AIAA 2001-2061
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16th AIAA Aerodynamic Decelerator Systems Seminar and Conference
21-24 May 2001
Boston, MA

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ABSTRACT

This paper describes recent developments in a virtual reality (VR) training device developed to teach parachute guidance and control from deployment through landing. Parachute training simulation originated over 12 years ago for training to improve the safety and performance of smokejumper and military parachutists. While improvements and developments continue for these functions and are discussed in this paper, progress has been made in applying this concept to a number of other applications such as sport jumping , arcade and theme park entertainment, museums, aircrew emergencies , and operational mission planning and rehearsal including GPS navigation.

INTRODUCTION

This parachute simulator[1] currently allows the jumper to deploy a parachute during free fall, visually check the canopy for proper deployment[2], mitigate malfunctions, and cutaway and deploy a reserve parachute if required, then exert control and guidance through to landing.

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A range of visual data base selections are available for a given jump, and methods are now being developed to allow rapid preparation of visual and wind field data bases for rehearsal of specific mission objectives. This process for developing mission rehearsal visual and wind scenarios will incorporate available digital terrain profiles, satellite or aerial photographic imagery of ground terrain and weather information. The simulator has also been interfaced with a commercial GPS navigation device designed for parachuting, which allows training in the use of this equipment for guidance and navigation. This combined system is described in this paper.

This parachute simulator has been modified and upgraded to provide various features to meet requirements of a range of applications and the interrelating benefits of these enhancements are the subjects of this paper.

USDA FS FS-14/SF-10A Simulator Developments

The parachute simulator dynamics allow for proper representation of response to control inputs and wind fields. Modeling the turning, pitching, rolling and descent response of a given parachute required data on performance and other information on significant nonlinear behavior that affects control sensitivity and oscillatory response. For example a new USDA Forest Service (FS) parachute[3], the FS-14 has improved characteristics over the FS-12, including: faster forward speed, ability to fly backwards in brakes, slower decent rate, more rapid turn rate, and has been supplied in three different sizes.

The higher performance of this parachute design required the development of a new version of the training flight simulator[4] for Forest Service. This version was adopted this year by all Forest Service training centers. It incorporates these improved flight dynamics characteristics and a number of enhanced training features.

These include a simulator scene developed to model a specific real-world Forest Service training landing zone with the difficult landing challenges typical of their rough terrain fire fighting operations, shown in Figure 1. Scene development for parachute simulation is a difficult task because due to the flight vehicle's steep glide slope angles and the parachutists need to look directly down at the landing zone below, towards the horizon for navigation and collision avoidance, and completely overhead to assess canopy condition. As a consequence, scenes must include the large overall details required for flight simulations with the small size details encountered in simulations for ground vehicles, with the further requirement that objects look correct from overhead as well as from horizontal viewpoint. This wide field of view is precisely what mandated the use of VR technology.

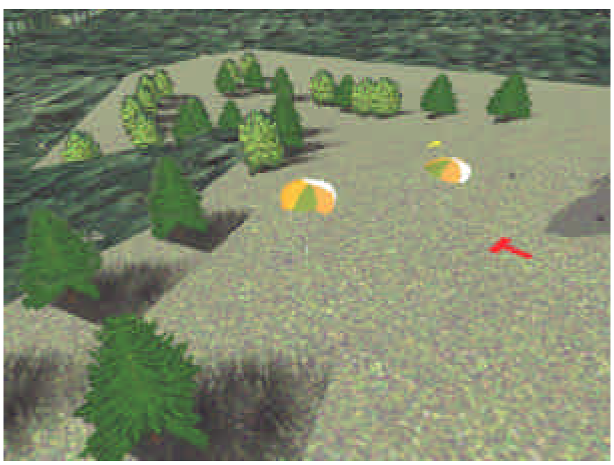


Figure 1. Simulated Montana USDA FS Landing Zone

Invisible 3D features like ambient winds can be a difficult concept to convey to a student. The streamer visualization feature, illustrated in Figure 2, shows a line representing a 3-d view of the actual path taken by a streamer dropped from directly above the selected target. This allows the instructor to demonstrate the effects of wind change with altitude and alert the student to any potential problem areas. When this feature is in use, the student's monitor shows the jump scene selected on the startup options screen with a yellow curving line starting at the initial altitude selected over the jump spot. The simulator computes a simulated path that streamer would take when dropped in the particular wind field selected.

Figure 2. Wind Visualization Through Streamer Simulation

Previous post-simulated jump view options were available to show the jump exactly as seen by the jumper or via a remote view of the jumper and jump scene from a view angle that can be moved by a joystick. While this perspective was particularly useful in viewing the effects of malfunctions and jumper motions, it and the previous jumper view playback mode presented problems in terms of understanding and critiquing of the navigational and collision avoidance tactics adopted by the trainee. For this reason and at smokejumper request, a jump review was added where the observer's eyepoint tracks along the windline above the jumper, and the joystick is not used. The jumper in the previous run is marked with a circle to distinguish it from any jump partner. This observation is useful for understanding the parachutist's path over the ground and relative to other parachutists.

The Forest Service has developed a new version of their simulator-based training syllabus. The large size version of this parachute has been adopted and has been bought in large quantity by the US Army Special Operations Forces (SOF) as the SF10A. The SOF has also mandated their own version of the Forest Service training program, including VR parachute simulators.

Arcade Entertainment Developments

A version of the parachute simulator has been adapted for arcade entertainment systems. The application, shown in Figure 3, was designed and is manufactured by Illusion Inc. This version is based on the MS Windows platform, and uses the OpenGVS rendering engine. (The earlier DOS versions of the parachute simulator used a proprietary TGE library and file format from Triac Inc.). The Windows graphics library uses the widely adopted Open Flight file format originated by Silicon Graphics

Inc. The parachute dynamics, head tracker, and jumper input sensor interface were ported to Windows by STI as part of this effort. Windows allows more versatile hardware compatibility and the use of a broader range of program and graphics scene generation tools.

Figure 3. Arcade Version

Figure 4. Simulation scene of MMFS at Yuma AZ

Mission Planning and Rehearsal Developments

STI is in the middle of a Phase II Small Business Innovative Research contract from the Special Operations Command (SOCOM) to develop a version to enable rapid generation of real world scenes based on digital terrain, photos, and weather data. This process involves the porting the current MS-DOS Windows implementation with a more modern graphics user interface (GUI), much better compatibility with modern PC hardware, and readily incorporate networking so that actual (rather than simply pre-recorded) interaction between parachutists will occur. Figure 4 shows two ram-air jumpers jumping above a scene replicating the Military Free Fall School (MMFS) area near Yuma Arizona. Figure 5 shows the process of generating real world simulator scenes.

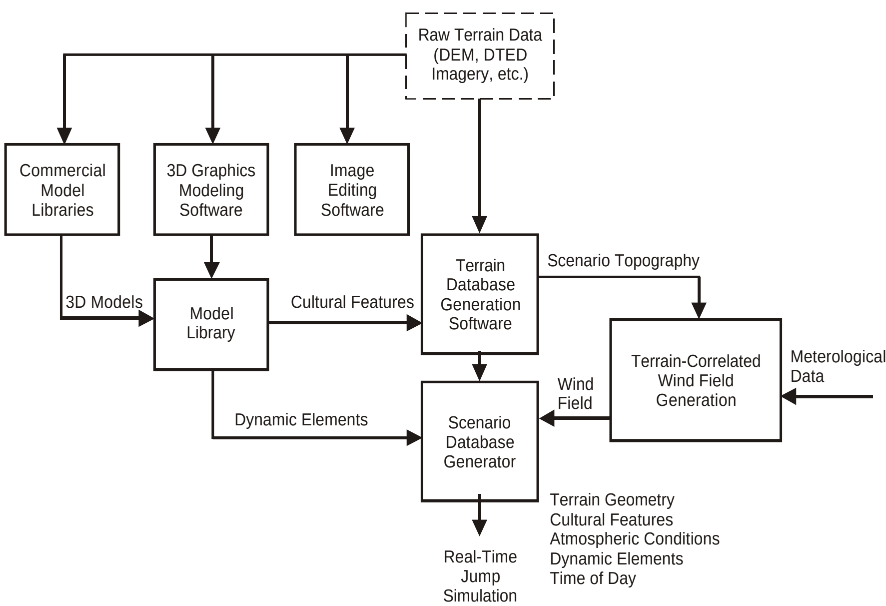
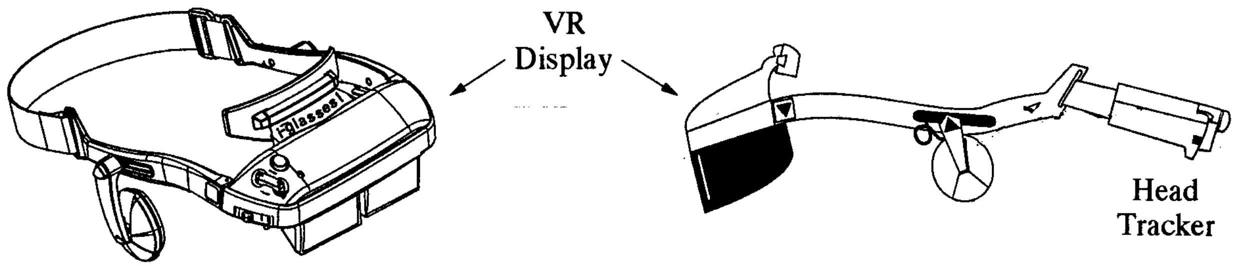


Figure 5. Process for Generating Mission Rehearsal Simulation Scenes



a) without head tracker b) with head tracker

Figure 6. VR Head Mounted Display (HMD)

a) HMD worn with elastic brow band b)Tracker attached to helmet c) full gear including oxygen mask and flight gloves

Figure 7. HMD Modified to Wear Under Helmet with Tracker Attached

<u>Aircrew Emergency Training</u>

The process of delivering and installing simulators in quantity for Aviation Physiology and Life Support training to the US Air Force Air Combat, Reserve, Air Education and Training Commands, Air National Guard, NASA, and the US Navy Naval Operational Medicine Institute Aviation Survival Training, provided an opportunity for review of this simulation by a wide variety of experienced life support and SERE (Survival, Evasion, Rescue, and Escape) instructors with a number of suggestions which were added for improved training capabilities[5]. In particular, scoring criteria were revised to accept a broader off-wind landing angle to align with aircrew parachute landing (PLF) goals and to allow for the high reverse landing speeds which may be encountered on the best of landings under the strong winds which can be encountered during emergency parachuting.

Additional aircrew training related improvements are in development. These include a VR system designed to be worn with a flight helmet and improved riser force sensors. Almost all current installations use a VR head mounted display (HMD) which can be worn alone with an elastic band between the ear pieces, or with an tracker substituted for the elastic band as shown in Figure 6.

Aircrew emergency procedures call for raising the visor and removing the oxygen mask (while wearing flight gloves) during descent under parachute canopy. Since aircrew would only experience actual parachute procedures and equipment operation as a dire and hopefully extremely infrequent occurrence, it was perceived as particularly important that training experiences replicate the actual event as closely (though safely) as possible.

Although there have been earlier attempts to use the HMD with the elastic band under a flight helmet and attach the tracker to the rear of the helmet, this had been unsuccessful due to interference between the HMD earpieces/earphones and the helmet. As a result, these procedures were taught prior to removing the flight helmet and donning the combined VR HMD/tracker for the simulated parachuting experience. However, the aircrew emergency training community expressed a strong desire to address complete training scenario issues in a single device in a continuous training experience.

In response to these concerns, the HMD has now been modified to remove the earpieces and attach the elastic band to the brow portion as illustrated in Figure 7a. Audio is supplied to the normal helmet earpieces, and the tracker is attached to the rear of the helmet with the visor cut away to clear the HMD as illustrated in Figure 7b.

Use of a Personnel Lowering Device (PLD) is required by certain aircrew emergency procedures. A lowering strap is snapped to the riser straps and then the harness fasteners are released (Figure 8). Sturdier riser sensors are being developed which include damping devices to withstand the abrupt shock from this sudden drop and unloading. This capability will remove the need to train for this procedure in a separate hanging harness device.

Figure 8. Using Personnel Lowering Device

Aircrew emergencies can occur under far more difficult conditions than operational jumps, which have limits on terrain, weather, etc. Obviously these limits do not apply to emergency situations when mishaps can occur over any terrain. Thus, simulators were supplied to the US Navy Aviation Survival Training Centers (and previous US Air Force Life Support units) which featured weather conditions such as rain, fog, overcast, and improved night lighting renditions.

Additional scenes emphasizing over water and coastal locations were also supplied. The Instructor's screen reminds of the need to coach the trainee below 200 feet altitude to minimize maneuvering, prepare for parachute landing fall, and watch the horizon. A typical jump scene is shown in Figure 9.

Figure 9. US Navy Aviation Survival Training Scene

Some aircrew ride in aircraft with ejection seats; others get parachutes but must bailout (egress) in emergencies. As shown in Figure 10, these parachutes are typically equipped with emergency manual ripcords (metal handle), a ripcord to arm an automatic activation device (AAD) with a red knob which then opens the parachute container when the jumper is below a preset altitude while in some systems simultaneously exceeding a specified descent rate, and a ripcord with a green round knob to release oxygen. Ripcords have been featured in the operational version of the program for some time and are now included in the emergency aircrew version as well. The AAD feature has now been added to the sport version of the program.

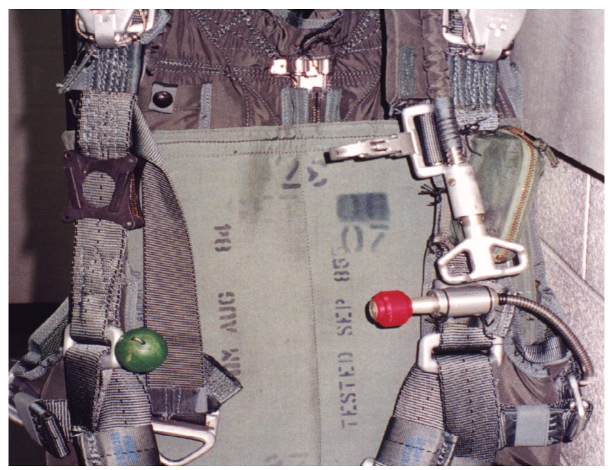


Figure 10. O_2, AAD, and Manual Emergency Ripcords

New Jumper Suspension Frames

Hanging harness training has long been mandated for operational, and especially for aircrew-emergency parachute training. The trainee hangs in an actual harness, suspended from above by riser straps, wearing flight suit, gloves, helmet with oxygen mask and visor, etc. Some of these rigs were suspended from a ring-attached overhead to a single point. These existing systems often had pulleys attached to the ring adjacent to the risers, and control lines were then run back and attached to the wall behind the jumper. When the jumper pulled on the lines, he was physically rotated in the direction he pulled. This was seen as advantageous in systems without a simulator, even though the control-motion-to-visual correlation was poor. Earliest versions of the VR parachute simulator system were installed with existing hanging harnesses. Attaching the controller box to the wall or floor modified these systems, and the control lines were routed from the box down through the pulleys to the jumper.

Figure 11. VR Parachute Simulator Suspension Frame

Some initial aircrew training installations used the single ring harness attachment discussed above, but it was clear that undesirable motions occurred during the simulated jump. More recently the frame shown in Figure 11 has been developed to give a consistent installation that stabilizes the trainee, and also allows for installation of four riser strap sensors that are used in conjunction with malfunction training.. With a VR simulator, the lack of synchronization between physical motion cues and visual motion due to the dynamics of the simulated parachute would be worsened further by the effects of the physical motion on the jumper's head tracker. When possible, to minimize this problem, horizontal suspension rings were attached via lines tied to fasteners anchored in adjacent walls.

The simulator now allows runs to start in free fall at up to 25,000 ft. altitude. A frame enhancement has been developed which attaches to the bottom of the parachute harness with a standard 3-ring release. For good opening parachutes, one part of a 2 line main ripcord is then routed though this release, and the other part is routed through the main ripcord sensor. The simulator jumper is pulled up to a horizontal position as shown in Figure 12. When the ripcord is pulled, the simulated parachute opens and the jumper feels himself moving to a vertical position.

Figure 12. Horizontal Start Hanging Harness

When a high speed malfunction is selected by the instructor, one part of a 2 line reserve ripcord is then routed though the harness pull-up bottom release, and the other part is routed through the reserve ripcord sensor. Thus in this case, when the jumper pulls the main ripcord, he stays physically horizontal, but when he pulls the reserve, he physically moves from a horizontal to vertical position.

GPS Guidance System Simulator Based Training and Rehearsal

OPANAS (Operational Parachute Navigation System) is a GPS, altimeter, and magnetic compass based guidance system originally developed by NAVOCAP S.A. and enhanced by SSK Industries for use by HAHO (High Altitude High Opening) jumpers. The parachutist views position, altitude, and relative position to the target.

Prior to the mission, the guidance system is programmed with course data derived from target coordinates, forecast wind aloft data and canopy performance information, and displays in moving map format a flight path and the real-time position of the jumper.

Mission Management Planner (MMP) is a SSK software program that runs on a PC computer (typically a laptop which can be attached to the guidance system) that permits complete HAHO mission planning. Mission information is entered into the MMP, including target coordinates and elevation, forecast wind data and canopy performance. An exit area is calculated and displayed on the mapping program. The MMP is also used to program the guidance system.

Field reports from HAHO troops had indicated that the logistics and expense of practicing HAHO jumps limit the training available. Less than acceptable results are obtained when the jumps are performed in practice or actual insertion activities. STI and SSK addressed this problem by developing the On-Target System, which combines the OPANAS and MMP with the VR training simulator to enable HAHO troops to fly simulated missions using realistic wind, meteorological and terrain information. Figure 12 shows the components of the On-Target system and Figure 13 shows the data flow between them.

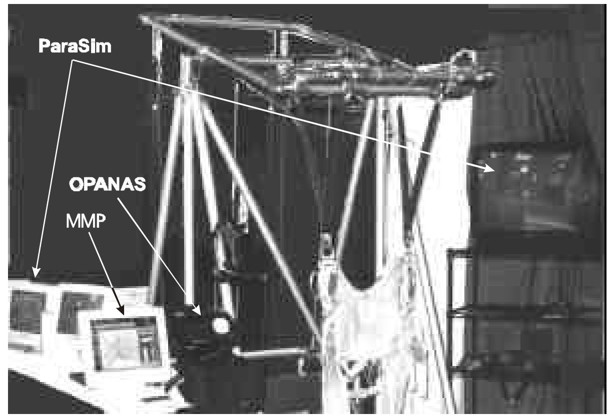


Figure 12. On-Target system with OPANAS, MMP, and ParaSim™

The On-Target System permits multiple practice flights to be completed prior to a practice jump or actual mission. In the case of mission training, the MMP also programs the parachute simulator (ParaSim™). The MMP is used as a control panel during simulated training missions. MMP allows the instructor to vary certain simulated conditions during mission planning, such as adjusting the winds aloft from the forecast values. The instructor can also monitor on the MMP the path followed by the jumper in real time during simulation.

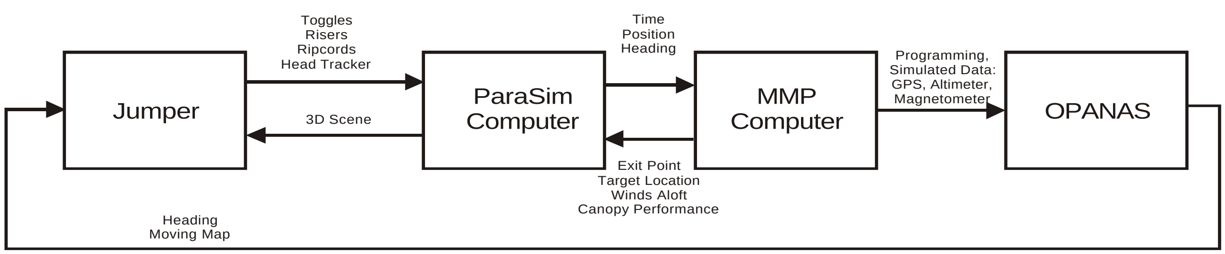


Figure 13. Data Flow Diagram for the On-Target Training System

<u>Sport Parachuting</u>

Over the last few years, sport parachutes have evolved into very high performance, small size, very high wing loading designs. These canopies require high skill levels to be flown with any degree of safety, so there is an obvious motivation for the frequent requests for simulator training. While these parachutes are sold based on published flight data for forward and vertical descent speeds, the data provided is not necessarily for the same flight condition; and suspended weight, altitude, temperature, and barometric pressure are not stated but are required to accurately simulate the parachute dynamics. In addition, the simulation needs data for braking and turning inputs.

The answer to this problem was to develop a flight test aerodynamic data acquisition system specifically to produce data for simulation modeling. Important parameters to measure include forward and vertical inertial speeds (together with measured suspended weight, temperature, barometric pressure, and altitude) at full flight and the full range of brakes, and turn rates, bank angles and vertical acceleration through the full range of toggle deflection. Consistent data sets had been previously obtained from Para-Flite, Inc., manufacturer of MC-5/MT-1XX series, and other US military canopies. The SSK system described below and shown in Figure 14 is based on instrumentation similar to that used by Para-Flite to collect performance data for their canopies.

The SSK system measures canopy performance using a barograph package designed for use under paragliders. The barograph, an IQ-Competition model manufactured by Brauniger Flugelectronic GmbH of Weilheim, Germany, measures time, altitude, rate of descent, and total airspeed. Given w, rate of descent (vertical airspeed) and V, total airspeed, simple trigonometry computes horizontal airspeed. A GPS is connected to the barograph to measure position and heading data.

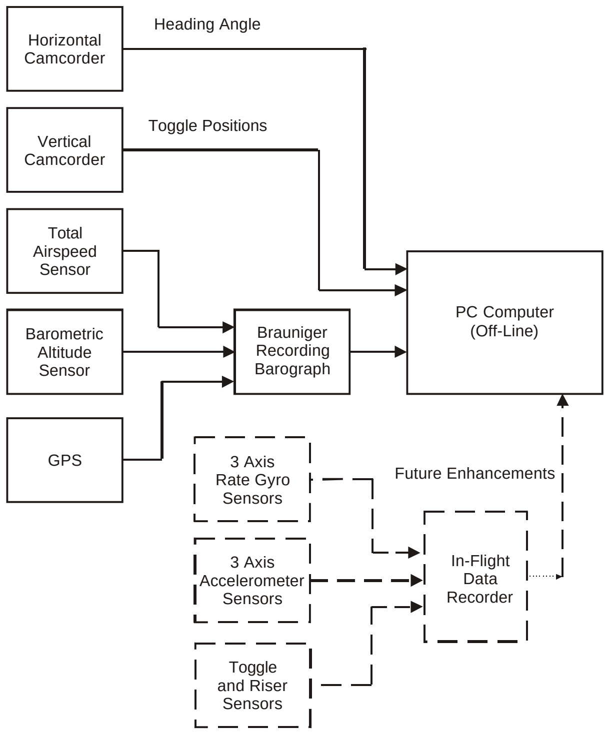


Figure 14. Parachute Data Acquisition System

The instrument package calculates altitude by measuring the pressure difference between it's location and a pre-set reference pressure, typically the surface pressure or sea level pressure. Airspeed is measured by a calibrated propeller sensor suspended beneath the jumper, clear of airflow interference.

Data are recorded once per second in the instrument package, and up to 50 flights can be recorded. The data is downloaded into a PC through a serial connection and a software program supplied with the barograph. The software program downloads the raw recorded data and also prepares graphs of the altitude, airspeed, and vertical speed.

GPS information sent to the instrument package updates once every two seconds, and is not useful as a heading indicator during rapid turns. To measure turn rates, a digital camcorder, pointing horizontally, is mounted to the jumper, who uses a well-defined landmark (such as a road) for an initial heading and reference line. This also gives bank angle information during turns. Another camcorder, vertically oriented, records toggle and riser inputs. Under development is a system that will include a 3-axis accelerometer and gyro system to collect more detailed canopy performance data.

Conclusions

The availability of a parachute flight simulator has lead to the development of a variety of particular requirements for a wide range of applications. These requirements have been met by a number of program improvements that benefit all of these applications.

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