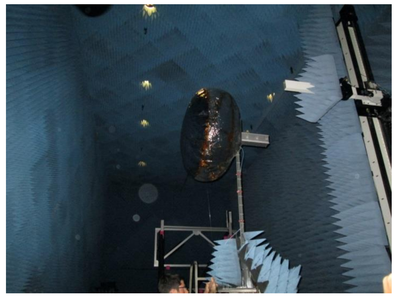


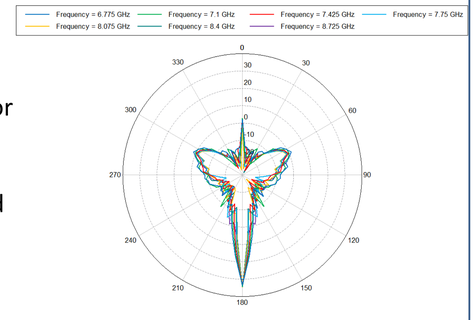
The coverage analysis show that for most of the Mars surface the constellation would guarantee the simultaneous coverage of at least 2 satellites.

Bandwidth and Components

- 2 telecommunication bandwidth are considered: UHF and X-Band
- The UHF link can be implemented for the proximity link:
  - UHF antenna: monopole or dipole
  - UHF transceiver: commercially available
- The X-Band link is considered for the mars-to-Earth link. It requires a certain EIRP to be closed with respect to the Earth Station. The solution is the following:
  - X-Band amplifier: 10 W power
  - X-Band antenna: inflatable or deployable (currently the inflatable antenna design is being extended from S-Band to X-Band)

  The rest of the spacecraft can be designed using available COTS components





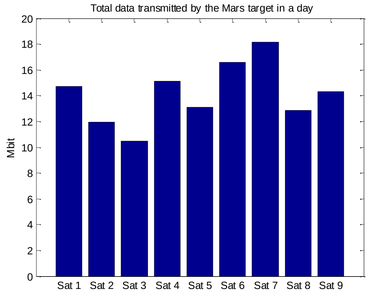
Link Analysis and Network Capacity

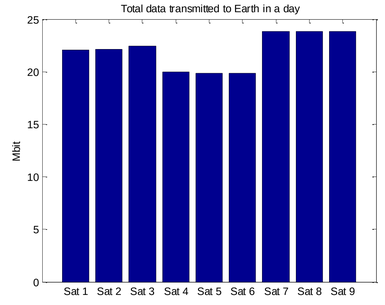
Link Analysis assumptions:

- On board: inflatable antenna +10 W amplifier
- On ground: 70 m DSN (or 34 m with 2 m inflatable antenna)
- LDPC coding
- Worst and best case scenario computed with respect to propagation path

Item	Units	Downlink Worst Case	Downlink Best Case	Uplink Worst Case	Uplink Best Case
Transmitter Power	dBW	10.00	10.00	17.00	24.00
Line Loss/Waveguide Loss	dB	-0.50	-0.50	-0.70	-0.50
Transmit Antenna Gain (net)	dBi	30.00	30.00	72.41	72.40
Equiv. Isotropic Radiated Power	dBW	39.50	39.50	88.71	95.90
Frequency	GHz	8.40	8.40	7.10	7.10
Receive Antenna Gain	dBi	73.87	73.86	30.00	30.00
Propagation Path Length	km	400,000,000.00	200,000,000.00	400,000,000.00	200,000,000.00
Total Additional Pointing and Atm. Losses	dB	-2.10	-2.10	-2.10	-2.10
Data Rate	bps	7,000.00	25,000.00	2,500.00	50,000.00
System Noise Temperature	K	25.58	25.58	340.00	340.00
E_b/N_o	dB	4.36	4.84	4.40	4.60
E_b/N_o required	dB	1.80	1.80	1.80	1.80
Margin	**dB**	**2.56**	**3.04**	**2.60**	**2.80**

The capacity analysis for the network shows that a total capacity of 128 Mbit of data per day can be reached between a target on the Mars surface and the satellite network. A relay capacity of 200 Mbit per day can be achieved between the satellite network and the DSN stations. Single satellite capacities for both the links are shown in the bar plots.





Future Work

Future research will focus on the design of the 6U spacecraft and on analyzing and solving eventual compatibility issues between DSN and the CubeSat hardware.

Acknowledgment

Part of this work was performed at the Jet Propulsion Laboratory, California Institute of Technology, under a contract with the National Aeronautics and Space Administration.