Large Scale Test Simulations using the Virtual Environment for Test Optimization

(VETO)

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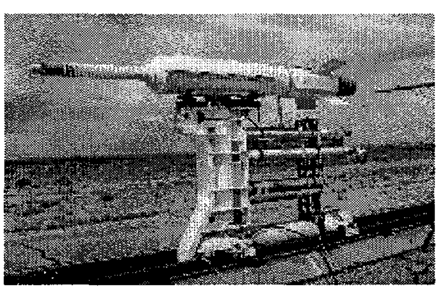


Introduction and Motivation:

The Virtual Environment for Test Optimization (VETO) is a set of simulation tools under development at Sandia to enable test engineers to do computer simulations of tests. The tool set utilizes analysis codes and test information to optimize design parameters and to provide an accurate model of the test environment which aides in the maximization of test performance, training, and

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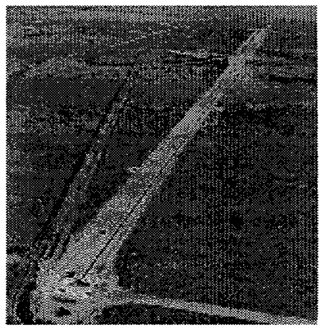
safety. Previous VETO effort has included the development of two structural dynamics simulation modules that provide design and optimization tools for modal and vibration testing [1, 2]. These modules have allowed test engineers to model and simulate complex laboratory testing, to evaluate dynamic response behavior, and to investigate system testability. Further development of the VETO tool set will address the accurate modeling of large scale field test environments at Sandia. These field test environments provide weapon system certification capabilities and have different simulation requirements than those of laboratory testing.

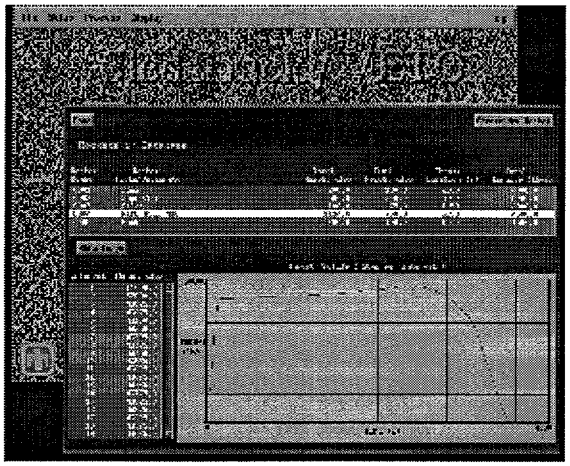
This paper describes the VETO simulation module which models the dual rail 10,000 foot sled track facility at Sandia. This module includes accurate models of terrain, test buildings, observation towers and laser tracking site mounds to combine with models of propulsion systems, payloads, track, and sleds. The resulting integrated set of test-based models, analysis codes, and advanced visualization makes it possible for engineers to rapidly perform numerous sled test simulations, to evaluate test designs, and to select an optimal set of test parameters prior to conducting a physical test. This can be very important when expensive one-of-a-kind test units are being certified. By including specific test and instrumentation models, the VETO environment also provides a means of evaluating the data acquisition options for a sled test. VETO utilizes advanced visualization software to display test setup, test animation, support operator training, and safety analysis. A major objective in developing the sled track simulation environment is to provide test engineers with a tool that is easy to use and provides all the needed functionality to design a test and maintain test information. To maximize our effort, existing software tools, including commercial code, are being utilized wherever possible to build this environment. The following sections detail how VETO integrates a graphical interface, a simulation database, analysis codes and advanced visualization to meet this objective. The final section of the paper will compare a sled track ejection simulation with an actual sled track ejection test.



Simulation Database and Graphical Interface:

A user of the sled track module of VETO creates a test design and then simulates the behavior of the designed system. Test designs combine information specific to an individual simulation with characteristics of test apparatus common across multiple simulations. Databases are created to hold records of test designs and the apparatus available to use in tests. Users have access to the databases via a graphical interface developed in C using the Motif libraries. This interface enables users to efficiently create a test design, perform a simulation of the design, and visualize the results of the simulation.

The descriptions of common test apparatus are maintained in multiple user extensible databases. Databases are provided for sleds, tracks, propulsion systems, rockets, payloads, targets, instrumentation, and drag shape tables. When a new piece of test apparatus is built or acquired, its characteristics can be added to the appropriate database. For example, if a new rocket motor has been acquired, information such as total weight, fuel weight, thrust time history, and total impulse will be added to the rockets database for use in future test simulations. The databases for test apparatus are shared by all users of the VETO tool set and are available at the time the environment is entered.



A default common database to record the information specific to a particular test's design is also provided. ***(Click on image to view in more detail)*** The user may elect to use a personal database for this information or a group of users may share a database for a common task.

The process of creating a new test simulation design begins with the preparation of an entry in the test design database. This entry will record the data specific to the current test design. The user is able either to select a previous test design from the database as a template or to construct an entirely new record. After specifying the desired global test record information, the test apparatus (sled, rocket, propulsion system, etc.) is integrated into the simulation model from the available databases. Finally, specific initial conditions for the test are provided. Initial conditions will include information about the sled's starting track location, environmental conditions (temperature, pressure, etc) and the desired ejection velocity for any payload released from the sled. Additional dynamic constraints would also be included in the design at this point.

After the preparation process is completed, the sled test simulation is ready to be conducted using the supplied information. The graphical interface acts as a controller; sending information, in the form of C data structures, to the appropriate analysis code to calculate the motion of the sled and payload under the specified test conditions. This kinematic data is integrated into a visualization preview that enables 3-D display of the test simulation. The motion data as well as other results from the analysis codes are also stored in the simulation database for future access. The stored results can be easily viewed in both tabular or 2-D forms to support evaluation of the test design's performance. Thus, the graphical interface provides a convenient mechanism for storage and retrieval of all the provided and computed information related to a particular test design.

Simulation Analysis Codes:

There are four analysis codes used in our sled track ejection simulation. These codes were originally written in FORTRAN, but have been re-coded into C to more easily interface with the data structures coming from the graphical interface. Each code independently calculates different test parameters to support the overall simulation of the sled track environment. However, there is coupling among the codes because output of one is used as input to another.

The initial analysis code driving the ejection sled test simulation is a **sled acceleration** code. This code integrates the user inputs defining the sled, rocket, propulsion system, payload and drag information into the simulation. Through the graphical interface setup process, multiple stages can be defined which allow the adjustment of ignition times for the selected number of rocket motors or the use of a pusher sled in the simulation. The ultimate goal of varying these propulsion parameters is to create a customized thrust profile for the sled motion down the track. The thrust profile may also be adjusted based on the environmental conditions. These profile changes incorporate a different thrust duration into the simulation while holding the total impulse constant. From the calculated thrust profile, an estimate of the sled velocity is computed to provide a friction coefficient. Air drag tables for the selected sled and the payload are interpolated to determine an overall system drag value. The sum of the thrust, air drag and friction is used to calculate the system total force. Additional parameters that are estimated by the track acceleration code are the distance traveled down the track and the average weight of the entire sled system as a function of time.

Simulation continues with the **cobra** ejection code which is used to predict the necessary stroke and column piston pressures needed to release the payload and achieve a desired free flight apogee. This code requires the piston assembly weight, payload weight, and the desired apogee as inputs. As part of the actual test design, the tabular output from the cobra code can be used to bound the acceptable piston pressures that can be used in reaching the desired ejection height.

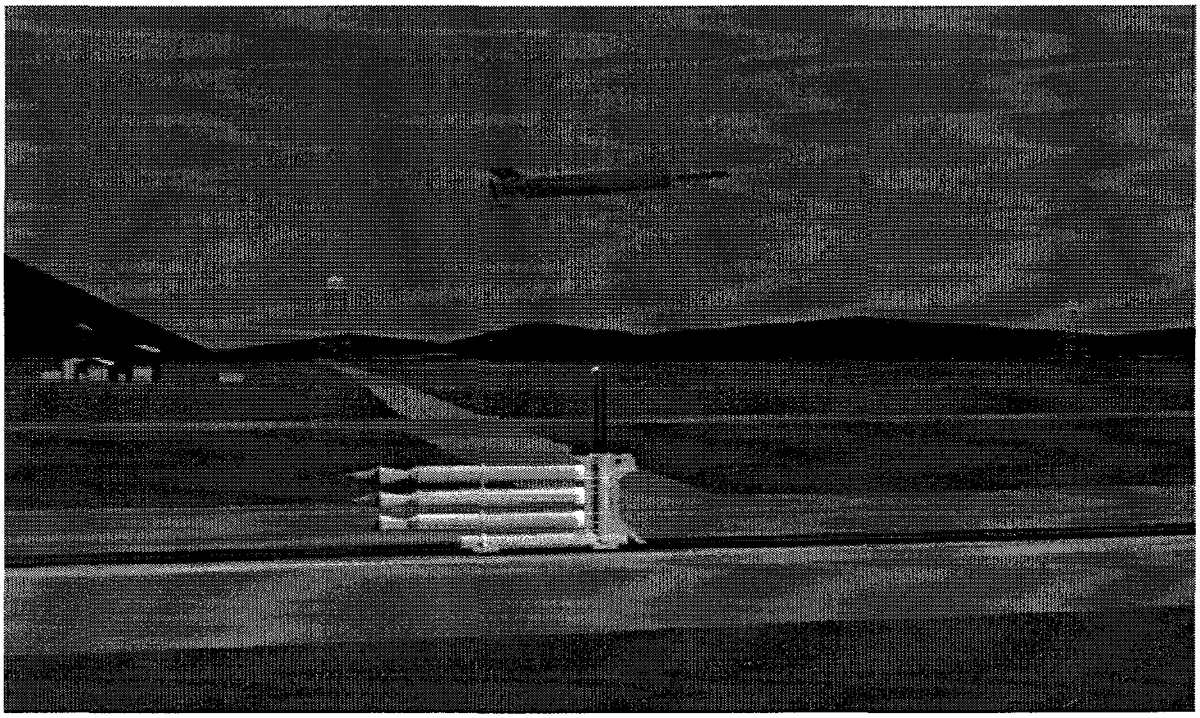
After ejection, the ballistic motion of the payload is simulated by the **free flight** code. Information such as desired ejection velocity, free flight angle, payload weight, payload drag and environmental conditions are used to calculate the free flight trajectory. The height and the distance of the payload relative to the ejection point are computed and the output is appended to the record in the simulation database. In addition to using payload drag tables, parachute drag information can also be integrated into the simulation codes to properly simulate the aerodynamics of the payload trajectory.

Finally, in order to properly recover the ejection sled following a test, a **water brake** code is used to simulate the deceleration of the sled after the ejection has occurred. A built-in gradient to the sled track enables the test operators to utilize a water trough located between the two rails to decelerate the sled. By specifying the water depth at a number of locations down the track, the user is able simulate the braking provided by the scoop of a particular sled. The braking code also enables the engineer to simulate the forces created as the sled decelerates to determine if a maximum allowable force is exceeded. As with the other simulation codes, the water brake output is appended to the simulation database.

Data Visualization:

Following the simulation code analyses, the user has a number of data display and visualization options available. The output data saved into the simulation record database can be parsed for specific information to display in tabular or 2-D form. This gives a quick response view of the data, enabling the user to make a determination to enhance or abandon the test design. Further display capabilities allow the user to proceed with a full 3-D visualization of their customized ejection sled test design.

In order to have rapid 3-D views of the test setup, code has been written that will automatically incorporate selected user inputs into a visualization preview. This preview contains needed information for the Alias/WaveFront visualization software package. A digital terrain model of the sled track area (Digital Elevation Model format, DEM) has been developed and included into a default visualization preview. Also included are visualization objects that represent the laser track data acquisition mounds, buildings, roads and observation towers. This preview creates a realistic model of the sled track environment for training and safety analysis support.



To specialize the preview for a particular sled test design, specific objects such as the ejection sled, the type and number of rocket motors and the desired payload are integrated into the file. Finally, using the output from the analysis codes, motion data for the sled and the payload are created and incorporated into the preview.

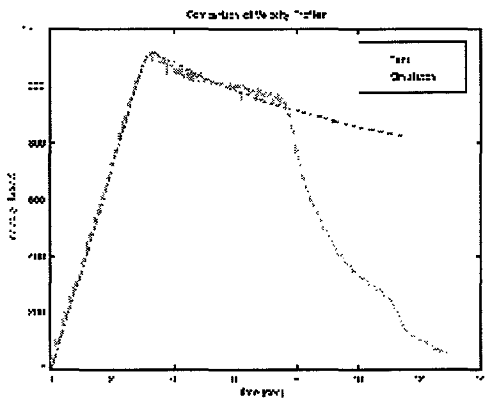
When the user selects to view the 3-D visualization of their sled track test simulation, the Alias/WaveFront software is started and the preview file is loaded. The interface for the visualization software allows the user to observe the scene from a number of different views using camera objects that are placed around the visualization model. Each of the camera views is "parented" or tied to the payload in the simulation model. The user can simultaneously select multiple camera views to observe their simulation. The available viewpoints include the four laser tracking site mounds (which provides the user with a tool for comparing data acquisition locations), a birds-eye camera view of the payload and a top view (which is used to analyze safety zones). Plots of the sled and payload motion files can also be displayed along side the 3-D visualization increasing their value to the test engineer.

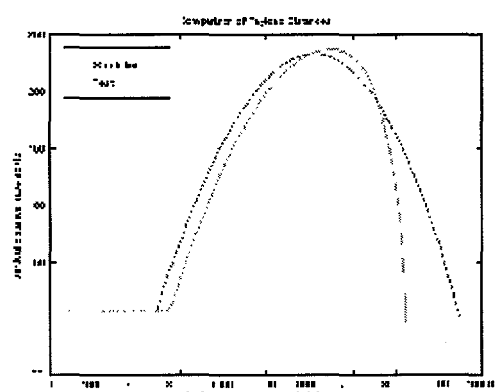
Comparison of Large Scale Sled Track Ejection Test and Simulation:

The real value of a test simulation tool can be determined by how well that tool is able to predict the results of an actual test. Our desire was to compare the results of a large scale sled ejector test with the results calculated in the simulation environment. A test was conducted on a payload using an ejector sled to launch the payload so that the its aerodynamic performance could be monitored during free flight. This particular test was performed before the simulation environment was completed, therefore, the simulation tool was not used in the test design efforts. However, this gave us the perfect opportunity to compare the test and simulation results to determine where more development effort in the simulation analysis codes might be required.

A sled track test was conducted using the large ejector sled with two Nike rocket motors to propel the sled down the track. After the rocket motors burned out (approximately 4 seconds), the sled was allowed to coast for a short time before ejecting the payload to a desired height of 250 feet. The particular Nike motors used were selected for this test in order to reach a desired ejection velocity of approximately 1100 ft/sec. The performance of the payload was monitored through its free flight during which a parachute was deployed to allow the system to safely glide back to earth. Two laser tracker systems (located on mounds II and III) cooperatively tracked the payload during the test and Time Space Position Information (TSPI) was collected. Water braking stations along the south end of the sled track were setup to safely recover the sled after the ejection phase of the test. Video footage was also collected from a number of different views to document the results of the test. ***This quick-time movie shows several clips of the actual sled test. Be patient it will take some time to load.***

Similar test parameters were incorporated into the graphical interface as inputs to a sled track ejection simulation. Based on these inputs, a visualization preview, including payload and sled motion, was created for the 3-D visualization. Our goal was to try to make a direct comparison between the simulation and test and to analyze any differences within the visualization software. The TSPI data collected from the laser tracker systems during the test were used to generate additional payload and sled motion data for comparison purposes. A similar set of visualization models or objects were used for the comparison in Alias/WaveFront. In general, the results of the comparison were very encouraging. The track acceleration code used to predict the sled system thrust profile and velocity compared very closely with the actual sled test. Additionally, the ejection code used to estimate apogee or maximum free flight height also compare closely with the test results. ***(Click on image to view in more detail)***





The part of the simulation that did not directly compare with the test was the result of a lack of parachute drag information for the payload simulation. Thus, one of the major differences we see in analyzing the test and simulation data in Alias/WaveFront is related to the drag values for the payload. The result is that the payload, representing the actual test, travels for a longer time but for a shorter distance in free flight. Without the parachute drag values, a direct relationship between the test and simulation can not be made, but the simulation data does provide an upper bound on the distance that the payload will travel. This is often of concern in determining exclusion areas. Another difference that can be observed through the visualization is in the timing of the payload ejection. The simulation predicts the payload ejection approximately 0.15 seconds sooner than the actual ejection occurred for the test. This difference can be attributed to the location of the trip wire used in the test to trigger the payload ejection. This wire is located at a certain distance down track based on a desired or idealized ejection velocity.

The following quick-time movie shows a comparison of the test (red payload color) and the simulation (blue payload color). Be patient it will take some time to load.

Summary and Follow-on Work:

The VETO sled track tool has been developed to enable test engineers to rapidly and efficiently design and visualize sled track tests. Multiple views of the simulation provide the engineers with the needed data for answering difficult questions about their designs. It is estimated that using this simulation environment could significantly reduce test design time while providing test engineers with critical design information needed for the actual physical test. This tool also provides a mechanism for archiving the test information for later analysis and simulation studies. Because the sled tests can often be very expensive one-of-a-kind tests, the VETO simulation tool increases the probability of success by allowing users to "optimize" their test design before conducting the field test. This unique visualization capability has also shown success in comparing actual test and simulation performance data. Additional VETO work will include the development of optimization codes that can be used to determine a set of test parameters given a desired set of results or outcomes.

Acknowledgment:

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References:

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