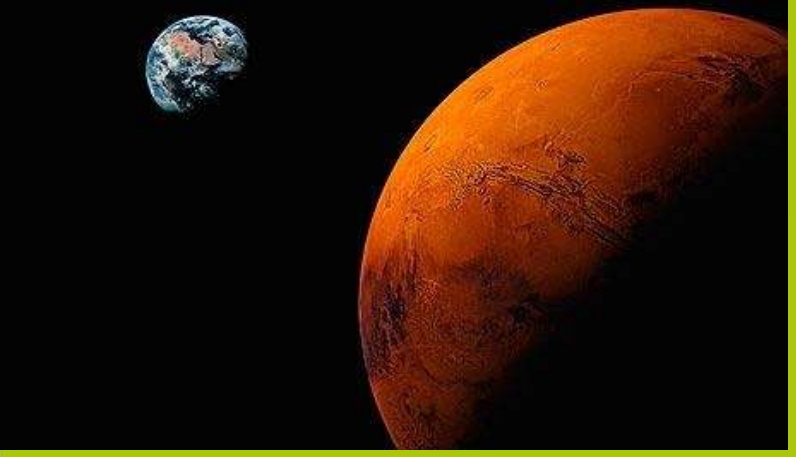
5TH IAA CONFERENCE ON UNIVERSITY SATELLITE MISSIONS AND CUBESAT WORKSHOP



Interplanetary Communication Architecture for Future Human Settlements

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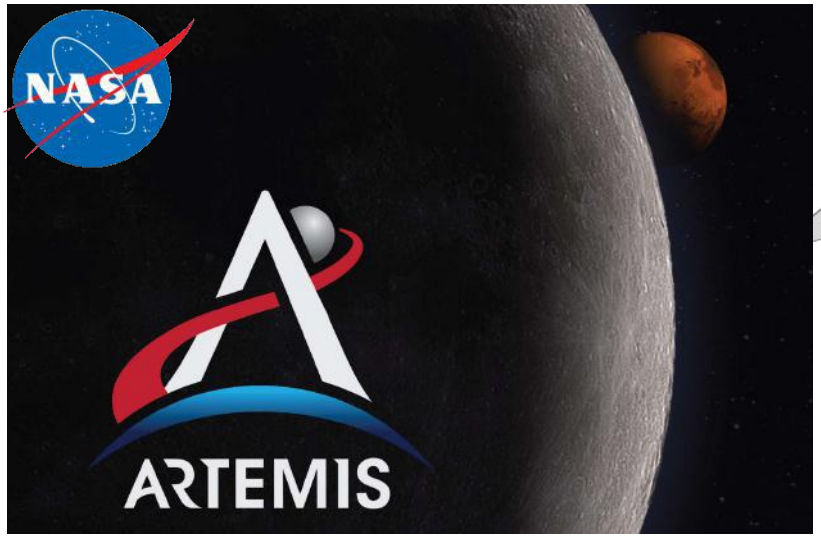
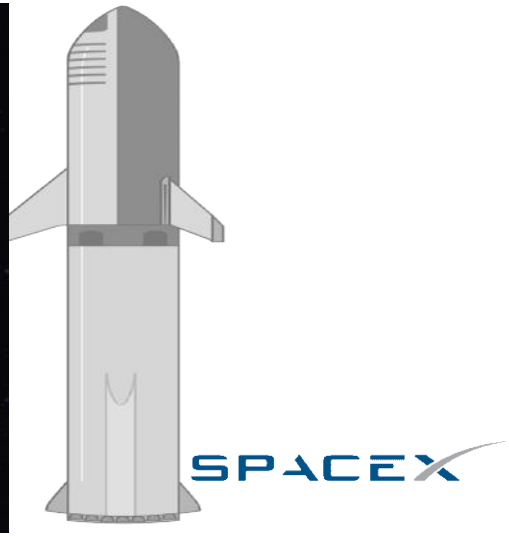
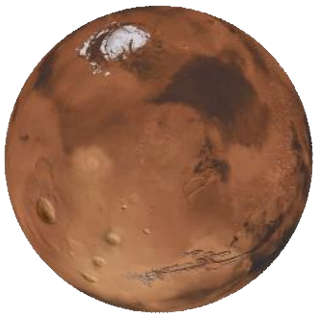
NASA=>ARTEMIS=>MARS (2030)





National Aeronautics and Space Administration (NASA) is in its final stage to kick off the Artemis Mission. With this, it aims to put the 'Next Man and First Woman' on the Lunar soil by 2024. With its Deep Space Transport (DST), it aims at long term stay on Lunar & Martian soil. Challenge? Communication for interplanetary human settlements.



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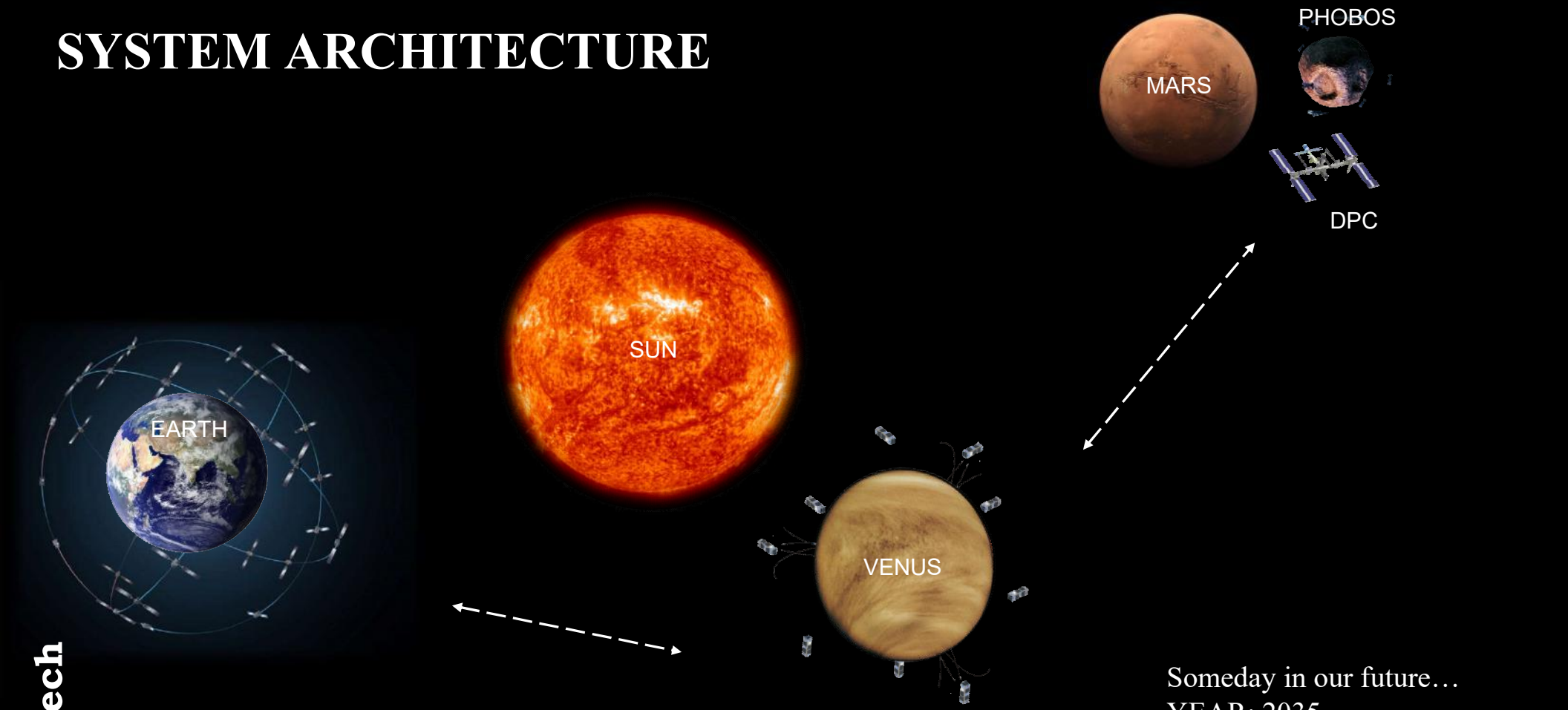
REQUIREMENTS

1. The size and rate of data transfer
2. The active and passive data transmission time to Earth (Email vs Post!)
3. Efficiency and power limitation of the entire communication set up
4. Data transmission and link budget
5. Traffic management and Space Weather Monitoring (SpWM)

SYSTEM ARCHITECTURE



Someday in our future…
YEAR: 2035
Data Rate: 512Kbps
Link: Earth-Venus-Mars

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OPERATION

Earth-Moon-Mars expressway

- The floating Data Processing Center (DPC) around Mars will provide uninterrupted communication to colonies
- Local data management: Communication and Traffic management, Space Weather etc.
- Docking facility for Space Taxis

Ground Station: Earth

- Deep Space Network (DSN)
- Frequency: S-band (2110-2115 MHz)
- Earth relay constellation of CubeSats in LEO
- Link: Earth - Venus Constellation - DPC, utilization of Inter-Satellite Link (ISL)

SmallSat Constellation: Venus

- Primary: To relay communication signal from Earth to Mars (& conversely)
- Secondary: Remote sensing and monitoring volcanic activities
- Constellation: 24 satellites, >250km altitude from the surface

LINK BUDGET

Using Constellation

Link	Distance, million km	Transmitter power, kW	Rx antenna gain, dBi	Tx antenna gain, dBi	Link margin, dB
Earth-Venus	235	400	40	70	7.1
Venus-Mars	228	150	70	40	3.6
Mars-Venus	228	200	40	70	9.8
Venus-Earth	235	150	70	40	3.2

Direct LOS

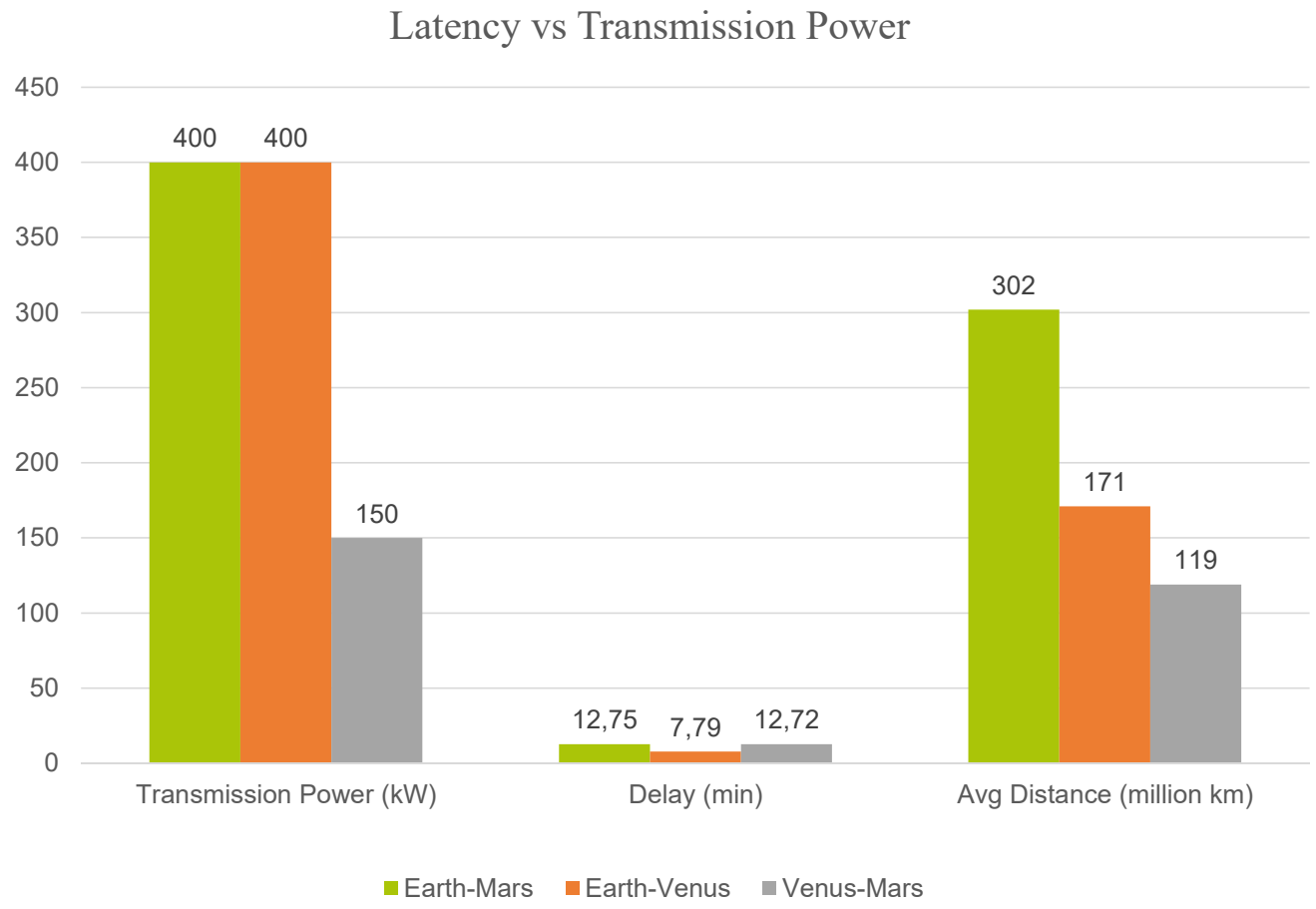
Link	Distance, million km	Transmitter power, kW	Rx antenna gain, dBi	Tx antenna gain, dBi	Link margin, dB
Earth-Mars	360	400	70	70	33.4
Mars-Earth	360	200	70	70	30.9

LATENCY

Date	Time Delay (in min)	Earth-Venus (million km)	Description
01.08.2030	2.212	39.802	**Min** Earth-Venus Distance
13.08.2030	13.37	240.670	**Max** Earth-Venus Distance

Date	Time Delay (in min)	Earth-Mars (million km)	Description
01.08.2030	4.643	83.529	**Min** Earth-Mars Distance
05.05.2031	20.93	376.607	**Max** Earth-Mars Distance

RESULTS AND DISCUSSION



- Delay between Earth-Mars communication decreases by introducing a **Venus constellation** (marginally)
- **Venus Constellation** is utilized as an additional **power source**(and much higher than Mars), as it is closer to Sun
- **Venus Constellation** is necessary for minimum **5 months** a year when Mars is far/out of sight.

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CHALLENGES

1. TWO MONTHS per TWO YEARS, both Venus & Mars are in conjunction: No communication can be realized.
2. Determine and quantify the active and passive data transmission
3. Register the inbound and outbound space vehicles.

FUTURE WORK

1. A constellation of SmallSat around the Sun can serve dual purpose: uninterrupted communication and Solar Weather Monitoring (SoWM)
2. Revisit frequency bands for periodic efficiency
3. Increase data transmission rate

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[7] The Sky [*last visited: 23rd Jan 2020*].
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Appendix 1

Date	Earth-Venus (distance in million km)	Earth-Mars (distance in million km)	Description
2025.01.01	112.458	98.292	Start point
2025.03.23	41.978	157.612	Earth-Venus min distance
2025.10.15	233.509	356.799	Venus relays to shorten the path, Earth sees Mars though
2025.11.05	243.422	360.943	Earth can't see Venus and connects directly to Mars
2025.11.23	249.564	362.465	When Venus can't help and we can't connect to Mars
2026.02.18	251.042	352.585	When Venus can't help but we start the connection with Mars
2026.04.01	234.78	343.365	Venus starts to help as no connection happens with Mars
2026.06.01	188.031	326.783	Earth sees Mars while Venus can't
2027.11.12	226.280	329.230	Venus starts the relay as Earth get farther from Mars
2028.04.01	95.186	358.445	Venus was relaying until Earth and Venus can't see Mars

Appendix 1(continued)

2028.06.01	43.155	360.060	Earth establishes a connection with Mars while Venus can't help
2028.07.01	60.014	355.314	Venus starts to relay to shorten the path, Earth also sees Mars
2028.11.01	192.229	268.443	Earth connects Mars as Venus gets farther, no need to Venus
2029.09.10	153.680	238.997	Venus starts the relay to shorten the path, Earth sees Mars

Minimum/Maximum Distances

Earth-Venus (distance in million km)	Venus-Mars (distance in million km)	Earth-Mars (distance in million km)	Description
39.802			**Min** Earth-Venus
240.670			**Max** Earth-Venus
		83.529	**Min** Earth-Mars
		376.607	**Max** Earth-Mars
255.209	354.621	99.412	**Max** Venus-Mars
68.797	103.129	76.828	**Min** Venus-Mars

Thank You
Q&A

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