EROS – AUTOMATED SOFTWARE SYSTEM FOR EPHEMERIS CALCULATION AND ESTIMATION OF PROBABILITY DOMAIN

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Introduction

- In present time modern knowledge-intensive software is necessary in any fields of science. Automation in manufacture means reduce of expenses, automation in solving of science problems is extension of possibilities for researcher, simplification and acceleration of solving typical problems, possibility of realizing of global and difficult projects.
- Theoretically speaking the procedure of positional observations of Solar System asteroids can be divided on four stages. The first stage includes solving of prepared problems such as choice of objects for observation, calculation of ephemeris, observation program creation and others. The second stage is realizing of observations that is receiving of CCD-images of investigation objects with set calibrating frames. This stage demands software for telescope and CCD-array control.

On the third stage received frames are processed and output data in this case is equatorial spherical coordinate of investigating objects. The fourth stage is study of dynamical properties of asteroids,orbit elements improvement, orbital evolution investigation and some others. Each stage requires serious approach and appropriate tools.

This paper is devoted to creation of automated software that is intended for simplification of the first stage of asteroid positional observation to one button click. Certainly in our time there are numerous of different software that are aimed to solving ephemeris support problems. The MPC and NASA services are available for users. EPOS[1] and Ample[2] software are distributed in Russia. Main part of available application have friendly interface, are free or propagated on preferential terms but in most causes similar software demands user presence. Our target is creation of software that available to solve the problems in many causes by outself.

- [1] L'vov V.N., Tsekmeister S.D. The use of the EPOS software package for research of the solar system objects // Solar System Research. Vol. 46. Is. 2. P.177-179
- [2] V.A. Shor, Yu.A. Chernetenko, O.M. Kochetova, G.A. Netsvetaeva, E.Yu. Parijskaya, T.A. Vinogradova, N.B. Zheleznov. AMPLE – integrated multi-purpose software package for minor planets. Version 1.5 // Communications of the IAA RAS. – 2009. – No. 182

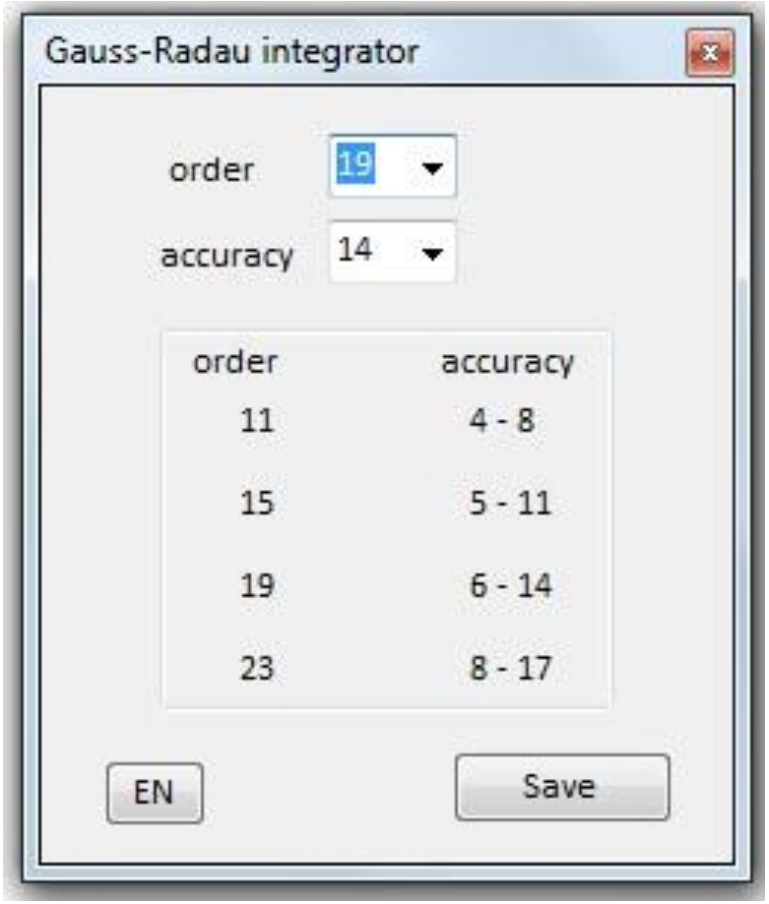
Ephemeris Researches and Observation Services

- According to our plans EROS will have following properties:

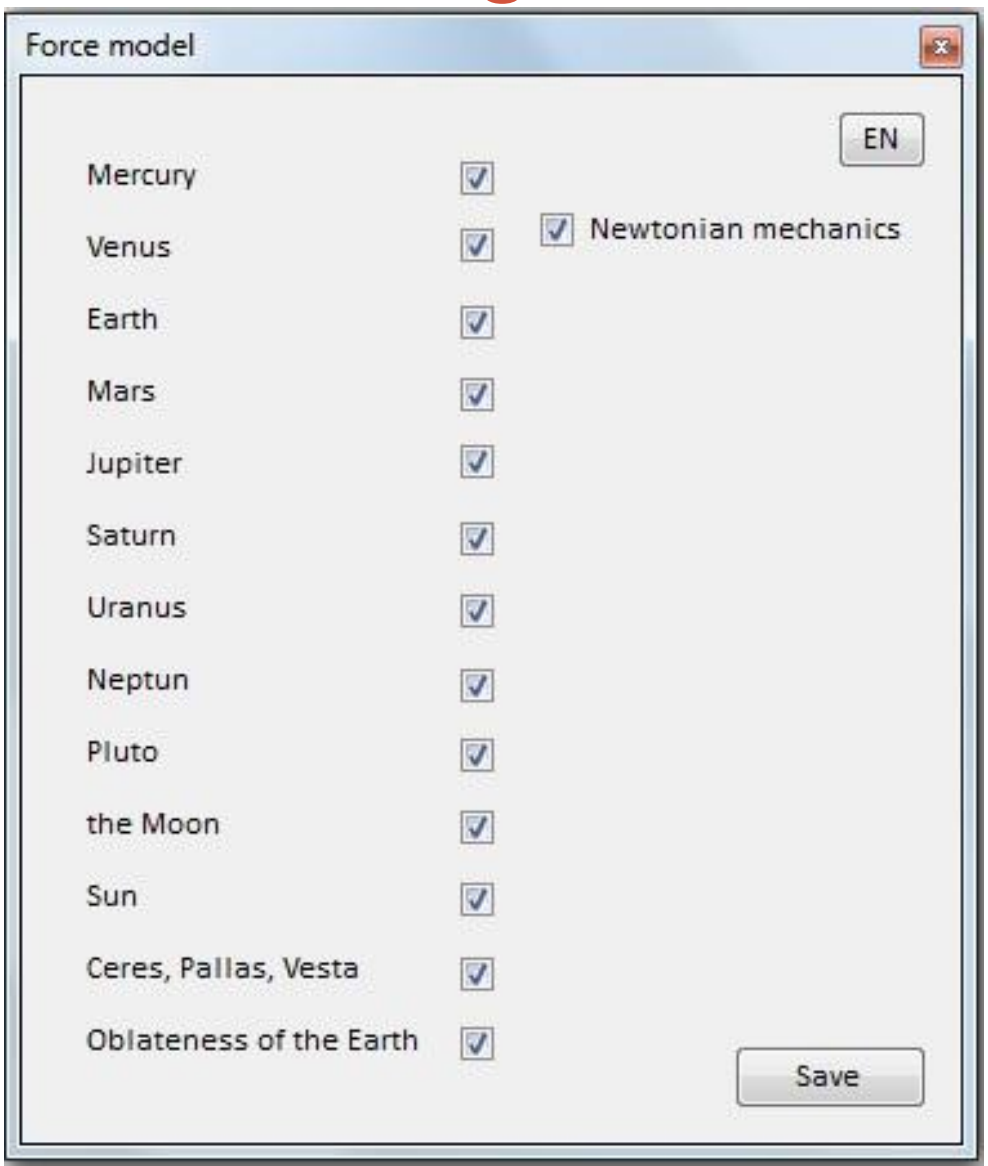
- Functional elements for realization of all preparing stages for positional observations (from objects choice to creation list of telescope instruction)
- Module structure that allows to group functional solution for other problems
- Possibility of users access to main stages of work
- System of intellectual settings which take into account user needs
- Full-automated calculation mode

Integrator and force model

- The Gauss-Everhart integrator (under 19 order) is used in EROS for solving of differential motion equations.
- The current perturbing accelerations set includes perturbations from planets, Pluto, the Moon, Ceres, Pallas, Vesta, the Earth and Sun oblateness and relativistic effects from Sun.



Integrator and force model



The setting system allows user to vary integrator parameters and perturbing acceleration set if it is necessary. In future we plan to add account of Jupiter oblateness and relativistic effects from Jupiter, to change the account of perturbing acceleration from main belt asteroids and some others.

Structure of EROS

- GUARD – calculation of night time
- HUNTER – object search
- SCOUT – definition of objects for observation
- NUMERATOR – ephemeris calculation
- APPRAISER – probability domain estimation
- NUMERATOR++ – review ephemeris calculation
- LIBRARIAN – operation with catalogs
- GERHARD – telescope instruction list creation

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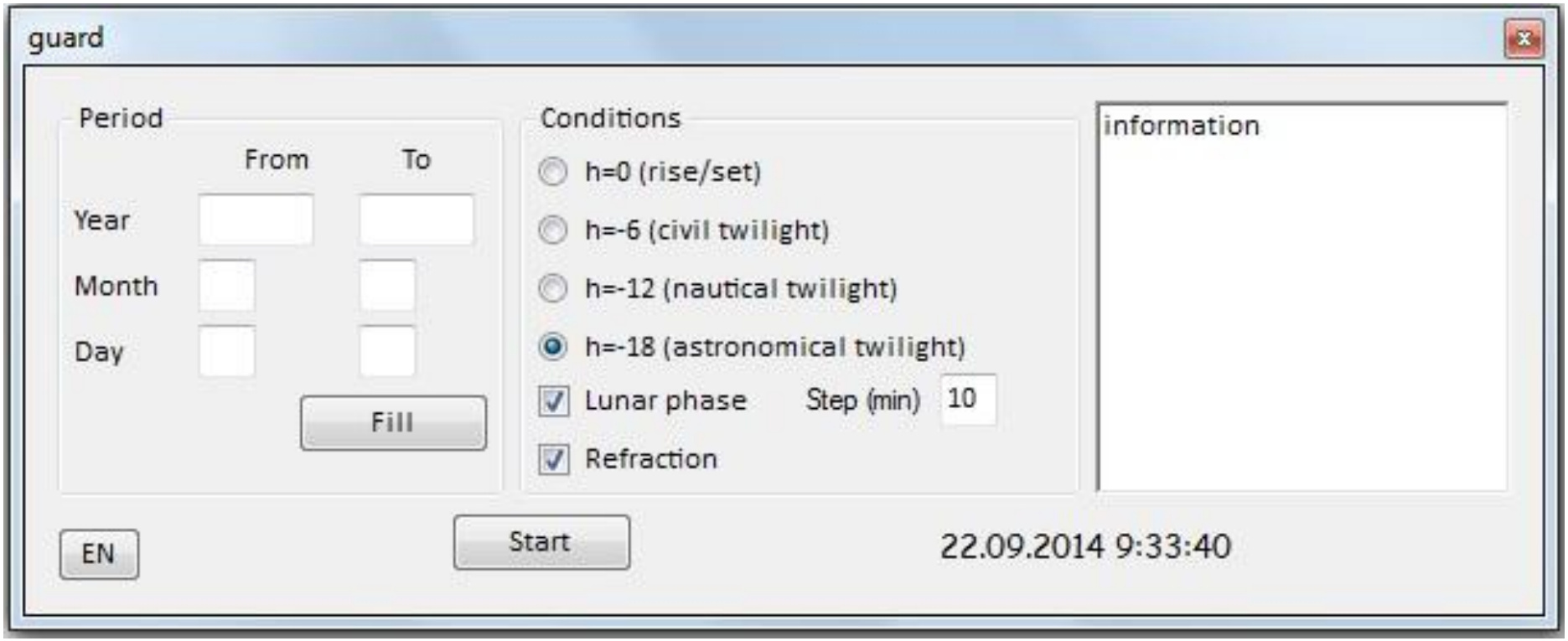
GUARD

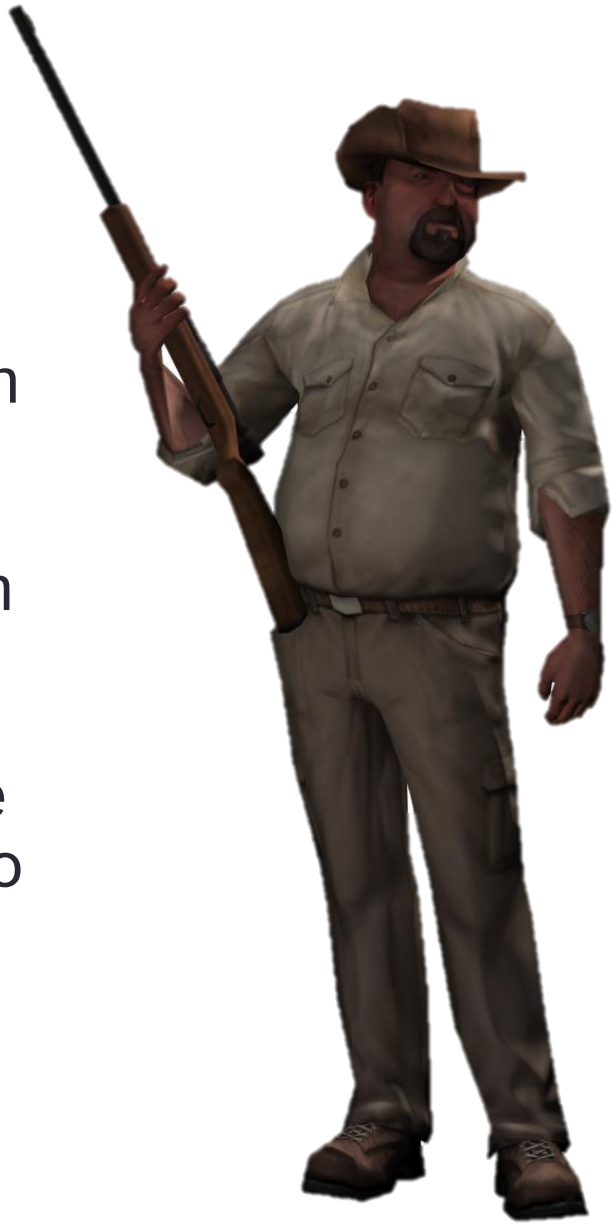
- This module is aimed to definition of observation time. It is necessary in order that time intervals are limited. Inside this time intervals ephemeris support problem is solved.
- The module asks to planet coordinate fond DE405 for receiving rectangular coordinates of the Earth in heliocentric coordinate frame. By means of coordinate transformations GUARD calculate the horizontal spherical coordinates of Sun for even place on the Earth surface.

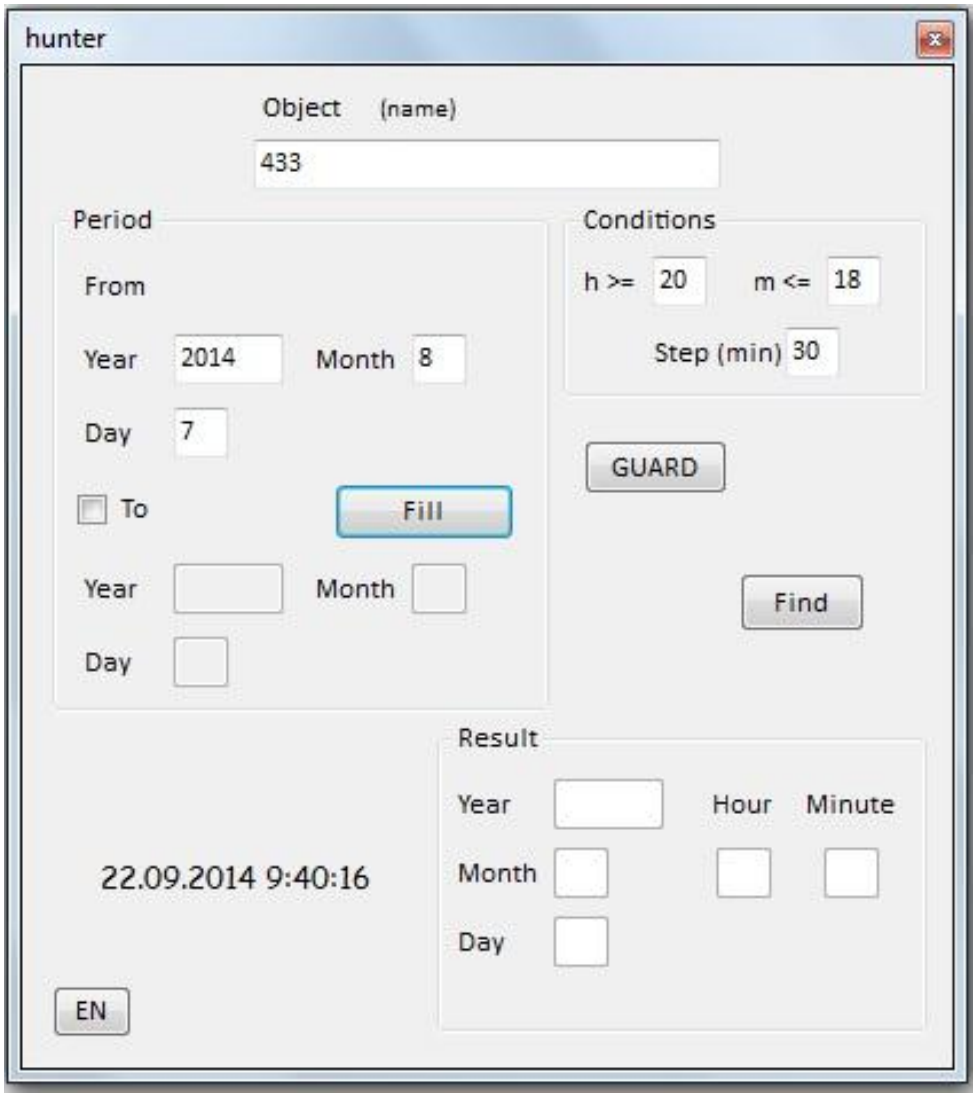


- The module have possibility of calculation for any number of nights. Output data of GUARD use by other modules of EROS.

HUNTER

- The module deals with search of objects which are interesting for user. For example, if for realization anything science project observation run of chosen object or objects group is necessary then HUNTER will define moment of investigating asteroid appearance for users observatory. The module asks to observatory's catalogue, to Bowell's catalogue for receiving initial coordinates of investigating objects, to DE405 and uses the output data of module GUARD

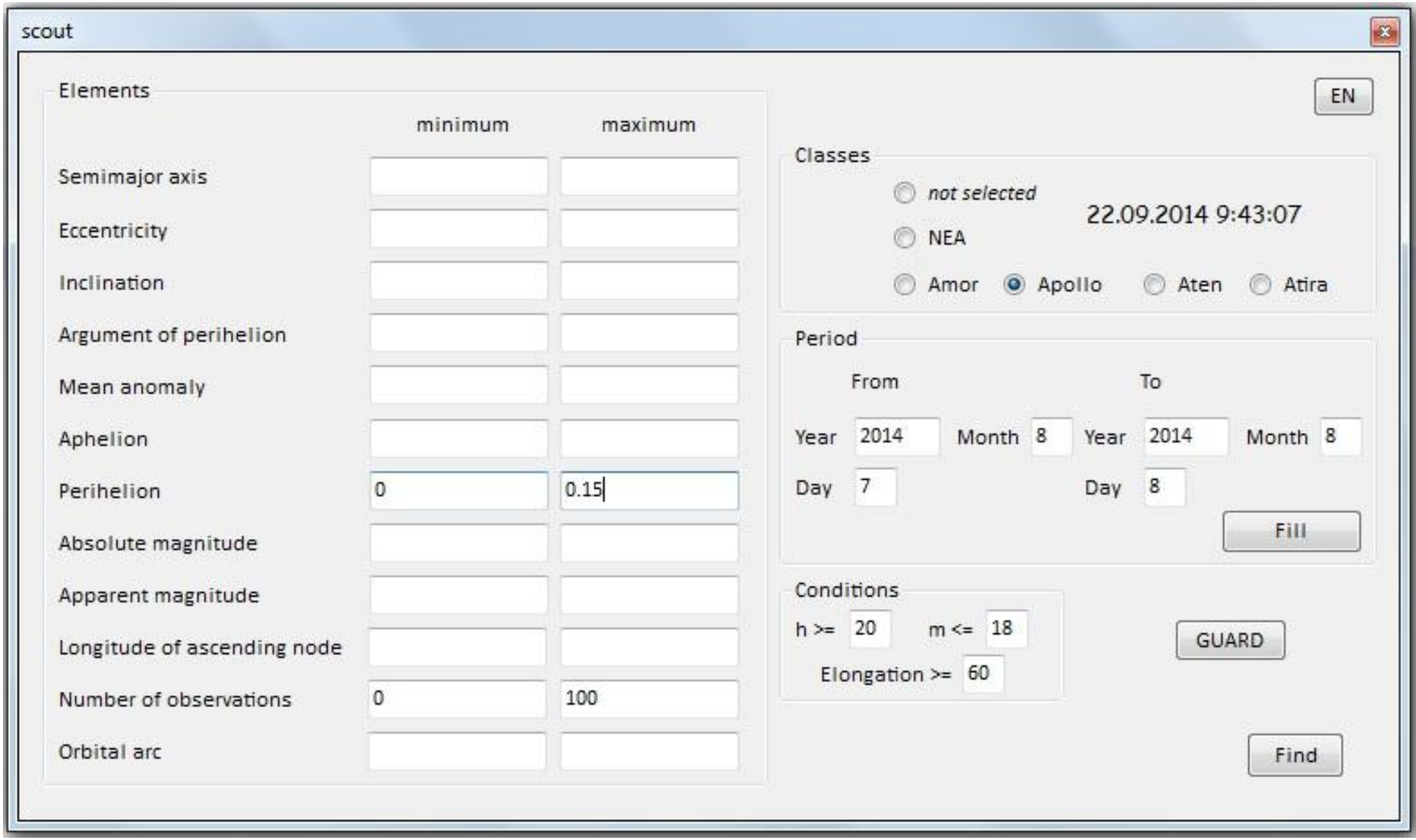




- User have opportunity to choose numbers or names of investigating objects, observatory's for which calculations are necessary, limits on appearance (extreme magnitude, height of culmination) and time interval into which search is necessary.

SCOUT

- SCOUT forms list of object which available for observations in given nights. The input data of SCOUT is similar input data of HUNTER, but its target is another. For HUNTER priority is object for observation and it find nights in which this object observation will be possible. For SCOUT priority is observation night and it defined which objects from even list is possible for observation in given night. User choose extreme magnitude and height of culmination.


scout
Elements
minimum
maximum
Semimajor axis
Eccentricity
Inclination
Argument of perihelion
Mean anomaly
Aphelion
Perihelion
0
0.15
Absolute magnitude
Apparent magnitude
Longitude of ascending node
Number of observations
0
100
Orbital arc
EN
Classes
not selected
NEA
22.09.2014 9:43:07
Amor
Apollo
Aten
Atira
Period
From
To
Year
2014
Month
8
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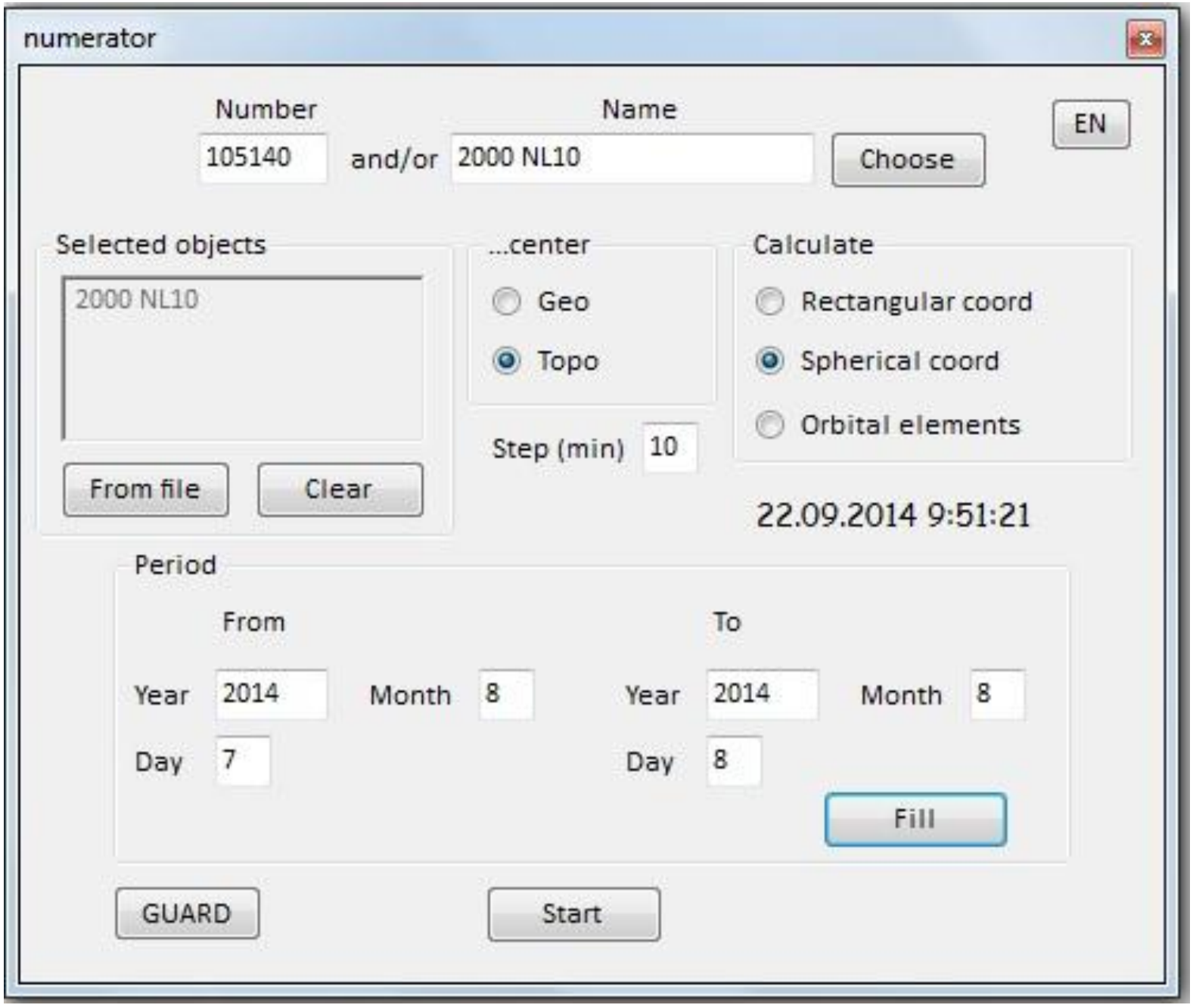
2014
Month
8
Day
7
Day
8
Fill
Conditions
h >=
20
m <=
18
Elongation >=
60
GUARD
Find

NUMERATOR

- NUMERATOR realizes asteroid ephemeris calculation. The merits of this module is possibility of calculation for object's group on observatory's group, varying force model, access to integrator parameters. There is possibility of calculation of geocentric ephemeris in the form of rectangular or spherical coordinates or orbit elements. Formats of input data is according to modules GUARD, HUNTER and SCOUT.


numerator
Number
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GUARD
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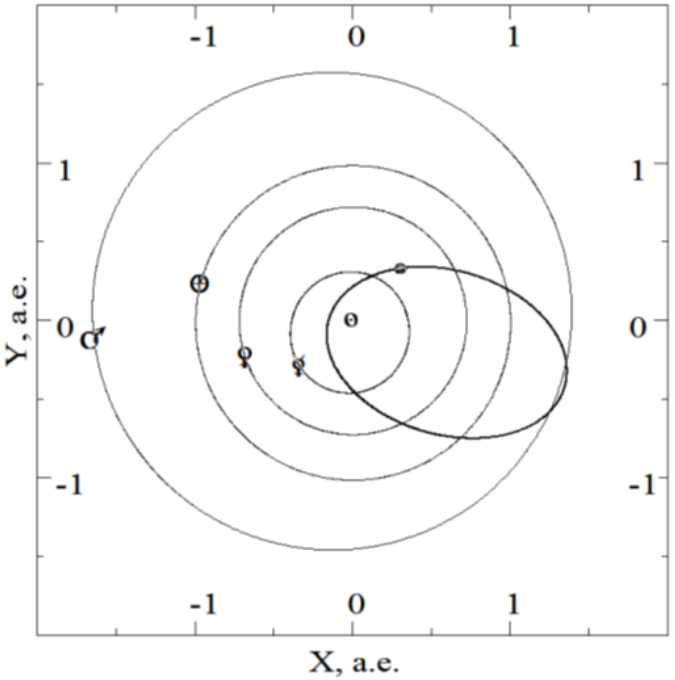


Parameter	Value
a, a.e.	0.91429483
e	0.81697482
i, deg	32.523736
Ω, deg	237.411993
ω, deg	281.575774
M, deg	93.442256
H	15.8

EROS and EPOS

T, h:min	α, h min sec	δ, deg min sec	m
17:00.0000	20 26 13.803	57 25 23.00	17.9
	20 26 13.577	57 25 22.98	17.9
17:30.0000	20 26 08.005	57 24 51.24	17.9
	20 26 07.779	57 24 51.21	17.9
18:00.0000	20 26 02.206	57 24 19.37	17.9
	20 26 01.980	57 24 19.34	17.9
18:30.0000	20 25 56.408	57 23 47.39	17.9
	20 25 56.183	57 23 47.36	17.9
19:00.0000	20 25 50.613	57 23 15.30	17.9
	20 25 50.387	57 23 15.26	17.9
19:30.0000	20 25 44.822	57 22 43.09	17.9
	20 25 44.596	57 22 43.05	17.9
20:00.0000	20 25 39.037	57 22 10.77	17.9
	20 25 38.811	57 22 10.73	17.9

APPRAISER

- Often observations are necessary for those objects that have small number of observations on short arcs. It is evident that accuracy of receiving ephemeris will be depend on accuracy of initial data. It is possible that uncertainly of asteroid ephemeris definition will be more then field of vision of telescope. In this case it is necessary to realize so called review observations. Probability algorithms are requested for ephemeris support. APPRAISER deals with estimations of sizes of investigating objects probability domain.

APPRAISER output data

Name	Data	Magnitude	Alpha	Domain	Delta	Domain
1987 SF3	2456921.3	17.2	19 43 1.5	0.220	-14 39 5.7	0.132
1987 WC	2456921.3	19.7	5 21 44.2	1.185	-76 56 15.1	3.530
1996 AW1	2456921.3	21.0	8 11 28.8	157765.520	13 29 30.7	58798.552
1995 FO	2456921.3	21.0	4 12 37.1	1382.288	12 42 39.5	3944.231
1985 WA	2456921.3	21.4	8 47 15.5	0.009	23 55 22.2	0.014

We see that for asteroid 1996 AW1 probability is may large. It is reason cause we cant use “classical” ephemeris for observation but it should calculate review ephemeris.

NUMERATOR++

- NUMERATOR++ is a twin of NUMERATOR which have possibility to calculate ephemeris of probability domain borders. The output data of the module contains ephemeris for review observations. NUMERATOR++ receives object's list and domain's sizes from APPRAISER.

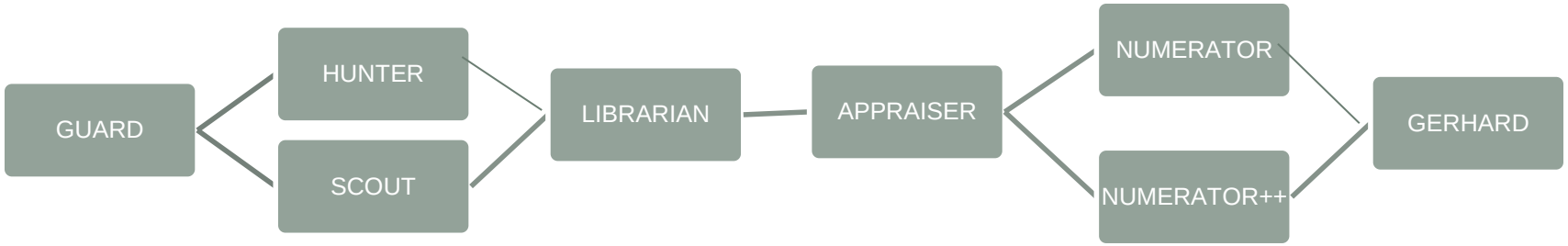
LIBRARIAN

- The module intends to actual update and manipulate with asteroid elements catalogue, asteroid observation's catalogue and observatory's list. LIBRARIAN allows efficiently update elements in catalogue if new observations of investigating objects is appearing on MPC website. There are procedure of orbital element improving and exception of observations by 3-sigma rule in the module.

GERHARD

- The module forms observation program. In fact output file of GERHARD is a set of instructions for telescope with time moments, ephemeris and necessary exposition, which calculated from ephemeris magnitude. The module deals with data set from NUMERATOR, NUMERATOR++, forming program according users requirements. We plan to use genetic algorithms as there are numerous possible observations program and it is necessary to choose optimal program. GERHARD allocates time in program for receiving calibrating frames and minimized number of telescope rotations.

Automatic mode



Each module can be used individually in user mode, but main task of this software is automation of procedure of preparing to observations. Filling of setting data is requested for work in automatic mode. Each stage will be realized without direct contact with user.

Automatic mode

- On the first stage GUARD will define duration of night for given observatory. Later HUNTER and SCOUT will give information about objects which possible for observation. For chosen objects LIBRARIAN will take new observations from MPC website, will improve orbital elements and update elements in catalogue. On the base of new elements APPRAISE will calculate probability domains, NUMERATOR will determine ephemeris and NUMERATOR++ will define review ephemeris. In final stage GERHARD will form list pf instructions for telescope. In fact user should chose setting set and indicate interesting objects.