Improved NEO data processing Capabilities for the ESA SSA-NEO software system

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ABSTRACT

"ESA SSA-NEO software system" is defined as the overall system composed by the ESA-NEOCC (Near-Earth Object Coordination Centre) system in ESRIN, Frascati (Italy), together with the NEODyS (Near-Earth Object Dynamic Site) and AstDyS (Asteroids Dynamic Site) systems, located at the University of Pisa and managed for ESA by the University Spin-off SpaceDyS. The ESA Space Situational Awareness (SSA) Programme foresees that both NEODyS and AstDyS systems will migrate to the NEOCC during the next two years through an activity that includes a full software rewriting of the orbit determination software (OrbFit). In the meantime, the SSA programme has built the precursor services in ESRIN and has funded several projects aimed to provide new and unique services to the scientific community and the general ESA customers. One of these projects, called P2-NEO II, foresaw an enhancement of OrbFit and the implementation of a visualization tool for the display of impact corridors and of the fly-by area based on the calculations produced by OrbFit. DEIMOS SPACE Romania was in charge of developing this tool which consisted in two separate visualizations, ICV (Impact Corridor Visualizer) and FAV (Fly-By Area Visualizer), depending on the close encounter scenario. First, if the object is on a collision course with our planet, it shows the impact corridor (i.e. the possible locations where it could hit the Earth surface consistent with the uncertainties of the trajectory determination) and provides essential information for mitigation purposes. Secondly, when the object performs a deep fly-by to our planet and a collision can be safely excluded, it shows the nominal trajectory and the associated uncertainty region and it provides an important graphical support for understanding the underlying dynamics. In this paper we will present in detail the functionalities of the ICV and FAV tools.

KEYWORDS: NEO, ICV, FAV, ILD

NOMENCLATURE

API – Application Programming Interface
ESA – European Space Agency
FAV – Fly-By Area Visualizer
ICV – Impact Corridor Visualizer
ILD – Impact Location Displayer
NEO – Near Earth Object
SSA – Space Situational Awareness

1 ICV TOOL

The ICV (Impact Corridor Visualizer) software is responsible for displaying in a user-friendly way the impact corridor area using the Google Map/Google Earth APIs and its main function is to plot the contour lines of the impact corridor on the Earth surface. It is available on the ESA NEO web portal but only to registered users having the necessary privileges.

1.1 Functionalities

The ICV tool already incorporates the following functionalities:

- Produces a high-quality 2D and 3D graphical visualization of the impact corridor on the ground for identified potential impactors with Earth, the Moon and other planets.
- Draws the boundaries of the region where an impact is possible.
- Allows the user to show information of the underlying data such as the time corresponding to impact locations and the corresponding geographical coordinates.
- Is able to produce an additional output suitable for printing on A4 paper.
- Is using Google Maps and Google Earth to represent the 2D Earth surface and the 3D Earth globe respectively.
- Uses the contour lines for displaying the impact corridor on the ground at different sigma levels (1, 3, and 5).
- Draws the contour lines corresponding to atmospheric entry, e.g. the contour lines at 100 km altitude.
- Uses a green colour to represent the impact corridor in the atmosphere and a red colour for the impact corridors on the Earth surface.
- Allows to exchange the standard topographic representation of the Earth surface with freely available thematic maps (e.g. population density).
- Runs on any browser adopting HTML 5 web technologies with no significant overhead time during the loading of the data.
- Accepts as input JS and KML formatted files in order to use existing software assets such as Google Earth/Maps.
- Produces graphical outputs downloadable in jpg format.
- Produces 2D interactive outputs using Google Maps.
- Allows displaying coordinates and time of impact using cursor-tips.
- Produces a downloadable file with instructions for displaying it on the user computer using Google Earth.
- Reports the total impact probability in the plot.

The ICV tool was implemented using JavaScript and Google APIs.

1.2 Snapshots of the functionalities

After authentication, the link to the ICV is made available on the web portal. By clicking the ICV link, a web page with the list of asteroids is made available. The last two columns in the provided table (see **Figure 1**) redirect to the visualizer corresponding to the selected object.

Figure 1: Past impactors list for ICV

The following figures present the functionalities using 2008TC3 asteroid:

- First view when 2D visualization window is opened and "Location region" functionality (**Figure 2**)
- View of 2D ICV for 2008TC3 at 100 km altitude over the terrain (**Figure 3**)
- View of 2D ICV for 2008TC3 at 0 km altitude over the terrain (**Figure 4**)
- View of 3D ICV for 2008TC3 at 100 km altitude over the terrain using .kml file and Google Earth (**Figure 5**)
- View of 3D ICV for 2008TC3 at 0 km altitude over the terrain using .kml file and Google Earth (**Figure 6**)

Figure 2: 2008TC3 ICV 2D view with Locate region enabled

Figure 3: 2008TC3 ICV 2D view 100 km altitude over the terrain

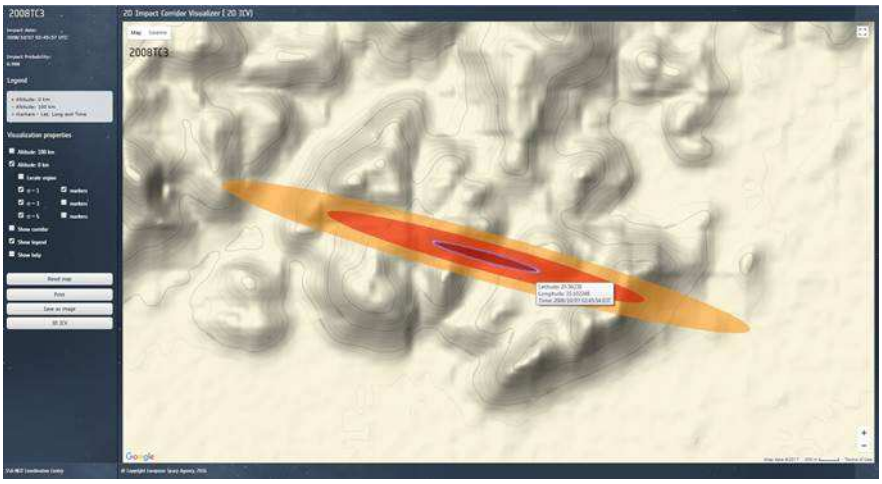

Figure 4: 2008TC3 ICV 2D view 0 km altitude over the terrain

Figure 5: 2008TC3 ICV 3D view 100 km altitude over the terrain using .kml file and Google Earth

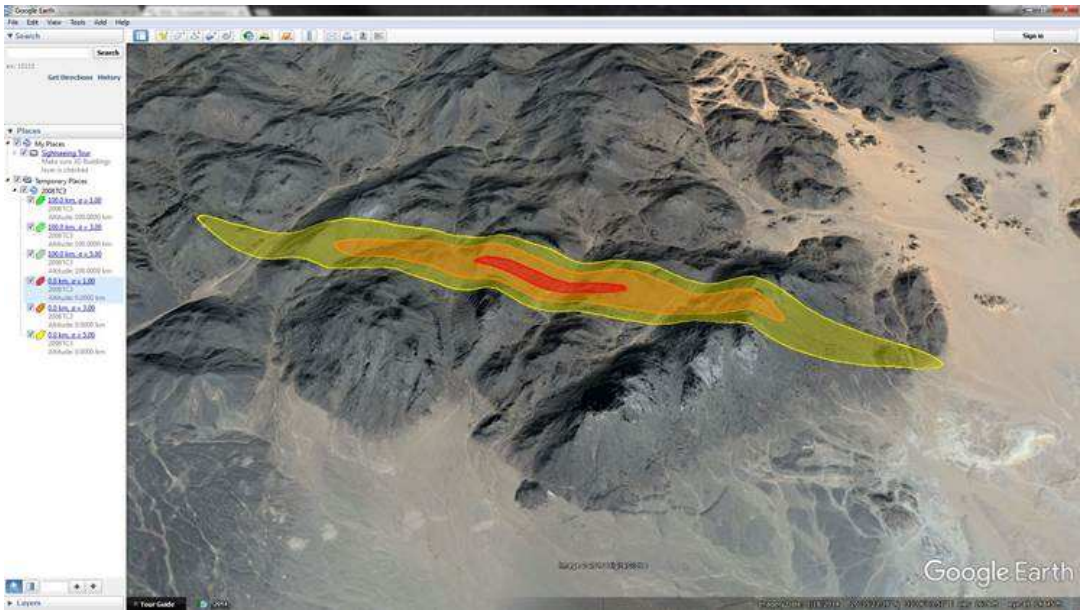

Figure 6: 2008TC3 ICV 3D view 0 km altitude over the terrain using .kml file and Google Earth

2 FAV TOOL

The FAV (Fly-By Area Visualizer) software is responsible for displaying in a user-friendly way the flyby area, which includes the nominal trajectory and the error ellipse contour lines at the time of closest approach. It plots on a 3D representation of the near-Earth space the nominal trajectory and the associated error ellipse. It is available on the ESA SSA-NEO web portal but only to registered users having the necessary privileges.

2.1 Functionalities

The FAV tool already incorporates the following functionalities:

- Produces a high-quality 3D graphical visualization of the flyby area near-Earth space for identified potential impactors with Earth, the Moon and other planets.
- Draws the nominal trajectory of the asteroid and the uncertainty area around it using contour lines.
- Is able to produce an additional output suitable for printing on A4 paper (e.g. using white background).
- Displays Earth fly-bys occurring at distances less than 3 lunar distances. If the fly-by occurs outside the threshold, it will be always possible to run the program on a single object on demand.
- Runs on any browser adopting HTML 5 web technologies with no significant overhead time during the loading of the data.
- Accepts as input JS files in order to use existing software.
- Shows on 3D visualization: the minimum distance during the close approach (i.e. the object distance at closest approach), the time of the closest approach, the position of the object at closest approach, a sampling of the confidence region boundary at closest approach, nominal trajectory, Sun direction with respect to the Earth at the time of the closest approach, position of the Moon at the time of the closest approach, Moon trajectory computed for the same time interval of the asteroid's flyby, Moon direction, axes, country borders, asteroid direction.
- Produces graphical outputs downloadable in jpg format.
- Draws a static 3D representation of the fly-by area.

- Allows the user to interactively change the point of view and the zooming factor.

  The FAV tool was implemented using JavaScript API WebGL.

2.2 Snapshots of the functionalities

After authentication, the link to the FAV is made available on the web portal. By clicking the FAV link, a web page (**Figure 7**) with the list of asteroids is made available. The last column in the table redirects to the visualizer corresponding to the selected object.

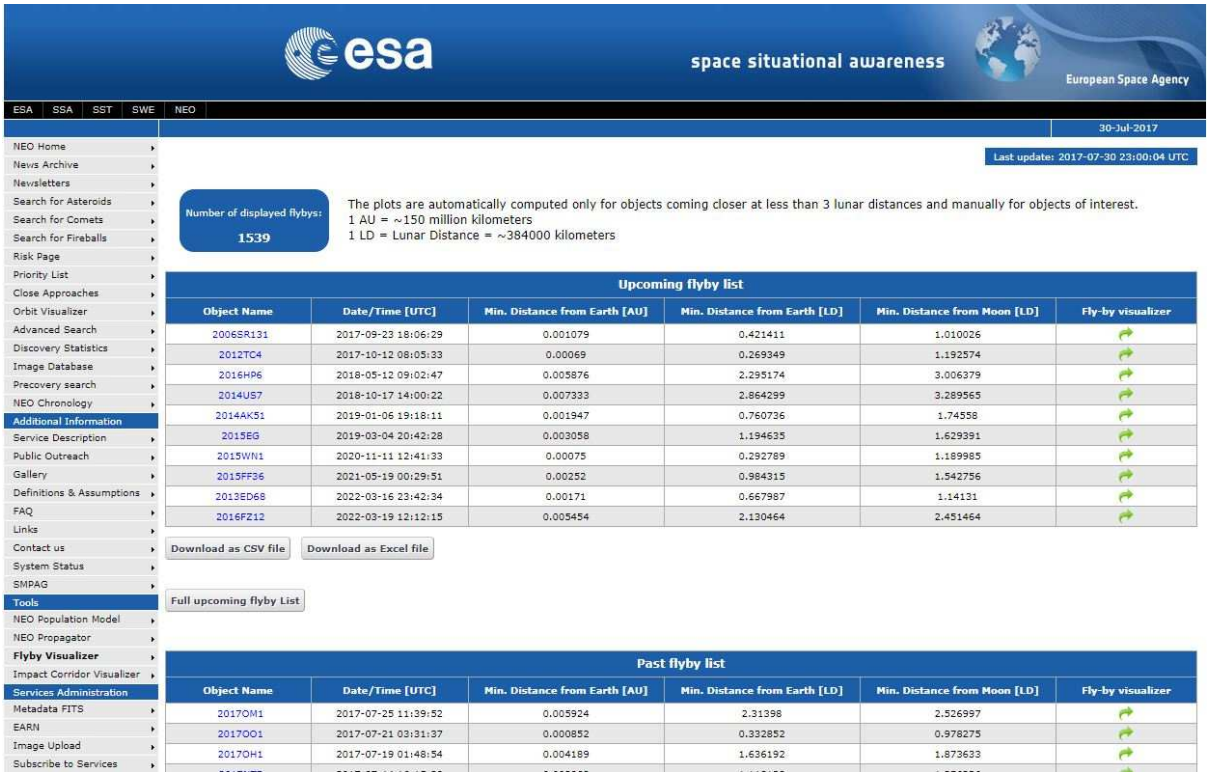

Figure 7: FlyBy table on NEOCC portal

Next figures will present the functionalities using different asteroids:

- 3D flyby visualization window for 2017OM1 asteroid at closest approach, the small confidence ellipse which means the position is very well determined, Earth-Sun direction, Moon position and trajectory functionality (**Figure 8**)
- 3D flyby visualization window for 2014US7 asteroid at closest approach, confidence ellipse is more visible (**Figure 9**)
- 3D flyby visualization window for 2015WN1 asteroid at closest approach, white background for printing, zoom, save as image and print functionality (**Figure 10**)

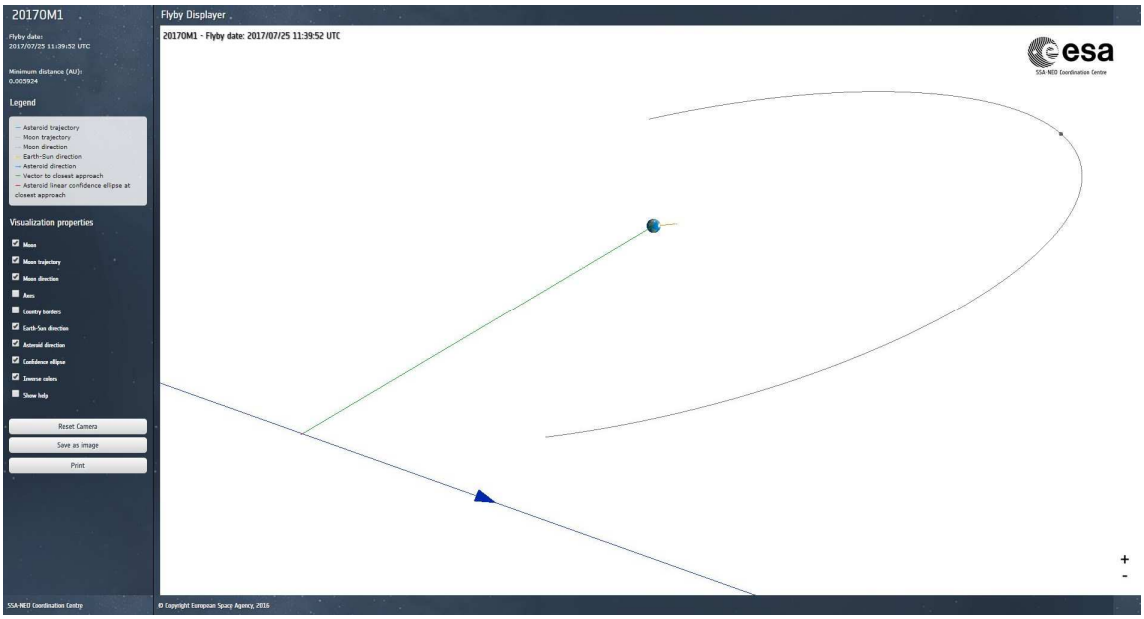

Figure 8: 3D flyby visualization window for 2017OM1 asteroid at closest approach

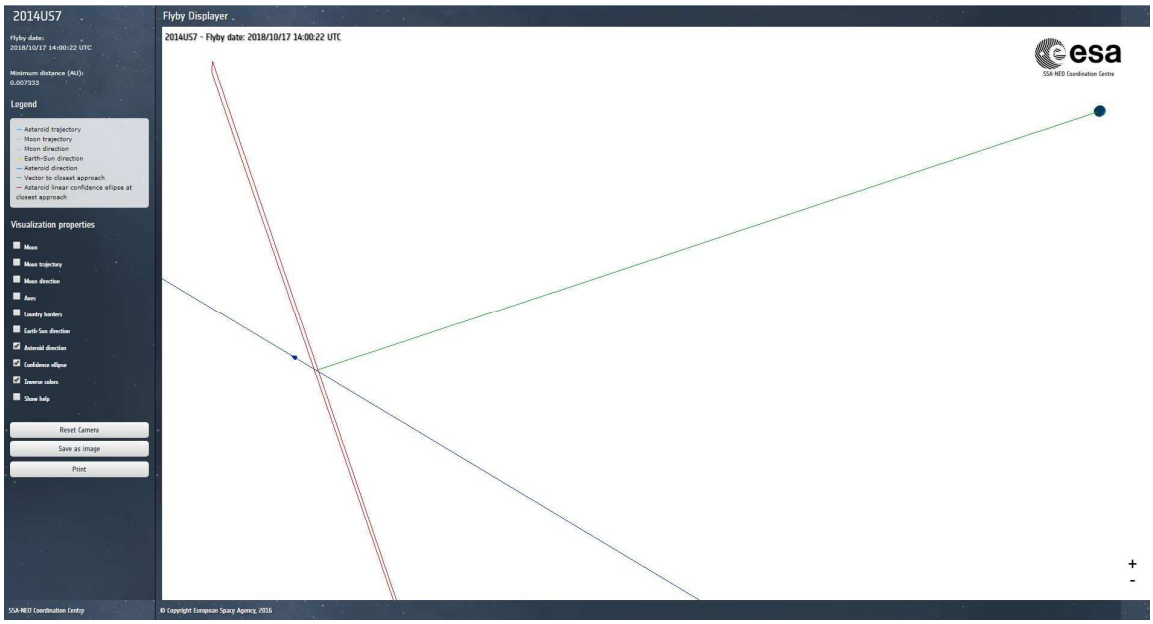

Figure 9: 3D flyby visualization window for 2014US7 asteroid at closest approach

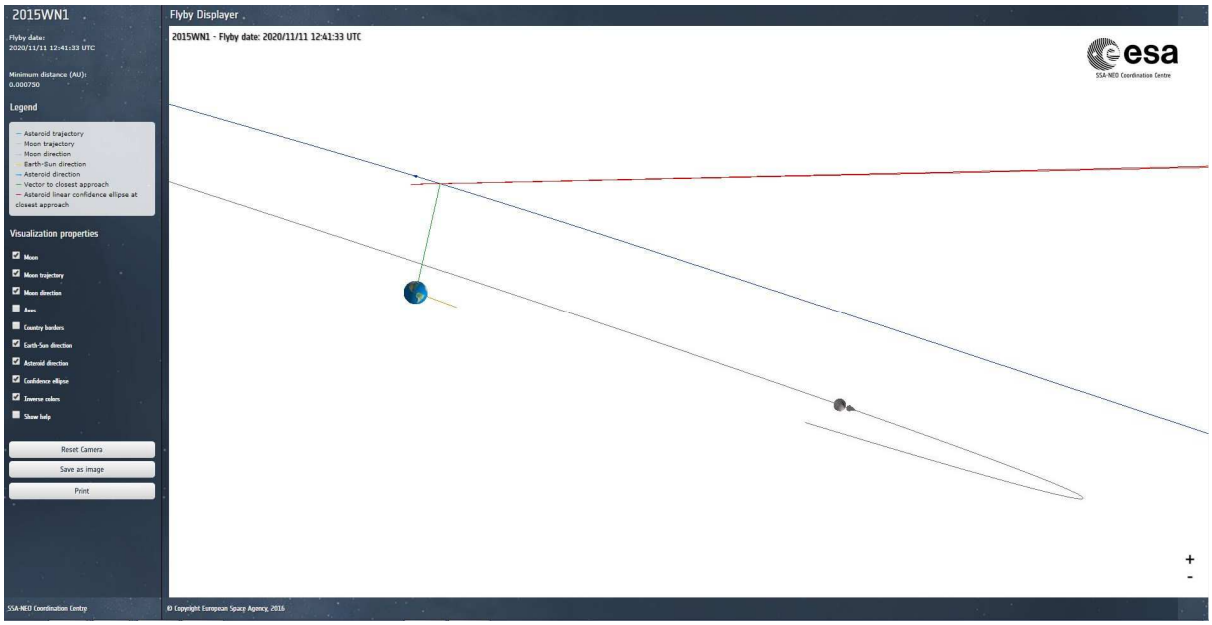

Figure 10: 3D flyby visualization window for 2015WN1 asteroid at closest approach

CONCLUSIONS:

In this paper we presented the main functionalities of the ICV tool that shows the impact corridor on Earth and of the FAV tool that shows the fly-by area during a close approach.

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