A series of periodic orbits in the Earth-Moon circular restricted problem of three bodies has been found which is ideally suited for exploring the Earth's geomagnetic tail. The mean apsidal motion of the basic highly elliptical Earth orbit is maintained at about one degree per day by a sequence of lunar swingbys, keeping the apogees in the anti-Sun direction. Hence, the orbits are periodic in reference frames rotating at both lunar and solar rates. Apogee distances are alternately raised and lowered by the lunar swingby maneuvers. Several categories of these “Sun-synchronous” double lunar swingby orbits are identified. The strength and flexibility of this new trajectory concept is demonstrated with real-world simulations. A large variety of trajectory shapes can be used to explore the Earth’s geomagnetic tail between 60 and 250 R_E. Some of these orbits will be shown in a movie. NASA plans to use this technique during its proposed four-spacecraft program called Origins of Plasmas in the Earth’s Neighborhood (OPEN). More details can be found in AIAA Paper 80-0112, “A New Trajectory Concept for Exploring the Earth’s Geomagnetic Tail.”
The following plots are a representative sample of the many existing types of these doubly-periodic orbits. The gravity model employed consisted of the Earth and Moon point masses, and the Moon's orbit was assumed to be circular. A patched-conic method was used for orbit computations. All trajectories are in the moon's orbital plane, and a projection of the Sun-Earth line is shown as a fixed reference. A classification scheme is used whereby each periodic orbit is specified by four numbers, \([A, B, C, D]\), where:

"A" is the approximate number of months between lunar swingbys in the inner segment.

"B" is the number of complete circuits (apogees) in the inner segment.

"C" is the approximate number of months between lunar swingbys in the outer segment.

"D" is the number of complete circuits (perigees) in the outer segment.

"D" equals zero with most orbits applicable to magnetospheric studies, so these are specified by only three numbers, \([A, B, C]\). For "D" larger than zero, the orbits become butterfly shaped, with the spacecraft spending most of its time far from the anti-Sun line outside the geomagnetic tail. For "C" greater than 3 and "D" equals zero, the outer loop extends well beyond the Sun-Earth \(L_2\) libration point, where strong solar perturbations make the restricted Earth-Moon model unrealistic.
DOUBLE LUNAR SWINGBY ORBIT - (1.1.1) CLASS

PERIGEE 5.9 RE
APOGEE-1 86 RE
APOGEE-2 141 RE

LUNAR ORBIT

EARTH

TO SUN

P

A1

A2

S1

S2

ONE DAY

L2

PERILUNE RADIUS AT LUNAR SWINGBYS 27,664 KM
DOUBLE LUNAR SWINGBY ORBIT - (1,1,2) CLASS

PERIGEE 5.4 RE
APOGEE-1 87 RE
APOGEE-2 205 RE

PERILUNE RADIUS AT LUNAR SWINGBYS 18,104 KM
DOUBLE LUNAR SWINGBY ORBIT - (1.1, 3) CLASS

PERIGEE 7.1 RE
APOGEE-1 82 RE
APOGEE-2 257 RE

PERILUNE RADIUS AT LUNAR SWINGBYS 15.766 KM

18-5
DOUBLE LUNAR SWINGBY ORBIT - (2.3.1) CLASS

PERIGEE 6.0 RE
APOGEE-1 75 RE
APOGEE-2 141 RE

PERILUNE RADIUS AT LUNAR SWINGBYS 19,936 KM
DOUBLE LUNAR SWINGBY ORBIT - (2.4.2) CLASS

PERIGEE 1.0 RE
APOGEE-1 67 RE
APOGEE-2 205 RE

PERILUNE RADIUS AT LUNAR SWINGBYS 7.831 KM
DOUBLE LUNAR SWINGBY ORBIT - (3.4.3) CLASS

PERIGEE 16.2 RE
APOGEE-1 72 RE
APOGEE-2 249 RE

LUNAR ORBIT

TO SUN

EARTH

A1

S1

A2

L2

ONE DAY

PERILUNE RADIUS AT LUNAR SWINGBYS 19.712 KM
DOUBLE LUNAR SWINGBY ORBIT - (3.5.1) CLASS

PERIGEE 8.5 RE
APOGEE-1 70 RE
APOGEE-2 139 RE

PERILUNE RADIUS AT LUNAR SWINGBYS 19.489 KM
DOUBLE LUNAR SWINGBY ORBIT - (3.6.2) CLASS

PERIGEE 3.9 RE
APOGEE-1 66 RE
APOGEE-2 202 RE

LUNAR ORBIT

TO SUN

EARTH

ONE DAY

PERILUNE RADIUS AT LUNAR SWINGBYS 9.536 KM
DOUBLE LUNAR SWINGBY ORBIT - (3.7.3) CLASS

PERIGEE 2.0 RE
APOGEE-1 61 RE
APOGEE-2 256 RE

LUNAR ORBIT
TO
SUN
EARTH

S1

ONE DAY

PERILUNE RADIUS AT LUNAR SWINGBYS 4.795 KM
DOUBLE LUNAR SWINGBY ORBIT - (4.9.2) CLASS

PERIGEE 4.1 RE
APOGEE-1 62 RE
APOGEE-2 200 RE

LUNAR ORBIT
S2

TO SUN P

EARTH

A1

S1

ONE DAY

L2

A2

PERILUNE RADIUS AT LUNAR SWINGBYS 6.944 KM
DOUBLE LUNAR SWINGBY ORBIT - (5.10.3) CLASS

PERIGEE 9.9 RE
APOGEE-1 62 RE
APOGEE-2 248 RE

LUNAR ORBIT

TO SUN

EARTH

S1

S2

A1

A2

L2

ONE DAY

PERILUNE RADIUS AT LUNAR SWINGBYS 7.924 KM
DOUBLE LUNAR SWINGBY ORBIT - (1.1.3.1) CLASS

PERIGEE-1 11.4 RE
PERIGEE-2 33 RE
APOGEE-1 73 RE
APOGEE-2 148 RE

PERILUNE RADIUS AT LUNAR SWINGBYS 24.116 KM
DOUBLE LUNAR SWINGBY ORBIT - (1.1.4.2) CLASS

PERIGEE-1 14.9 RE
PERIGEE-2 41 RE
APOGEE-1 66 RE
APOGEE-2 123 RE

PERILUNE RADIUS AT LUNAR SWINGBYS 27.354 KM
DOUBLE LUNAR SWINGBY ORBIT - (2.4.2.1) CLASS

PERIGEE-1  4.4 RE
PERIGEE-2   27 RE
APOGEE-1    62 RE
APOGEE-2    118 RE

LUNAR ORBIT

TO SUN

EARTH

P1  S1

P2  S2

A1  A2

L2

ONE DAY

PERILUNE RADIUS AT LUNAR SWINGBYS 11.448 KM
DOUBLE LUNAR SWINGBY ORBIT - (3.6.2.1) CLASS

PERIGEE-1 7.8 RE
PERIGEE-2 35 RE
APOGEE-1 61 RE
APOGEE-2 113 RE

PERILUNE RADIUS AT LUNAR SWINGBYS 12.578 KM