POSITIONAL AWARENESS MAP 3D (PAM3D)

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ABSTRACT

The Western Aeronautical Test Range of the National Aeronautics and Space Administration's Dryden Flight Research Center needed to address the aging software and hardware of its current situational awareness display application, the Global Real-Time Interactive Map (GRIM). GRIM was initially developed in the late 1980s and executes on older PC architectures using a Linux operating system that is no longer supported. Additionally, the software is difficult to maintain due to its complexity and loss of developer knowledge. It was decided that a replacement application must be developed or acquired in the near future. The replacement must provide the functionality of the original system, the ability to monitor test flight vehicles in real-time, and add improvements such as high resolution imagery and true 3-dimensional capability. This paper will discuss the process of determining the best approach to replace GRIM, and the functionality and capabilities of the first release of the Positional Awareness Map 3D.

KEY WORDS

Impact prediction, Situational awareness, Sonic boom, 3D Mapping, 2D Mapping

INTRODUCTION

Located at the National Aeronautics and Space Administration (NASA) Dryden Flight Research Center (DFRC), a tenant of Edwards Air Force Base, the Western Aeronautical Test Range (WATR) supports aerospace flight research, technology integration, space exploration vehicle concepts, airborne remote sensing, and a wide variety of science missions. The WATR provides a comprehensive set of resources for the control and monitoring of flight activities, real-time acquisition, reduction of research data, and effective communication of information to flight and ground crews. Part of these resources is providing real-time situational awareness display to project personnel while monitoring a mission. The Positional Awareness Map 3D (PAM3D) is providing a major upgrade to WATR's existing capability, by replacing the Global Real-Time Interactive Map (GRIM) application.

GRIM, which was initially developed in the late 1980s, contains well over one million lines of code, and is difficult to modify or improve. GRIM executes under a version of the Linux operating system, which

is no longer supported; and makes use of an early 1990s database for global imagery and terrain from the Defense Mapping Agency, which contains many errors and is of low resolution. GRIM has the ability to display one view, either 2D or limited 3D capability. With the application running on an older Linux OS and therefore older hardware, it is only a matter of time before the hardware fails with no replacements available. Throughout the years, additional features were added to GRIM per customer requests to meet their specific mission support requirements. Some GRIM features were added with minimal turnaround time due to project schedules, which caused maintenance of the GRIM code to be more difficult and time consuming.

The WATR began the process of identifying GRIM features that made it an invaluable part of the WATR Integrated Next Generation System (WINGS). For more information on WINGS, refer to International Telemetry Conference Paper number 2003-01-02 titled, "Wings Concept: Present and Future" [1]. Following the generation of a GRIM feature list, a study of various mapping applications including commercial off-the-shelf (COTS) and Government off-the-shelf (GOTS) products was performed to determine if an application existed that could be utilized to minimize development time and resources. The graphics applications that contained one or more of these capabilities/features were added to a matrix for comparison. Just as GRIM had been developed entirely from scratch; the in-house complete end-to-end development option was added to the matrix as well. Several criteria were evaluated for each option, including the number of required features satisfied, the ability to modify and add new capabilities, estimated time for the release of an initial capability, and overall cost. The matrix of this information was created and presented at PAM3D's preliminary design review.

A mixed in-house solution using a third party library, Analytical Graphics, Inc. (AGI) (Exton, Pennsylvania) Satellite Tool Kit (STK) option was selected. Out of the box this option made available libraries and display controls to provide the 2D and 3D positional earth mapping needed. Without having to dedicate a great deal of time to the design and development of the display environment, PAM3D could be developed sooner by focusing on the development on the user interface, data acquisition, processing, and data distribution. Because PAM3D's data flow architecture was developed in-house, future enhancements to processing, such as new data formats and rates, or additional functionality will not be constrained by COTS software. Therefore, PAM3D can add specialized processing functionality such as Impact Prediction and Sonic Boom without issue. On the display side, the development is tightly coupled to the underlying AGI threading, processing, and display architecture. There is some ability to manipulate the AGI processing, but the decision was made to give up backend graphics control for a decreased time of development.

Overall, the AGI solution is a good balance of initial capabilities, flexibility, and priced to provide the ability to satisfy the highest percentage of features possible in the least amount of time. In addition, AGI technology is a tested and certified industry-standard analysis and visualization software, thus reducing testing of lower level components, and ensuring accuracy and maintainability.

PAM3D USERS AND OPERATIONAL SCENARIOS

One of the difficulties in the development of PAM3D was gathering requirements from the various stakeholders. The stakeholders assumed that the developers of PAM3D were aware of how each group used the application, so instead of relaying specific features and needs, the overall request was to make

it like GRIM. Unfortunately, GRIM has so many features and capabilities, that it was difficult to discern which features were beneficial to each type of user. The developers undertook the task of analyzing the GRIM code to generate a feature set and a list of requirements. It was determined that the first release of PAM3D would be scheduled as a demonstration and evaluation version with the intent to get feedback from the users as to what capabilities were most important.

The users of PAM3D can be broken down into four major groups, WATR range personnel, Range Safety Officers (RSOs), mission controllers, and research engineers. Range personnel consist of the Range Control Officers (RCOs), WINGS operators, and Test Information Engineers (TIEs). The RCOs use PAM3D during a real-time mission to monitor position of the aircraft (latitude, longitude, and altitude). WINGS operators use PAM3D prior to a real-time mission to verify the correct operation of the system. For example, they will perform "board checks" (a board check consists of verifying the physical and electrical alignment of the radar) with the radar to ensure the map is tracking properly with the radar.

As the use of UAVs (unmanned aerial vehicles) has increased in Dryden's research and development projects, so has the requirement for an RSO's presence in the control room. Prior to a mission, the RSO provides the TIE with the UAV waypoints and impact prediction data. This information is added to PAM3D, and is verified and validated by the TIE and RSO. During a real-time mission, the RSO uses PAM3D to monitor the position of the aircraft or target to ensure it is following its predicted path. If the aircraft loses link with the ground control station or veers off course, the RSO has the ability to terminate the aircraft. The impact points displayed on PAM3D show where the fragments of the aircraft will land if terminated. This data is important, both for public safety and for recovery of the aircraft.

The mission controller is another important role in the control room. This user is in constant communication with the pilot during a real-time mission. NASA Dryden operations on Edwards Air Force Base take place in restricted airspace, the R-2508 Complex. The R-2508 Complex is comprised of military operations areas (MOAs), Air Traffic Control Assigned Airspace (ATCAA), and other special restricted airspaces, which have all been incorporated into PAM3D. The mission controller has the ability to turn on any of the aforementioned areas within the R-2508 Complex where the aircraft will be conducting operations. They can also turn on areas where other aircraft are operating to ensure those areas are not breached. The mission controller uses PAM3D to monitor the position of the aircraft and notifies the pilot when they are approaching boundaries of specific restricted or keep-out areas.

Research engineers are the principal users of specialized processing available in PAM3D. The main function used in GRIM by research engineers is the sonic boom capability.   This functionality gives the researcher the ability to view sonic boom chevrons on the PAM3D display. With researchers on the ground listening for the booms, the engineers viewing PAM3D in the control room can compare the locations of the booms displayed on PAM3D with the locations of the researchers in the field. The future plan is to modify the sonic boom algorithm to predict where the sonic boom will hit before going supersonic. The purpose of sonic boom prediction is to minimize booms reaching the ground and disturbing the public. Another goal is to implement this technology on a cockpit PC so the pilot can see if, or where, the booms are impacting the ground to allow supersonic flight over populated areas.

PAM3D FEATURES

The PAM3D application supports the monitoring of up to ten aircraft, at a minimum data rate of 20 samples per second. PAM3D provides a 2D window (God's eye view) similar to the legacy GRIM application, incorporating pan and zoom capabilities, and a 3D window for more advanced viewing, allowing full rotation and zoom about objects. As shown in Figure 1, the 2D window is a flat earth overhead view, while the 3D window has detailed terrain and the freedom to move about objects. These graphics windows are part of STK's visualization features, such as certified mapping accuracy (performed by The Aerospace Corporation, El Segundo, California), high resolution terrain and imagery (60 cm resolution), and Geographical Information System (GIS) support. In Figure 2, both the 2D and 3D windows are capable of displaying high resolution imagery. The 2D window demonstrates GIS data outlining flight line access, runways, and buildings. Additionally, Google Earth's Keyhole Markup Language (KML) files are supported. The ability to import KML files allows PAM3D users to create their own geographic features to display during missions. These feature files can be created in several different applications including Google Earth. Examples of features are waypoint definitions, expected flight paths, and the highlighting of specific ground features. PAM3D offers various graphical tools to enhance the visibility of a displayed vehicle position. These graphical tools include drop lines, history trails, geographical markers, such as lakes and lakebeds, and area objects depicting restricted and keep-out areas.
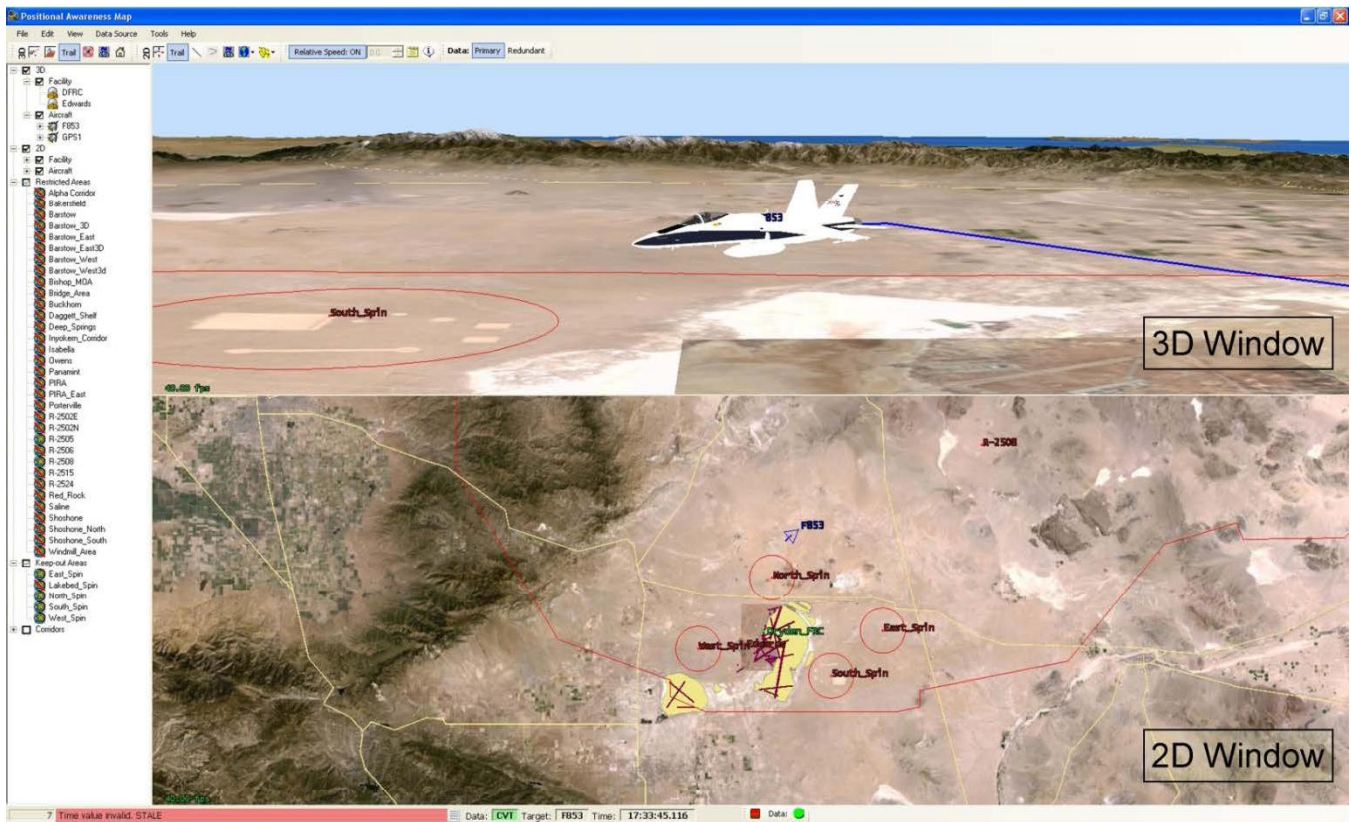

Figure 1. Graphical display windows.

Figure 2. High resolution imagery and GIS.

PAM3D's user interface follows a standard Microsoft Windows (Redmond, Washington) interface with six functional areas: menus, toolbars, object tree, properties, status bar, and graphic display windows (Figure 3). An object tree view organizes objects such as aircraft, facilities, and restricted areas into groups which allow the user to manipulate their properties. Additional property dialogs allow the modification of detailed properties. The status bar indicates current target, data status and time, and log messages. The tree view, toolbars, and graphic windows may be hidden or viewed at the user's discretion.
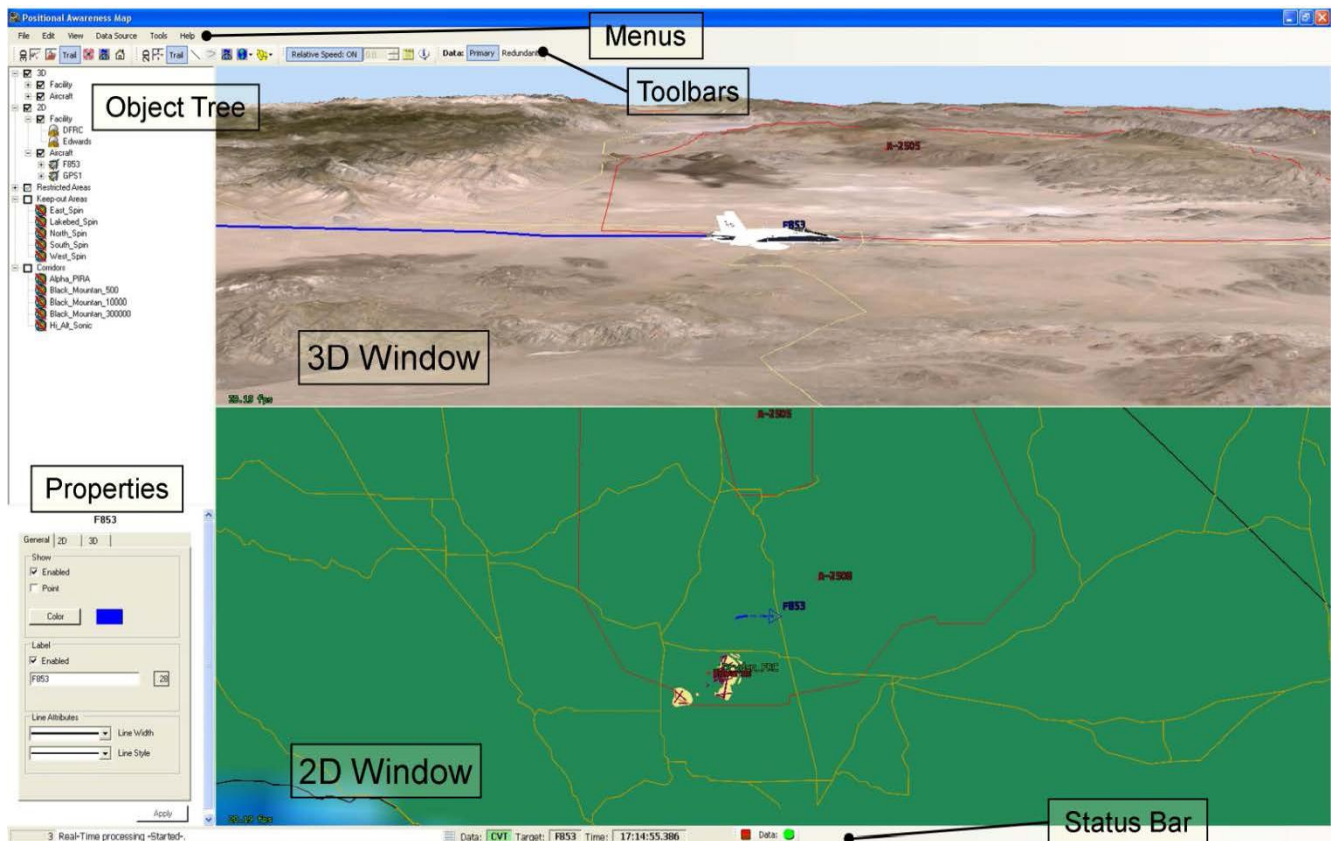
Figure 3. User interface.

Configuration of the PAM3D application is accomplished via an eXtensible Markup Language (XML) file with uniquely defined tags. An XML configuration file provides a format that is both easy to read for the user and easy to parse in development. The file defines the overall application setup, user preferences, and settings. The file includes aircraft definition, window properties, data source(s), GIS file requirements, impact prediction, and sonic boom selection.

PAM3D SPECIALIZED PROCESSING AND DISPLAY

PAM3D has the capability for adding special processing and display functions including impact prediction and sonic boom patterns. Impact prediction is used by the RSO to predict impact points for UAVs. The impact prediction algorithms were written by NASA researchers based on specific project requirements. This algorithm was converted from FORTRAN to C++ for incorporation into GRIM and was integrated into PAM3D. The impact predictor algorithm will define points to be drawn by a user defined shape (Figure 4). These calculated impact points are based on the active wind data file, ground speed, aircraft weight, coefficient of drag, surface reference area, and calibrated vehicle velocity. An impact predictor setup graphical user interface (GUI) (Figure 5) was implemented in PAM3D to assist the user in correctly setting all of the required inputs.
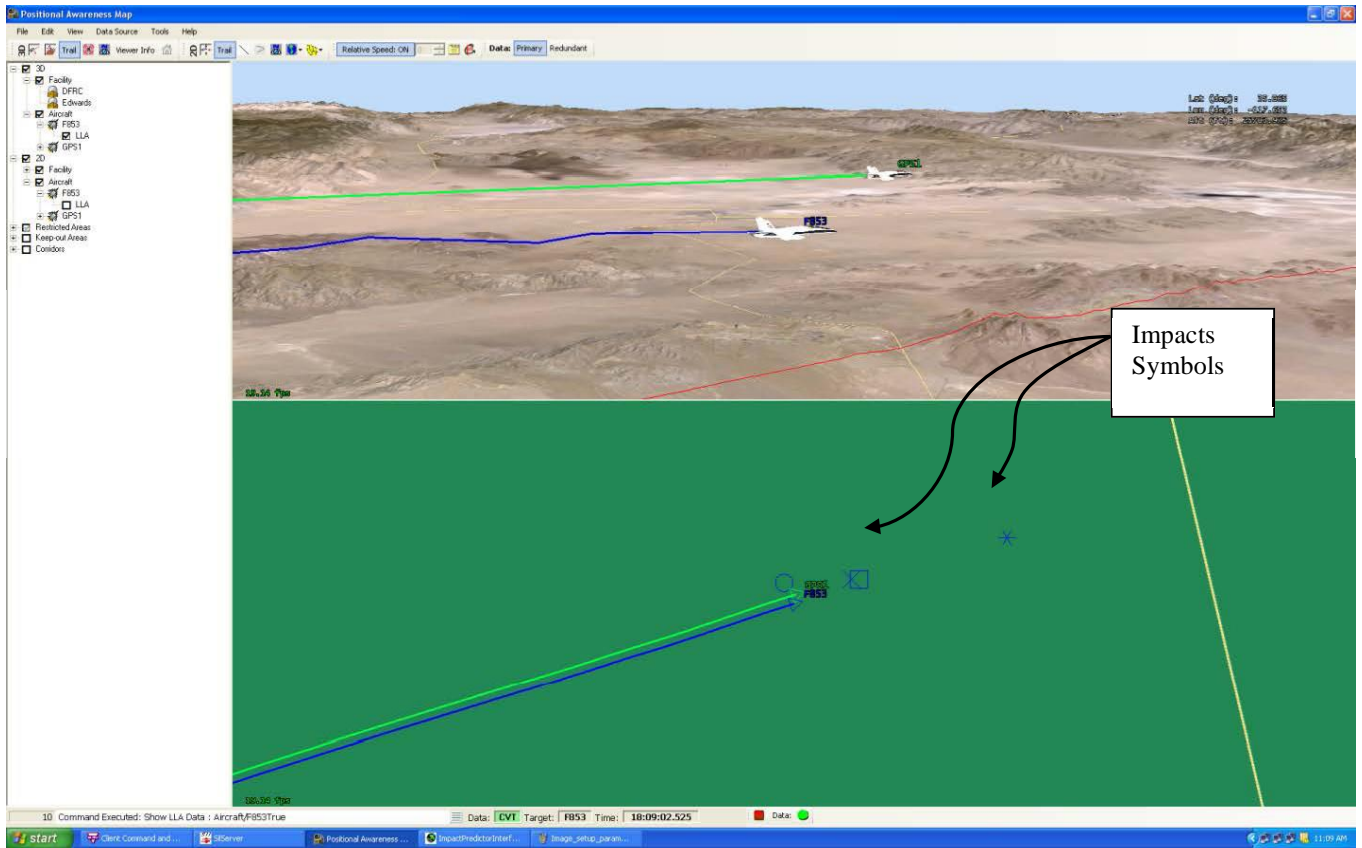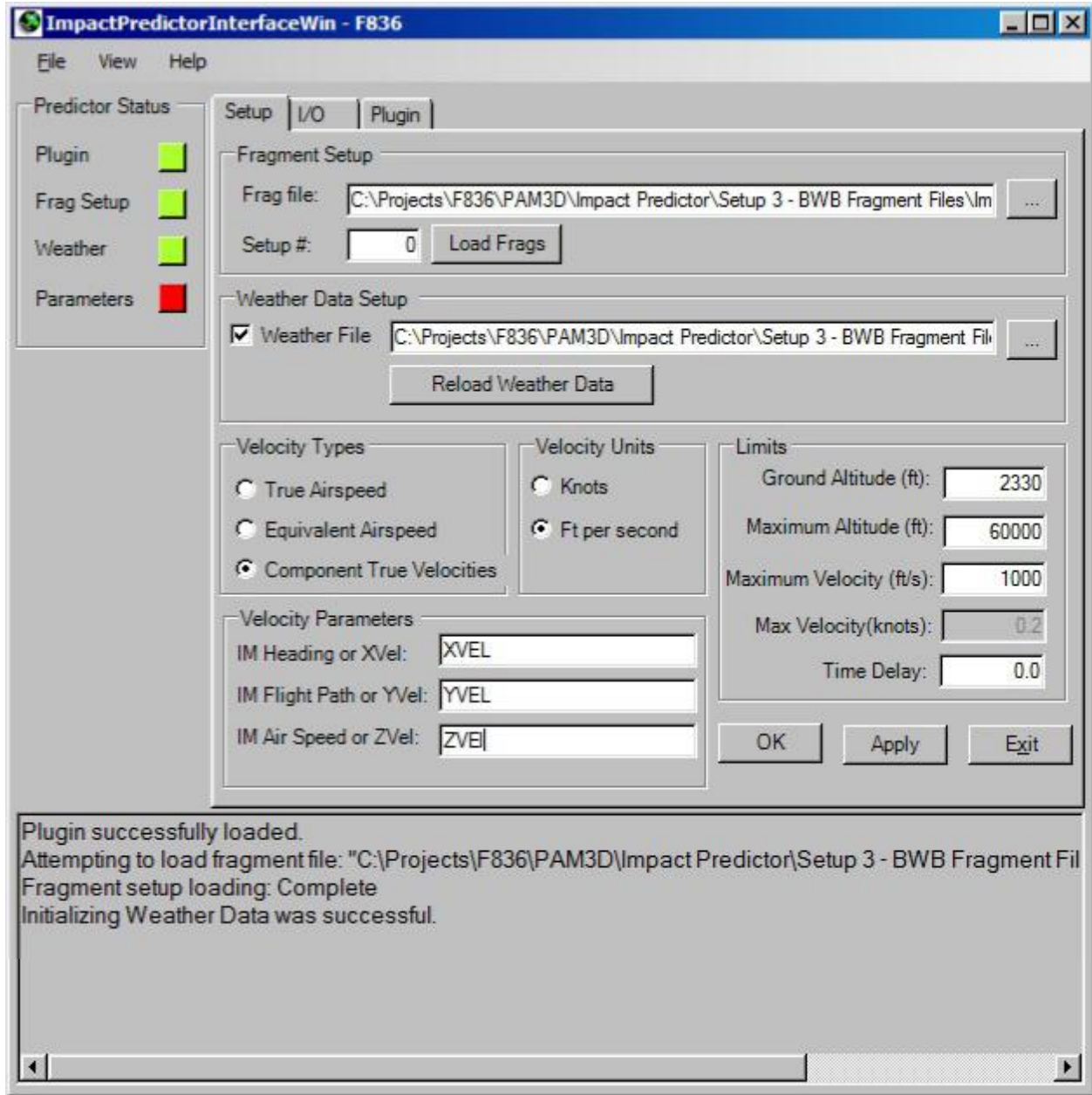
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Figure 4. Impact predictor example.

Figure 5.Impact predictor setup GUI.

For the impact prediction function to work, the user must specify variable names or a constant value for all required impact prediction inputs; these include heading or XVEL, flight path or YVEL, air speed or ZVEL, time delay, velocity type and units, wind file, and number of fragment files. The fragment files are generated by the RSO and include the unique vehicle data and fragment characteristics necessary to predict how each fragment will fall. The impact predictor algorithm can be used to track multiple targets or data sources acquired by PAM3D.

The sonic boom processing and display capability provides a view of where the impact of the sonic booms will occur on the ground. This is displayed as a chevron (parabolic wave pattern) as shown in Figure 6. The chevron represents the point of intersection with the ground from the center point to the furthermost points on the right and left.
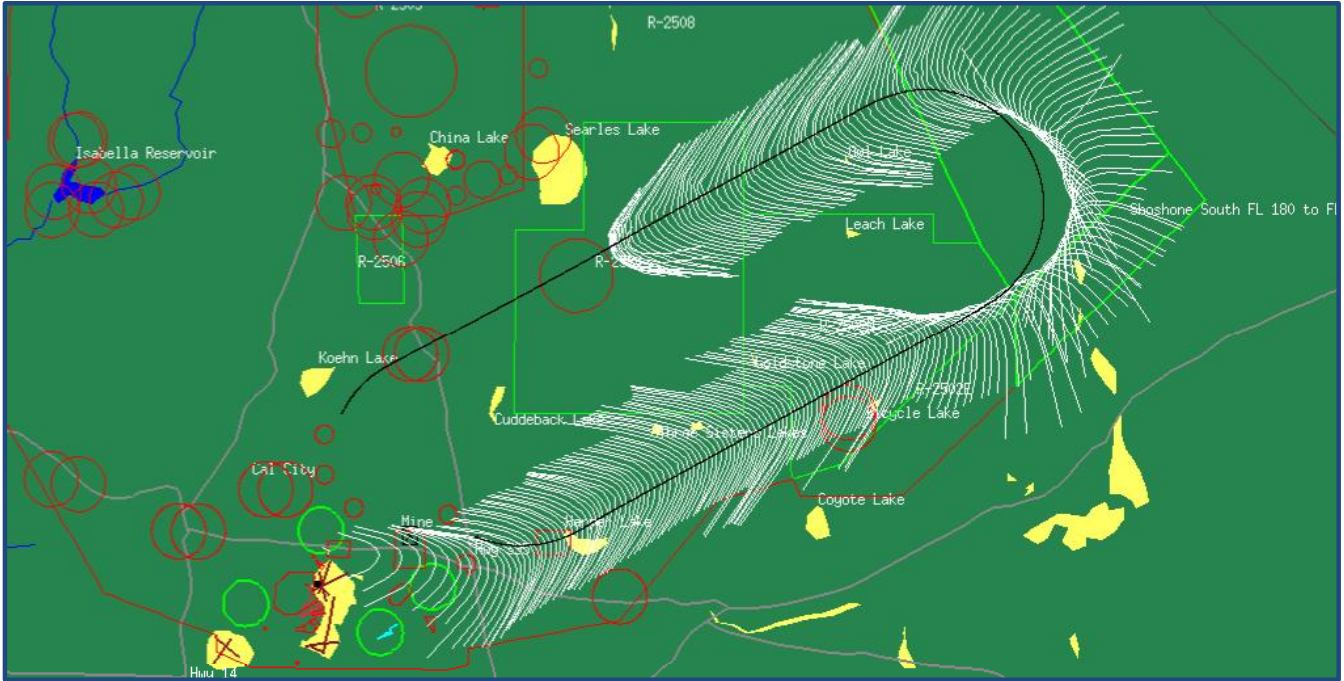

Figure 6. Sonic boom window with chevrons being displayed.

The sonic boom computational module is derived from a separate application known as CISBoomDA. The application was developed by D**r.** Kenneth J. Plotkin of Wyle Laboratories (El Segundo, California) to calculate sonic boom footprints and signatures from flight vehicles. CISBoomDA was ported to PAM3D by developing a near real-time wrapper and data interface between PAM3D and the Sonic Boom computational code. The CISBoomDA algorithm requires Mach, aircraft weight, and wind data (previously loaded in memory). The sonic boom algorithm only activates if Mach has a value greater than 1.0. Data checking, smoothing, and filtering are provided, as well as computations for 1st and 2nd derivatives before processing data. The sonic boom application processes the data and passes the latitude, longitude, and elevation of the chevrons to PAM3D for display.

FEATURES TO BE INCLUDED IN FUTURE RELEASES

PAM3D is an iterative development and will include several future releases. Planned future capabilities include:

- Configurable data display window for viewing parameter values.
- Ability to display 3D visualization of volumes' (e.g. restricted areas and flight corridors) floors, ceilings, and walls.

- Ability to determine bearing and distance from various objects, including aircraft, highways/roads, and restricted area and flight corridor borders.
- Project specific filters with proximity cylinder/sphere about aircraft with visual indication of penetration by other aircraft.
- Ability to predict sonic boom/earth ground intersection calculations with graphical display.

ACKNOWLEDGEMENTS

REFERENCE

[1]   Harris Jim, and Downing, Bob, "WINGS Concept: Present and Future," Paper 03-01-02, *International Telemetering Conference 2003*, Las Vegas, Nevada, October 20-23, 2003.