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ABSTRACT

Since aircrew ejection and bailout emergency parachuting can occur in dire circumstances with no opportunity for actual training jump experiences, it is particularly critical to maximize the scope and face validity of potential training experiences to accustom trainees to as broad and realistic situations as possible. The urgency of this training has been accelerated by the stresses of aging aircraft deployed in severe environmental and combat situations.

Recent new developments in graphics scene display hardware and software have been employed to provide more detailed and accurate scene depiction. Enthusiastic adoption by and interaction with both a large aircrew emergency and airborne paratroop training communities has suggested a number of improved instructor training controls. These visual improvements are described in this paper, together with developments in user-driven improved simulator training techniques and instructor interface.

BACKGROUND

Whether in training or actual combat, military flying is inherently hazardous. Aircraft and crew are subject to high stress; mishaps occur; and aircraft are lost. In these cases, the best that can be hoped is that ejection or bailout will have put aircrew under parachutes. These events can happen in far worse circumstances than would be acceptable for airborne paratroops, and while actual jump training is not practical, this highly stressful situation still requires confidence for success, quick but orderly, virtually automatic decision making, and skilled physical reactions. In almost all of these emergency parachuting incidents, the aircrew are uninjured when the parachute has opened successfully; the problem is then in following procedures to achieve a safe landing.

Figure 1. Aircrew Parachute Simulator Training

When training relied only on classroom lectures and simple suspended harness procedures demonstrations, trainees were required to pretend that they were under a canopy and exhibit actions without seeing their impact in the form of timely, correct results. Using this methodology resulted in significant landing injuries on more than half of emergency incidents, usually due to incorrect emergency procedures. Proper procedures and actions were not sufficiently ingrained through these teaching methods, and as a result, aircrew either performed incorrect actions or failed to perform correct actions and procedures. For example, 4-line releases were seldom deployed, resulting in oscillating, almost-uncontrollable canopies that led to landing injuries.

As with other physical skills-related (sports-type) activities, it is essential to avoid learning incorrect behaviors, as bad habits can be very difficult to unlearn and avoid, particularly in high stress circumstances. Actual real-life parachute training, however, is far too costly and dangerous to be required for aircrew personnel.

The solution lies in a simulator-based training system originally developed for USDA Forest Service (FS) smokejumpers [1] (civilian fire fighters operating round parachutes) to establish smooth basic parachute flight (canopy control) skills in extremely difficult conditions. The smokejumpers were faced with a similar dilemma: reducing training jumps to reduce injuries leads to more on-the-job injuries and poorer performance. The simulator provided training that reduced injuries and improved skills. Similar results were obtained when simulator-based training was adopted by military operational units [2].

Recent even wider acceptance in the airborne operational parachuting community has triggered an opportunity and initiative currently underway to greatly improve this concept by completely rewriting the Graphics User Interface (GUI), core scene graphics display engine, and other key programing and physical simulator components.

Former Secretary of Defense Rumsfeld mandated [3] as a first priority the adoption of technologies and devices that will save lives by training personnel for very trying circumstances. Secretary Rumsfeld stated that these have “must fund” priority and are no longer to be considered as “nice-to-have.”

Aircrew may be in far more trying situations than operational jumpers, since emergencies can occur without regard to daylight, weather, altitude, terrain, etc. restrictions. These factors are all available and controllable in the simulation environment. Moreover, aircrew emergency parachutes are much more likely to malfunction due to openings at severe speeds and adverse jumper body positions. A quick and accurate response is essential; there is no reserve parachute. These malfunctions can also be presented in the simulation, where aircrew can learn the correct procedures to follow for each type of malfunction under controlled classroom conditions, so that the skills will be well-practiced and automatically employed when they are most needed, in the critical situation of an actual parachute malfunction. Fig. 1 shows an aircrew deploying his parachute in a typical parachute simulator in use for bailout training. The installation places the trainee under a C-9 parachute draped over the suspension frame to reduce extraneous room lighting in the HMD (Head Mounted Display).

LESSON PLAN TRAINING GOALS

Widespread adoption of emergency parachute simulator training has led to the development of procedures manuals, instructor guides, and lesson plans[4]. These plans vary depending on the particular emergency circumstances foreseen, but all share the goal of presenting as complete as possible a sequence of challenges employing as much equipment and encountering as many of the events as can be expected in a real emergency; that is, a goal of minimizing the part-task aspects of this training. These plans incorporate the extensive sequence of operations required for success in emergency parachuting.

SYLLABUS SCOPE

Suspended in the appropriate parachute harness, the trainee can and should be fully equipped with helmet, visor, oxygen mask and communications equipment, flight gloves, LPUs (life preservers), ripcords if applicable, seat kit and other equipment. Fig. 1 shows an aircrew trainee fully equipped for simulator bailout training.

Figure 2. Instructor Observes Student

The instructor is equipped with two monitors as shown in Fig. 2. One monitor provides training control and status, the other provides the identical scene shown to the student through the HMD. Thus the instructor has a unique capability literally to see exactly where the student is concentrating his attention, and can move the mouse indicator over into this display to point out important concepts, all while observing and conducting a dialog and critique about the student's body positions and control actions.

After setting up the simulated mishap situation, the instructor's training task then is to see that the student proceeds rapidly but correctly through an extensive memorized specific sequence of actions. The simulator senses and responds appropriately to head orientation, ripcords, risers, and steering inputs.

Training starts in free fall, with canopy deployment automatically by the ejection seat (and should cover failures in automatic seat deployment), by the trainee's decision to pull the manual ripcord at lower altitudes, or to pull the Automatic Activation Device (AAD) and oxygen ripcords at higher altitudes. Standard emergency bailout procedures most often prescribe immediate AAD activation in case of accidents during egress that may preclude manual deployment. These procedures also require a tucked body position rather than the operational arched posture.

Figure 3. Simulated 4-line released and partial inversed C-9 parachutes seen overhead

Once canopy deployment has occurred, the aircrew should check overhead and identify possible malfunctions, and decide on and employ appropriate correction procedures to mitigate a malfunction. Typically these require riser inputs. Swift, correct actions are critical and must become almost automatic; there is no reserve canopy.

Next, the trainee should scan the sky: is immediate riser steering needed to avoid danger of collisions with other parachutes? This is not just a bailout problem; mid-air collisions are a significant cause of ejections.

This is followed by equipment procedures involving life preserver, visor, oxygen mask and communications equipment, LPU's (over water?), and seat kit. This equipment can and should be setup so that the instructor requires the trainee to actually complete the required actions, not just touch and discuss it.

Finally it is time to make the parachute steerable (or finally in the case of canopy rips and tears, to use the risers for steering; all parachutes can be steered this way), and to check again overhead, as shown in Fig. 3, to determine if the steering modification has worked.

It is then time to look down and assess the situation: do the controls steer the canopy, where is an attainable safe landing area, and what is the wind? The goal is to plan a safe, smoothly controlled and into wind landing. Near the ground, attention changes to looking ahead and positioning for a PLF (Parachute Landing Fall), or body configuration for tree or power line impact.

Given simulated night, cloud layers, overcast, and other possible visibility obscurations, the trainee may need to decide not to make the canopy steerable, and to assume a prescribed body position to prepare for a landing in hazardous terrain or other obstacles, since they cannot be seen to be avoided, and it is most likely also to be impossible to determine wind direction.

Simulator enhancements allow the inclusion of all these aspects in a single continuous dynamic VR experience. Many of the same sensory and procedural demands can be produced in the simulator with the same timing as might be experienced in a real emergency. Results of correct or incorrect actions are automatically displayed and scored, and a number of other program features are provided to facilitate instructor-to-student critique during and after the jump. In particular, with a jumper's view playback, the instructor can vividly illustrate concerns with where the jumper was looking during important jump phases.

HARNESS SUSPENSION FRAMES

Suspended harness training is well accepted as an essential component of all initial and recurrent parachute instructional programs. The trainee hangs in an actual harness, suspended from above by riser straps. Previously, lacking a simulator, trainees were required to pretend that they were under a canopy, and display actions without seeing timely and correct results. This is training for a control situation without supplying necessary visual feedback. Some of these rigs were suspended from a ring that was attached overhead to a single point (often attached to an electric winch) and some had elastic control lines attached to fixed points. 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 and vestibular cues correlation was poor.

Early VR simulator installations were made by attaching control sensors to existing suspended harness configurations[5]. It quickly became obvious that undesirable motions occurred during the simulated jump.

The challenge was to provide extremely robust, rigid, and yet economical systems[6] that can be readily customized to widely differing training room setups. This was met by a number of designs based on industrial shelving (shown in Fig. 4), extremely sturdy commercial scaffolding, or balcony railing components capable of supporting loads of several tons. These systems carry very conservative duty ratings of 300 lb. but actually vastly exceed applicable OHSA Standards 29 CFR 1296.451 and 1910.28 requirements, and do not need to be fastened to the floor, wall, or ceiling. Note that the lower front horizontal beam is installed at a seven foot level to provide a grab bar when snapping into the riser quick releases.

Figure 4. Industrial Shelving Based Frame

With users so valuing their simulator-based training that they were taking it with them on mission deployments, a more transportable 2x2x3 meter version, shown in Fig. 5, was developed and delivered.

The controller box for this transportable version has been reduced to one third of standard size, and the system can be operated from modern laptop computers with advanced graphics capability and auxiliary signal interface cards (although the unit in Fig. 5 added an auxiliary large plasma display). This capability allows aircrew to maintain proficiency while deployed near tactical operations.

Figure 5. Transportable Frame

RIPCORD PROCEDURES

Some aircrew ride in aircraft with ejection seats; others get parachutes but must bailout in emergencies. As shown in Fig. 6, these parachutes are typically equipped with emergency manual

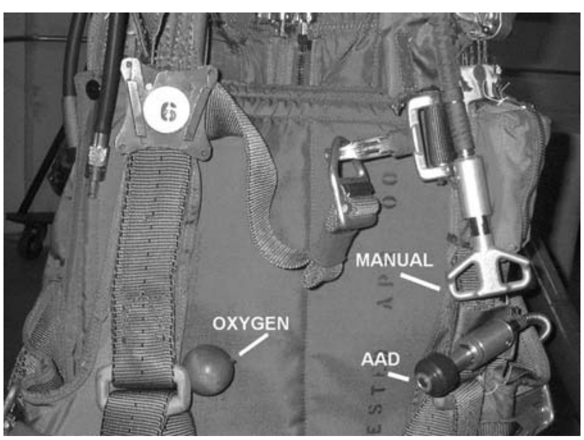


Figure 6. BA18 Manual, ADD, and Oxygen Emergency Ripcords

knob that then opens the parachute container when the jumper is below a preset altitude, after a specified time delay (14,000' and 4 second delays are typical). Some aircrew AADs also require that the descent rate exceed a specified value before initiating the opening. During bailout, aircrew also can pull a ripcord with a green round knob to release oxygen.

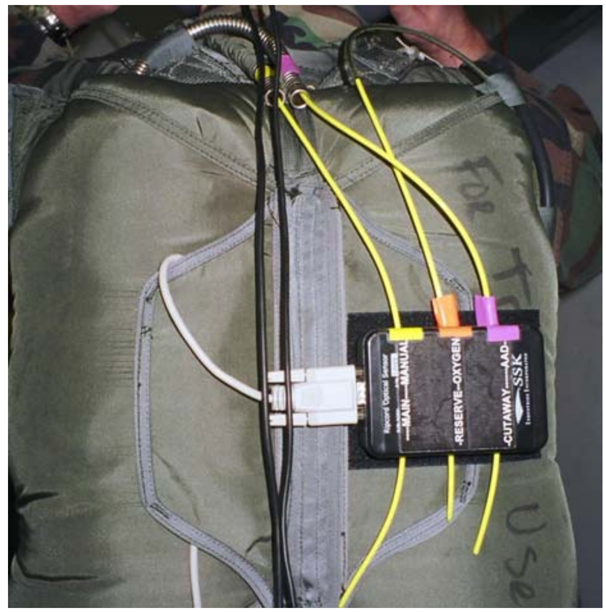


Figure 7. Optical Ripcord Sensor on BA22 Harness

In the simulator, these functions are provided by rerouting the ripcords and their housing to an optical sensor pack mounted by Velcro on the parachute container, shown in Fig. 7 on the back of a packed BA22 (Back style Automatic) harness. Using a packed harness provides the correct weight feel, useful in teaching the proper harness fit, which is essential to avoiding injury from parachute opening shock.

If a BA18 or BA22 aircrew simulation starts at 25,000 ft using ripcords, the trainee's display will gradually black out until the oxygen is deployed, at which point it will come back on. This blackout is somewhat accelerated for instructional effect.

Ripcord capability is also useful in ejection training, where it can be used to cover the possibility of automatic seat deployment failures.

PARACHUTE MALFUNCTIONS

Once a simulated parachute has deployed, the aircrew must look up and assess its condition. Malfunctions are much more likely in emergency parachute openings than in operational conditions, due to opening at severe speeds and adverse jumper body positions, and the consequences are more severe since there is no reserve parachute.

The simulator programming has recently been migrated to Windows DirectX, providing greatly enhanced graphics depiction and user interface capability. One use of this improvement was to produce significantly more detailed parachute models that more accurately illustrate normal and malfunctioning canopy conditions. This improves the aircrew's ability to provide quick and accurate corrective responses through the suspension risers.

Frequent riser manipulation to clear malfunctions and provide an alternative steering mechanism led to the development of a more rugged design with a shock absorber inside a suspension spring, as shown in Fig. 8.

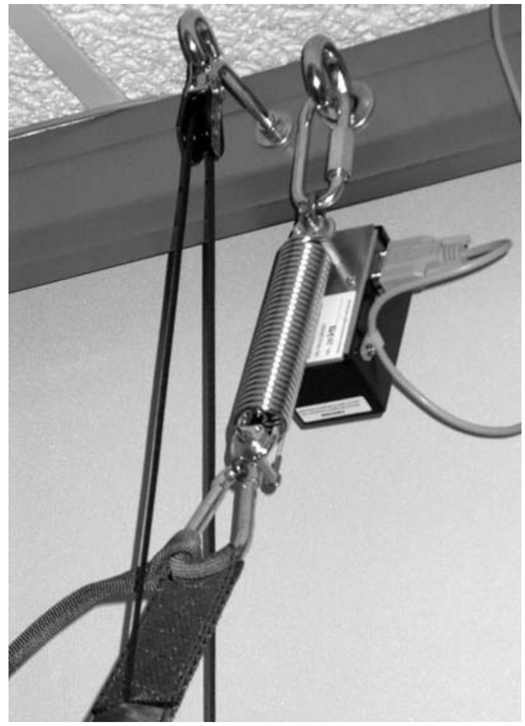


Figure 8. Damped Riser Force Sensor

EQUIPMENT PROCEDURES

As shown in Fig. 1, it is possible to use a HMD worn under a single (or dual) visor helmet. A head orientation sensing tracker is attached to the back of the helmet and senses the direction that the jumper is looking. This information is then communicated to the simulation computer, which uses this orientation vector and the toggle and riser sensor inputs to the parachute dynamics model to compute the corresponding jumper's location and orientation within the graphics scene model, with a typical view as shown in Fig. 2. This model view is then displayed to the jumper on the dual screen HMD.

The aircrew should be wearing flight gloves to replicate the difficulty that they create, and should have an oxygen mask attached to his helmet and CRU fitting. It is even possible to wear the aircrew chemical defense ensemble (First Generation) and the Aircrew Eye Respiratory Protection System (AERPS), as shown in Fig. 9. The aircrew can also be equipped with LPU's and a seat kit, as shown in Fig.1.

Figure 9. AERPS Under HMD and Hemet

SIMULATOR SITUATIONAL AWARENESS AIDS

Although the HMD-Tracker combination allows the VR simulation participant to see in any direction by turning his head, a real jumper has an extremely wide immersive view that he can rapidly scan with primarily eye motions to maintain flight situational awareness. One consequence is that the simulator task requires larger and more conscious scanning efforts that are more difficult than the real task would require; a proficient simulator-trained individual will then find it easy to exercise situational awareness during a real parachute jump. This increased difficulty can be mitigated by a number of orientation indicators under instructor control. These indicators include a digital altimeter, wind line marker, control toggles, jumper's boots, and a jump partner highlight locator symbol, as shown in Fig. 10.

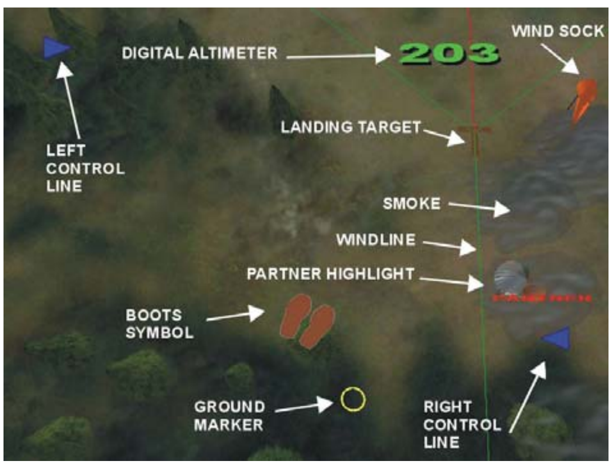


Figure 10. Simulator Orientation Aids

Jump Partners can be created by saving simulator runs for this purpose. This is useful in providing canopy collision avoidance for bailout training, or for ejections from two seat aircraft. When jumping with a jump partner, it is frequently difficult to locate the partner, particularly when the active jumper is at an appreciable distance. If Partner Highlight is enabled during the run, an indicator will be displayed under the partner to aid in locating him as is also shown in Fig. 10.

If the jump partner is off-screen, out of the active jumper's current field of view, the indicator will change color and move on the edge of the display indicating the jump partner's off-screen location.

IMPROVED VIRTUAL REALITY HEAD-MOUNTED DISPLAY AND TRACKER

As described earlier, the simulator has been enhanced with improved situational cue displays, much better and more geo-specific virtual scene detailing, and real time display of interactions with other real simulator parachutists. For these visual improvements to most effective, limitations in their display to the simulator jumper also needed to be improved in quality, field of view, and head orientation tracking.

Head Mounted Display

Almost all of the previous PARASIM installations used an S-Video (320X240) 30 degree field of view (DFOV) 3X4 ratio (18 deg vertical, a 20 deg horizontal), LCD i-glasses HMDs which could be adapted to attach to a flight helmet. A few installations used 60 DFOV 640X480 Kaiser ProView60 HMDs that were fairly fragile, quite large and heavy, extremely expensive, and not suitable for use with flight helmets. New PARASIM systems currently are being equipped with eMagin Z800 3Dvisor 40 DFOV SVGA 800X600 OLED (organic light-emitting diode) HMDs that can be adapted for helmet mounting as shown in Fig 9, thus reducing head motions for scanning and providing clearer views of visual cuing.

Head Orientation and Tracking

In both real and simulated jumps, it is essential that the parachutist be able to look well overhead and check out his parachute condition for proper opening, look down and observe where his feet are over the ground, look to the side for other jumpers, stay oriented with respect to surrounding terrain landmarks, and near the ground and landing, watch for obstacles and get a sense for velocity magnitude and direction, and altitude.

A jumper's torso is fairly rigidly restrained upright when suspended in a hanging harness; he can't rock back, lean forward or swivel around as when standing on his feet. Head neck pivoting or tipping rotations are limited to 30-40 deg in each direction, less if additional constraints from helmet, gear, or parachute risers are present. To some degree, a jumper can augment these rotations by pushing against the risers; this is an important and non-obvious concept to be simulator trained.

Unconstrained by viewing through a HMD, the eyes themselves can rotate to scan around 90 deg to the side and 70-80 deg down or overhead. Adding unconstrained head rotations and with only minor riser pushing, a suspended jumper has the ability to meet the discussed scanning requirements.

The head orientation tracker used in almost all of the previous installations was a somewhat limited dynamic range VI/O device equipped with pitch and roll fluidic tilt sensors, and a two axis (vertical and horizontal) magnetometer compass sensor for yaw. Display pitch and visual aids augmentations are required, together with vigorous riser pushes, to meet the discussed scanning requirements. This is another example of simulator system limitations mandating the same but even more conservative training of skills needed for safe flight.

The current PARASIM program versions include support for separate Intersense InertiaCube[7] trackers which are equipped with 3 axes each of accelerometers for tilt measurements, of tuning fork angular rate gyros, and of magnetometer compass sensors for stable angular references. Well developed Intersense software drivers supply optimally smoothed data for any head orientation angle and there are no rotational limitations.

This eMagin Z800 HMD[8] includes a head orientation tracker on the display's circuit board in the VR cover with similar transducers as in an InertiaCube. The eMagin-supplied software drivers have noticeable limitations that currently restrict PARASIM use to be specified for "Fail-Op" backup only. Current research and development is attempting to find and develop better PARASIM program support. A number of OEM eMagin HMD driver issues have already been fixed in PARASIM.

FUSED REALITY

As previously discussed, it is critical that the trainee learn to deliberately scan over a wide field in both simulated and real jumps. The jumper's torso, legs, boots, arms, and equipment like front packs, risers, etc. will block his view and interfere with this scan. While it is possible to include a virtual "body" model in the VR displays, it would be necessary to greatly complicate the system to sense detailed body motions and animate this model to show arm, hand (particularly control motions), and leg movements.

One solution is a technique STI created called "Fused Reality." Used in an ongoing Navy Phase II SBIR, Fused Reality[9] is a technology developed at STI by Dr. Bachelder that employs three proven technologies – live video capture, real-time video editing (such as blue screen imaging), and virtual environment simulation, where video from the user's perspective is sent to a processor that preserves near-space pixels and can make transparent the far-space pixels using blue screen imaging or object recognition techniques. This bitmap is overlaid on a virtual environment, and sent to the user's helmet mounted display. Thus the operator directly views the physical cabin environment, while the simulated outside world serves as a backdrop. Figure 11 illustrates this process, where a real cockpit environment is presented to the user and the windows are color-coded with the target color, magenta. The virtual forest backdrop is seen through the cockpit windows as the magenta pixels are made transparent.

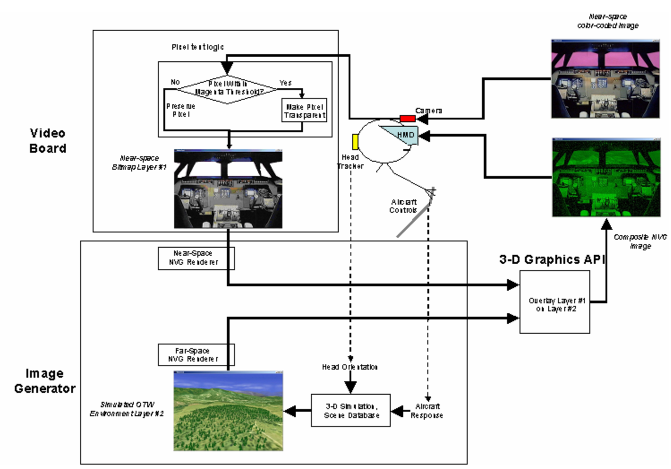


Figure 11. Fused Reality Representation

This concept has been demonstrated in combination with a PARASIM system by draping mono-color backgrounds on the front, sides, floor, and top of a suspension frame, including a portion attached to the top of the risers, as shown in Figure 12a. The jumper wears a HMD, tracker and video camera co-mounted and aligned combination. Early mockup development versions have progress to an implementation with displays and cameras contained with the barrels of a standard NVG device which is then attached to a flight helmet, as shown in Figure 13.

Figure 12. Simulator Frame Draped with Monochrome Fabric for Fused Reality

Figure 13. Fused Reality Camera and HMD Mounted on Flight Helmet

The trainee in the Fused Reality simulation sees the simulation display wherever the key color (in this case, magenta) exists. The monochrome drape over the simulation frame becomes an immersive display, completely surrounding the trainee, yet allowing him to see his own arm movements, body position, and the direction of his feet, as shown in Figure 14. The Instructor's displays in Figure 15 show the simulation controls, the simulation display, and the live video feed from the camera mounted on the HMD.

a) Monochrome Drape b) Fused Reality User's View

Figure 14. Fused Reality Parachute Simulation

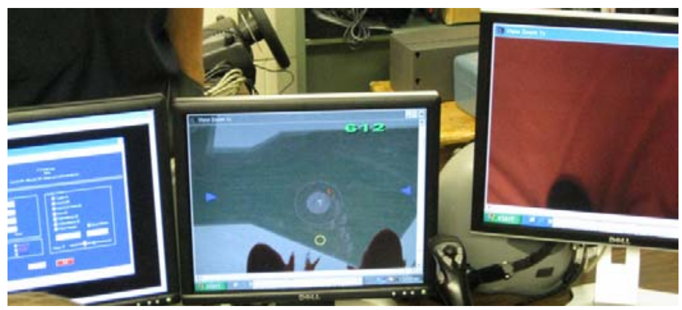
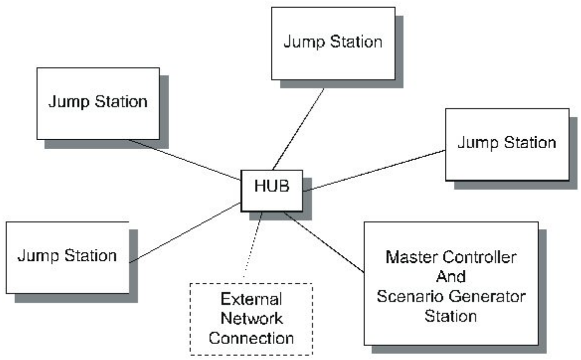


Figure 15. Fused Reality Parachute Simulation Instructor's Displays

MULTIPLE JUMPER BAILOUT TRAINING

The recorded jump partner is adequate for two-seat aircraft ejections, but large aircraft bailout situations may result in a number of jumpers in flight simultaneously. Training in this case can be provided by networked simulators originally developed for operational mission planning and rehearsal. In addition, an new optional feature will be available to allow building a group of prerecorded jump partners.

The networked system consists of a set of networked Jump Stations, a Master Controller, and a Scenario Developer consisting of a Visual Scene Generator and a Wind-Field Generator. A conceptual diagram of this network is shown in Fig. 16. This system provides the ability to simulate group parachute jumps using networked simulators and multiple users. They can operate either independently in a stand-alone mode or in a networked mode for group jump simulations. In stand-alone mode, each Jump Station operates much like the basic training system, running and recording jumps independently of the other stations and the Master Controller. Each station



stores its own copies of all data required for independent simulation operation.

Figure 16. Networked System Diagram

In networked mode, each Jump Station is controlled by the Master Controller. It receives scenarios and information about other networked jumpers from the network and displays them in the HMD, permitting a jumper to interact with others in a live, networked jump. In this mode, the Jump Station does not require a simulation operator; all operator commands are made at the Master Controller and relayed to the individual stations.

Figure 17. Networked Parachute School Simulators

Figure 17 shows one of two Canadian parachute schools with two networked simulators. In June 2006, ten networked simulators were installed at a Spanish parachute school. Each of these ten simulators was configured so that it could be used as a stand alone simulator, Jump Station, or Master Controller. The parachute simulation network program was enhanced to allow multiple Master Controllers on the same physical network. This allows a great deal of flexibility in meeting training needs. Nine jumpers could participate in one jump, ten jumpers could jump alone, or smaller numbers could participate in multiple independent separate groups or alone.

Note that networked aircrew training can help minimize required instructor staffing. Only one instructor is needed to control large numbers of aircrew making training jumps.

IMPROVING TRAINING FACE-VALIDITY

Immediate face-validity is a key training simulator issue. It is possible to perform an engineering analysis and determine that a very sparse graphics scene display may contain the essential feedback cues to train a student for a particular task, yet may be rejected by an actual training population, because they can not envision this experience as representative of the real world. The primary objection raised by the parachute simulator's user population was the difficulty experienced by trainees in visualizing operations in the somewhat austere generic scenes as a real world experience. This has now been overcome in the parachute simulator by a US SOCOM-funded development of the capability to rapidly create real world, location-specific, highly detailed simulator scene graphics. This capability is illustrated in Figure 18.

Figure 18. Airport at Canadian Parachute Center

This new capacity benefits from the development, acquisition, and open distribution of a large amount of digital terrain data, and aerial and satellite photographic imagery. As these data became available, a number of PC-based software tools that automate the rapid creation of simulator scene databases were developed. As the time and effort required to develop scenes to simulate specific geographical locations was reduced from man-years to man-hours following the process diagramed in Fig. 18, it became possible to transition the parachute simulator from simple generic training scenes to elaborate models of real world sites. The simulator has recently been enhanced with the capability to readily use the myriad of pre-existing military simulator visual databases.

These remarkable graphics improvements have received enthusiastic user evaluations. For example, Fig. 14 shows a scene based on a USDA FS training site west of Missoula Montana. These scenes can contain terrain specific wind fields with data obtained from weather forecasts. This rapid scene generation and forecast weather wind field capability was used to prepare former President Bush for his 2004 charity birthday jump at his library and museum.

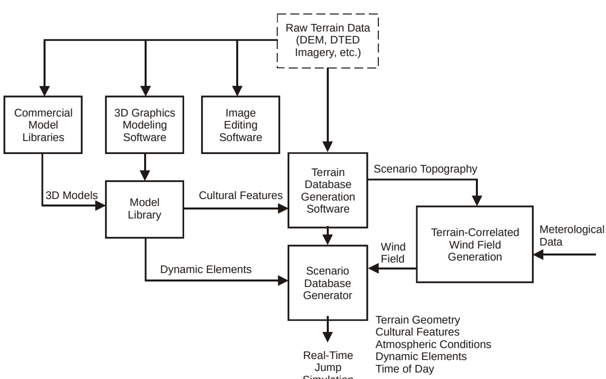


Figure 14. Process for Generating Mission Planning and Rehearsal Simulator Scenes

CONCLUDING REMARKS

To achieve optimal results, correct trainee preparation in the classroom and parachute equipment familiarization is required before initiating a training run. Instructors need to learn to carefully select and pace training challenges, assess performance during the simulation, and use the simulator-provided post-run tools to facilitate critiques through a dialog with the trainee. The instructional goal is to develop a useful positive transfer of skills training and self confidence within the tight time limits of aircrew training, through the most optimal means.

The simulator remains a good deal more difficult to fly and navigate in than is experienced in a real jump but it is really easy to learn how to cope when an instructor properly controls the training situation. The PARASIM jumper needs to learn and use a control strategy that emphasizes gentle control inputs, an orderly thought out navigational strategy, good scanning and situational awareness, etc. These are precisely the techniques that are required of safe aircraft pilots, and which experienced jumpers learn very quickly to ignore until they get into crisis emergency situations where they then have to attempt almost instantly to break all those bad habits built up over time.

The success of this approach can be judged from the widespread adoption of simulation as an essential training technique, as well as from the very positive assessments of this concept by instructors and students.

REFERENCES

1. Hogue, Jeffrey R., Walter A Johnson, R. Wade Allen, Dave Pierce, "A Smokejumpers' Parachute Maneuvering Training Simulator," AIAA Paper No. 91-0829, 11th Aerodynamic Decelerator Systems Technology Conference, San Diego, CA, April 9-11, 1991.
2. Hogue, Jeffrey R., Walter A. Johnson, R. Wade, Allen, Dave Pierce, "Parachute Canopy Control and Guidance Training Requirements and Methodology," AIAA Paper No.-93-1255, RAes/AIAA 12th Aerodynamic Decelerator Systems Technology Conference, 10-13 May 1993, London UK.
3. Hogue, Jeffrey R., R. Wade Allen, Marion K Hogue, Steve Markham, Arvid Harmsen, "Teaching Emergency Ejection and Egress Parachuting with Virtual Reality Simulation," 39th Annual SAFE

Association Symposium, 28 September 2002 to 3 October 2002, Jacksonville Florida.

4. D. Rumsfeld, "Reducing Preventable Accidents," Memorandum for Secretaries of the Military Departments, Chairman of the Joint Chiefs of Staff, Commanders of the Combatant Commands, Service Chiefs from The Secretary of Defense, 2006.

5. Hogue, Jeffrey R., Frederick G. Anderson, Cecy A. Pelz, R. Wade Allen, Steve Markham, Arvid Harmsen, “Parachute Simulation Enhancements for Post-Ejection/Egress Training,” 36th Annual SAFE Symposium, September 14-16, 1998, Phoenix, AZ.

6. Hogue, Jeffrey R., Noah S. Brickman, Cecy A. Pelz, Steve Markham, Arvid Harmsen, Cliff Schmucker, “Improving Parachute Training and Effectiveness Through Virtual Reality Simulation,” Parachute Industry Association Symposium 2005, 14-19 January 2005, Jacksonville, Florida.

7. Foxlin, Eric, Michael Harrington and Yury Altshule, Intersense Inc., “Miniature 6-DOF inertial system for tracking HMDs”, In SPIE vol. 3362, *Helmet and Head-Mounted Displays III*, AeroSense 98, Orlando, FL, April 13-14, 1998.

8. *NEC/TOKIN 3D Motion Sensor and Developer’s Kit*, NEC/TOKIN Corporation, Copyright 2004.

9. Bachelder, E., *Helicopter Aircrew Training Using Fused Reality* , NATO Human Factors and Medicine Workshop 136, Virtual Media for Military Applications (Westpoint VA, June 2006), NATO Research and Technology Organisation, November 2006.

BIOGRAPHIES

Jeffrey R. Hogue is a Principal Systems Engineer at Systems Technology, Inc. in Hawthorne, California. He has more than 45 years of experience in analysis, design, simulation, and test of flight vehicles. He has a B.S. degree in Aeronautics and Astronautics from the Massachusetts Institute of Technology and a M.S. degree in Mechanical Engineering from the University of Connecticut. He holds a Registered California Professional Engineer License, and is a co-author of a simulation display patent and the VR Parachute Simulation patent.

Noah Brickman is a Principal Software Architect at Systems Technology, Inc. Mr. Brickman is the head software integrator for ParaSim and has expanded STI’s technology assets in the areas of networking, 3D graphics, and multimedia. Mr. Brickman has been responsible for developing and enhancing the company’s simulator products including a networked parachute simulator, a driving simulator, and an aircraft flight planning system. Most recently Mr. Brickman has been responsible for developing the Fused Reality simulator system, an augmented reality approach to merging immersive VR and motion platform based cockpit simulators. He has a B.A. in Computer Science from U.C. Santa Cruz.

Cecy A. Pelz is a Senior Specialist at Systems Technology, Inc. She has over 10 years experience in 3D graphics modeling for real-time simulation. She has B.S. and M.S. degrees in Aerospace Engineering from Northrop University. Ms. Pelz is the co-author of the VR Parachute Simulation patent.

Edward N. Bachelder, Ph.D, is a Principal Research Engineer at Systems Technology, Inc. Subsequent to flying the SH-60B as a Naval Aviator (active duty), he received his Ph.D. (thesis entitled “Perception-Based Synthetic Cueing for Night Vision Device Hover Operations”) from the Massachusetts Institute of Technology (Dept. of Aeronautics and Astronautics) in the Division of Humans and Automation. His post doctoral work at MIT’s Software Engineering Research Lab investigated operator mode confusion, developing graphical ways of identifying it and designing guidelines for preventing it. He is the creator of the Fused Reality Concept and the Principal Investigator on numerous government-funded research programs.

Chi-Ying Liang, Ph.D, is a Senior Research Engineer at Systems Technology, Inc. He has a Ph.D. Mechanical Engineering, University of Michigan, 2000, Master of Science in Mechanical Engineering, University of Michigan, 1995, Master of Science in Industrial and Operations Engineering, University of Michigan, 1995, and Bachelor of Science in Mechanical Engineering, National Taiwan University, Taiwan, 1991. Dr. Liang's main area of research is vehicle dynamics, human modeling, control theory, and system analysis. He is currently working on an Army SBIR for the free fall study of parachute jumpers using anthropometrics and inverse dynamics. Dr. Liang has revised and updated STI's Parachute Flight training simulator to include various visual effects.

Robert D. Gates is a Senior Adviser, Parachute Training Systems, at Systems Technology, Inc. Mr. Gates has been a Skydiver since 1968. He has over 6000 jumps and has flown skydivers for over 8000 hrs. His ratings include Airplane Single and Multi-Engine Commercial Instrument Pilots Licenses, Multi-Engine Instrument Pilot, Static Line Jump Master and Instructor, Accelerated Freefall Jump Master and Instructor, and Master Parachute Rigger with Instructor / Examiner Skydiving Rating. Mr. Gates is a United States Parachute Association Instructor/Examiner and holds a BA Degree in Chemistry from Hiram College in Ohio

John K. Grant is Staff Engineer, Research at Systems Technology, Inc. He has a B.S. in Aerospace Engineering, Iowa State University, 2001. He has contributed to STI simulation products by writing a new graphics system which will take advantage of current and next generation features of PC video cards. In the development of the Fused Reality product, Mr. Grant balanced computation load by moving operations from the CPU to the GPU, improving sensor updates and graphics performance by 500% in some cases. Mr. Grant is software engineer with a background in aerospace engineering. He has experience has in presenting virtual environments in real time for simulation and interaction. He has used high level packages, like SGI's Open Performer, Open Scene Graph, O.G.R.E., and the low level library, OpenGL, to render virtual environments such as large scale sections of Earth and detailed architectural scenes.