DAILY REPEAT-GROUNDTRACK MARS ORBITS

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EXTENDED ABSTRACT

Introduction

The G. Marconi Orbiter (GMO), the first Mars orbiter optimized for relay performance rather than for science, will be placed into an orbit specifically designed to facilitate relay support to in-situ Mars probes. Relay users, such as rovers or small landers on the surface of Mars, desire relay contacts at the same times every day so that they can design their missions and their operations based on invariant communications patterns. Daily repeat-groundtrack orbits thus appear well suited to GMO.

This paper characterizes 42 Mars orbits with ground tracks that repeat every sol (Mars day). These orbits are divided into five orbit classes:

- 14 circular equatorial prograde orbits
- 14 circular equatorial retrograde orbits
- 11 circular sun synchronous orbits
- 2 eccentric equatorial orbits
- 1 eccentric critically inclined orbit

This paper compares the relay performance of some of these orbits based on coverage area, connectivity and data volume.

Orbit Identification Process

All orbits with daily repeating ground traces have the following characteristics:

1) The orbit period must be a subperiod of the planet rotation period relative to the sun.
2) If the orbit is not equatorial, the orbit plane must stay stationary with respect to the sun – i.e. the orbit must be sun synchronous.
3) If the orbit is eccentric, the line of apsides must stay stationary with respect to both the sun and to the equatorial plane of Mars.

Define Q, the Trace Repetition Parameter, to be the planet rotation period relative to the sun divided by the orbit period. Q must be an integer for an orbit to have a daily repeating ground trace.

Circular Orbits

To identify all circular Martian orbits with daily repeating ground traces, we first find all circular Martian orbits for which Q is an integer – see Table 1.

Table 1. Circular orbits at Mars with daily repeating ground tracks

Q	*Period, hours*	*Altitude, km*	*Sun Synchronous Inclination*
1	24.66	17061	–
2	12.33	9492	–
3	8.22	6440	–
4	6.16	4724	136.69°
5	4.93	3602	115.61°
6	4.11	2801	106.41°
7	3.52	2196	101.37°
8	3.08	1720	98.30°
9	2.74	1334	96.30°
10	2.47	1013	94.92°
11	2.24	742	93.94°
12	2.05	509	93.21°
13	1.90	306	92.67°
14	1.76	128	92.24°

Equatorial circular orbits at Mars with the periods and altitudes shown in Table 1 will have daily repeating ground tracks. There are two possible equatorial orbits for each value of Q: one prograde (0° inclination) and one retrograde (180° inclination). The equatorial circular prograde orbit with Q=1 is an areostationary orbit, akin to geostationary orbits on Earth – an orbiter in this orbit will always remain over approximately the same location on the equator of Mars.

For some values of Q, there is a sun synchronous inclination, i.e. an non-equatorial inclination at which the line of nodes rotates at the same rate as Mars rotates around the sun, resulting in an unchanging orientation of the orbit with respect to the sun and hence in daily repeating ground tracks. These inclinations are shown in the fourth column of Table 1.

Equatorial Eccentric Orbits

Table 2. Mars Elliptical Equatorial Orbits with Daily Repeating Ground Traces

Orbit Period, sols	½ sol	⅓ sol
Orbit Period *P*, hours	12.31 hours	8.21 hours
Semi Major Axis *a*	12,682 km	9,657 km
Eccentricity *e*	0.68	0.366
Inclination *i*	0°	0°
Periapsis Altitude h_{min}	661 km	2, 725 km
Apoapsis Altitude h_{max}	17,908 km	9,794 km

There are two equatorial eccentric orbits with integral values of Q in which the line of apsides rotates at the same rate as the rotation of Mars about the sun, resulting in daily repeating ground tracks. Table 2 characterizes both orbits.

Critically Inclined Eccentric Orbit

Table 3. Triply Synchronous Orbit Characteristics

Orbit period, sols	¼ sol
Orbit period *P*, hours	6.16 hours
Semi Major Axis *a*	8,163 km
Eccentricity *e*	0.462
Inclination *i*	116.565°
Periapsis Altitude h_{min}	913
Apoapsis Altitude h_{max}	8,456 km

At the critical inclination, i = 116.565° or 63.435°, there is no apsidal rotation with respect to the line of nodes. It is shown that there is a single critically inclined orbit with an integral Q for which the line of nodes rotates at the same rate as Mars rotates around the sun, resulting in a daily repeating ground trace. The orbit is characterized in Table 3.

Relay Performance

The paper compares the relay performance of GMO in several of the characterized orbits with the performance of relay radios on Mars science orbiters. Figure 1 compares the connectivity of various orbits:

Figure 1. Connectivity[1]

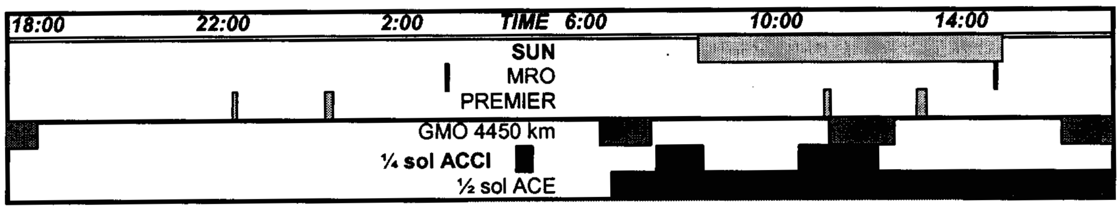

Figure 2. Data Volume[1]

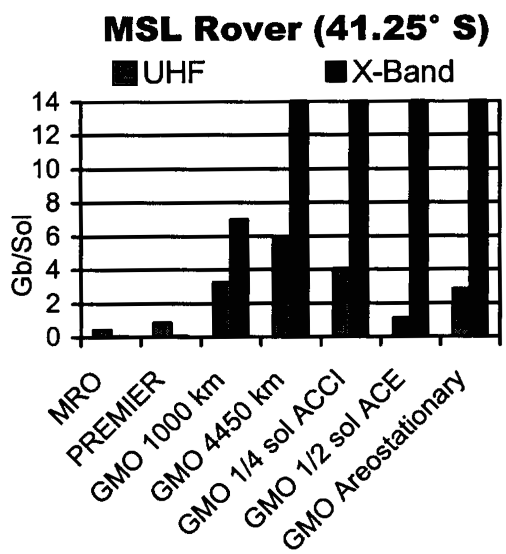

Figure 2 shows the data volume that could be relayed from the Mars Science Laboratory (MSL) rover through various orbiters.

Figure 3. Mean Pass Length of ½ Sol ACE Orbit

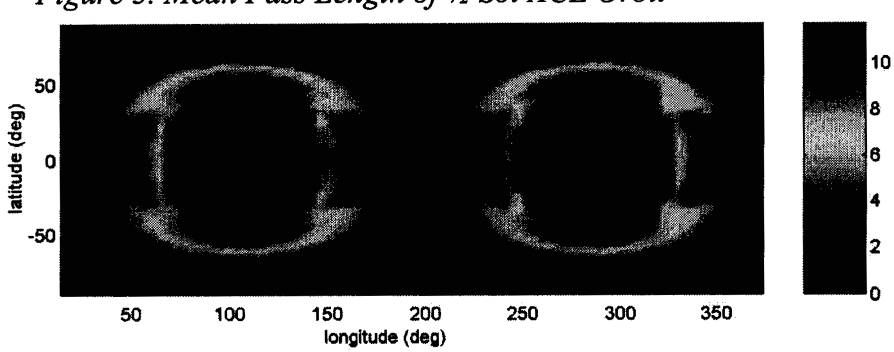

Figure 3 shows the amount of time in which an orbiter in the ½ sol orbit characterized in Table 2 would be in view of a lander each day.

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[1] MRO: NASA 2005 Mars Reconnaissance Orbiter; PREMIER: proposed 2007 CNES Mars orbiter; ¼ sol ACCI: the triply synchronous orbit characterized in Table 3; ½ sol ACE: the ½ sol orbit characterized in Table 2.

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SHORT ABSTRACT

The G. Marconi Orbiter (GMO) will be placed into a Mars orbit designed to optimize relay support to in-situ Mars probes. Relay users, such as rovers or small landers on the surface of Mars, would like GMO to be in a daily repeat-groundtrack orbit so that they can design their missions and their operations based on invariant contact times.

This paper identifies 42 Mars orbits with ground tracks that repeat every sol and compares the relay performance of some of these orbits based on coverage area, connectivity and data volume.