

Mutual Visibility Between Two Earth Satellites

This *Numerit* program (`sat2sat`) can be used to determine mutual visibility between two satellites in circular or elliptical Earth orbits. The software uses a combination of one-dimensional minimization and root-finding to calculate mutual visibility conditions.

The objective function for this numerical method is given by

$$f(t) = -\mathbf{r}_1 \bullet \mathbf{r}_2 + r_s - \sqrt{(r_1^2 - r_s^2)(r_2^2 - r_s^2)} \quad (1)$$

where

- \mathbf{r}_1 = ECI position vector of first satellite
- \mathbf{r}_2 = ECI position vector of second satellite
- r_1 = geocentric radius of first satellite
- r_2 = geocentric radius of second satellite
- r_s = local radius of the Earth = $1.02 r_{eq}$
- r_{eq} = Earth equatorial radius

Whenever this function is negative, mutual visibility exists. The beginning and end of mutual visibility occurs whenever this function is zero. Notice that the local radius r_s is increased by 2% to account for the Earth's atmosphere in the calculations. The orbits of both satellites are propagated using Kozai's method.

The software will prompt you for an initial calendar date and universal time. It will also ask you to input the classical orbital elements of each satellite. Finally, it will ask for a simulation duration in days.

The following is part of a typical draft output created with this program.

```
program sat2sat
< mutual visibility between two Earth satellites >

begin mutual visibility contact

calendar date          January 1, 1998
universal time         00 h 52 m 7.24363 s
Julian date            2450814.536

approach distance      14727.6235 kilometers

end mutual visibility contact

calendar date          January 1, 1998
universal time         3 h 3 m 10.3992 s
Julian date            2450814.627
```

Orbital Mechanics with Numerit

approach distance 14626.46573 kilometers

event duration 2 h 11 m 3.15558 s

begin mutual visibility contact

calendar date January 1, 1998
universal time 5 h 26 m 50.8011 s
Julian date 2450814.727

approach distance 14952.72737 kilometers

end mutual visibility contact

calendar date January 1, 1998
universal time 7 h 37 m 51.3776 s
Julian date 2450814.818

approach distance 14566.38204 kilometers

event duration 2 h 11 m 0.576595 s

begin mutual visibility contact

calendar date January 1, 1998
universal time 9 h 37 m 53.1929 s
Julian date 2450814.901

approach distance 14866.66216 kilometers

end mutual visibility contact

calendar date January 1, 1998
universal time 11 h 45 m 48.6632 s
Julian date 2450814.99

approach distance 14724.7847 kilometers

event duration 2 h 7 m 55.4703 s