

## Closest Approach Between Two Earth Satellites

This *Numerit* program (`ca2sats`) can be used to determine close approach conditions between two satellites in circular or elliptical Earth orbits. The user can enforce a minimum distance constraint during the computations. The software uses a combination of one-dimensional minimization and root-finding to calculate close approach conditions.

The objective function for this numerical method is given by

$$f(t) = \sqrt{|\mathbf{r}_1 - \mathbf{r}_2|^2} = \sqrt{(r_{1x} - r_{2x})^2 + (r_{1y} - r_{2y})^2 + (r_{1z} - r_{2z})^2} \quad (1)$$

where  $\mathbf{r}_1$  is the ECI position vector of the first satellite and  $\mathbf{r}_2$  is the ECI position vector of the second satellite.

During the root-finding process, the objective function is given by

$$f(t) = \sqrt{|\mathbf{r}_1 - \mathbf{r}_2|^2} - d_{\min} \quad (2)$$

where  $d_{\min}$  is the minimum separation distance constraint defined by the user. 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 and a simulation duration in days. Finally, it will ask if you would like to enforce a minimum separation distance constraint during the close approach search.

The following is part of a typical draft output created with this program. The minimum separation distance constraint for this example was 5000 kilometers.

```
program ca2sats

< closest approach between two Earth satellites >

time and conditions at constraint entry

calendar date           January 1, 1998
universal time          2 h 22 m 36.3454 s
Julian date             2450814.599

approach distance       4999.999102 kilometers

time and conditions at closest approach

calendar date           January 1, 1998
universal time          2 h 55 m 10.3973 s
Julian date             2450814.622

approach distance       2187.416951 kilometers
```

## *Orbital Mechanics with Numerit*

time and conditions at constraint exit

calendar date	January 1, 1998
universal time	3 h 35 m 10.3572 s
Julian date	2450814.649
approach distance	4999.999197 kilometers
event duration	1 h 12 m 34.0118 s

time and conditions at constraint entry

calendar date	January 1, 1998
universal time	9 h 23 m 51.0146 s
Julian date	2450814.892
approach distance	4999.999016 kilometers

time and conditions at closest approach

calendar date	January 1, 1998
universal time	9 h 50 m 22.7069 s
Julian date	2450814.91
approach distance	2529.849266 kilometers

time and conditions at constraint exit

calendar date	January 1, 1998
universal time	10 h 23 m 58.477 s
Julian date	2450814.933
approach distance	5000.00067 kilometers
event duration	1 h 00 m 7.46243 s