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An Improved Virtual Reality Parachute Simulator

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This paper describes recent developments in parachute training simulators for training from freefall through landing. The developments addressed here include accurate canopy models, training with real harness configurations, a motorized horizontal start frame for training from freefall, improved real-world scenes, capability for jump review, and training for formation jumps with network simulators. Many of these developments have been facilitated by new computer graphics software capable of much more realistic graphic scenes. This graphic capability can exploit the recent availability of increasingly detailed geo-specific terrain data. Malfunction recovery, landing techniques and jump log features particularly enhance mission safety. Generation of specific canopy malfunctions including closed end cells, line-overs, and line twists allow trainees to repeatedly and safely practice recovery from these rare but dangerous events. Integration of the parachute simulator with emerging technologies such as parachute guidance and navigation systems is also discussed. The paper concludes with training cost estimates that indicate that considerable cost savings can be obtained with simulator training. It is concluded that the parachute simulator and related emerging technologies can now be the mainstream training tools to dramatically improve mission success and safety while meeting current budget constraints.

I. Introduction

This paper describes recent developments in a virtual reality (VR) device for training parachutists from freefall through landing. This parachute training simulator originated over 20 years ago as a device to train smokejumpers (forest firefighters)[1]. Success in that application led to its use in military parachutist training[2]. The simulator development has been guided by three very important questions:

1. Is the simulator *real enough*?
2. Does the simulator support *all needed training*?
3. Does the simulator provide *positive transfer of training*?

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In the last several years, significant effort has been made to address these three questions by modernizing hardware, graphics, and user interface. These recent technology developments are reviewed in the following.

II. Supporting Mission Success

Current parachute simulator technologies that improve mission success include:

1. Accurate canopy model
2. Training with real harness configurations
3. Freefall training with motorized horizontal start frame
4. Real-world scenes
5. Jump review
6. Formation jump

Accurate canopy model: A parachute simulator must provide positive transfer of training. No matter how many hours are spent the on simulator; positive transfer of training requires accurate canopy dynamics. Thus the parachute simulator has a long list of supported parachutes. The most recent is the T-11 chute that is replacing the 45 year old T-10. A photorealistic replicate of the chute has been developed for the simulator (Figure 1).

Figure 1 Modeling of the T-11 Canopy

Training with real equipment: The simulator design allows operation with the user's own harness (Figure 2) with minor modifications. Use of real equipment trains "muscle memory" to avoid confusion in actual jumps.

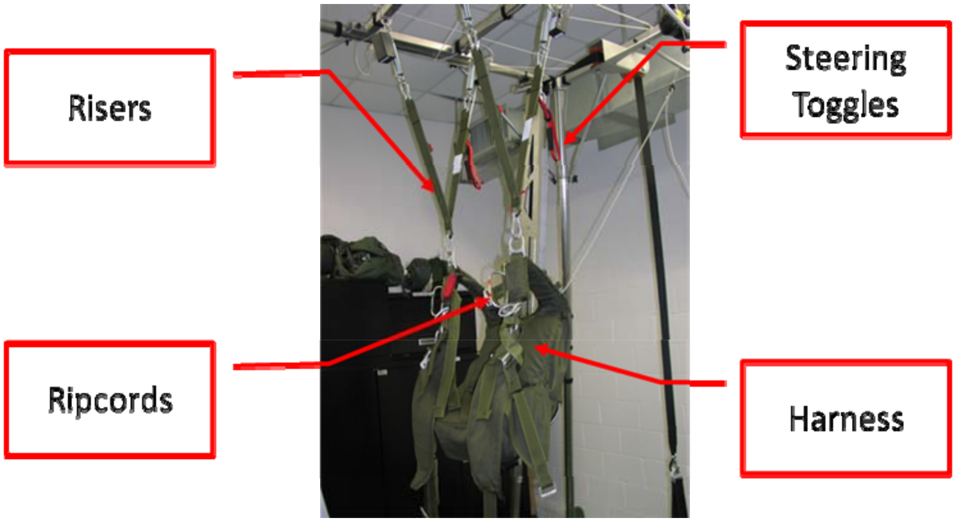


Figure 2 Incorporation of real equipment

Motorized horizontal start frame (Figure 3**):** The student starts in freefall (horizontal) position in the simulator. When the ripcord is pulled, sensors detect ripcord pull and canopy inflation, and the jumper swings into a vertical position. For the training efficiency, the frame is motorized and computer controlled.

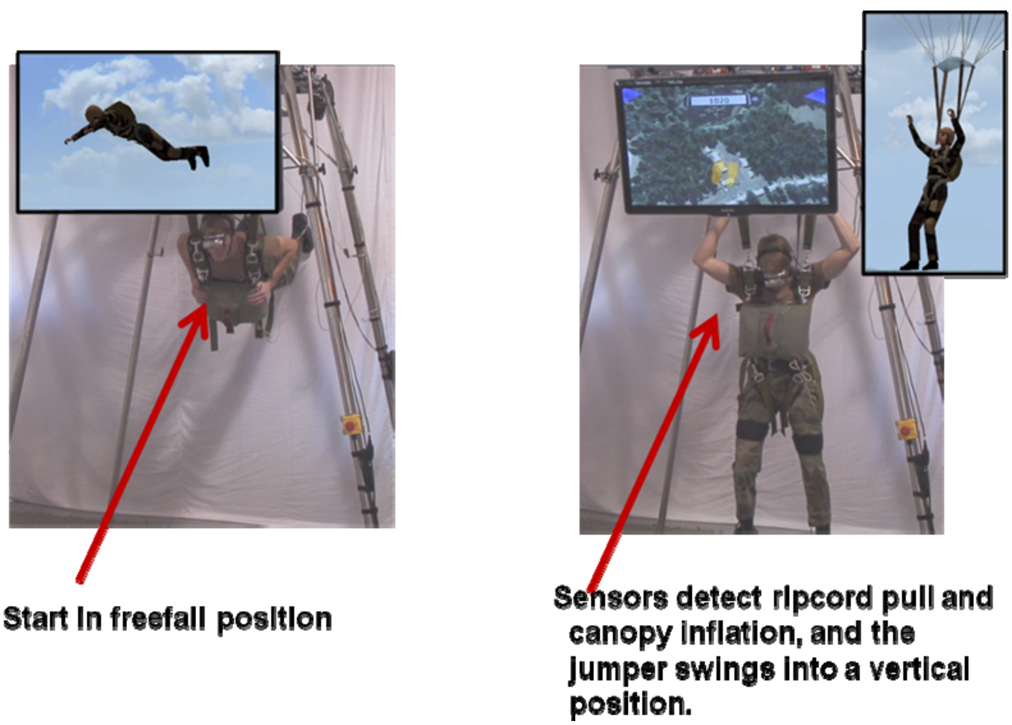


Figure 3 Horizontal start frame

Real world scenes: simulation scenes are based on satellite images of one meter resolution. A computer-generated world is created that is 200 miles across for HAHO operation (Figure 4).

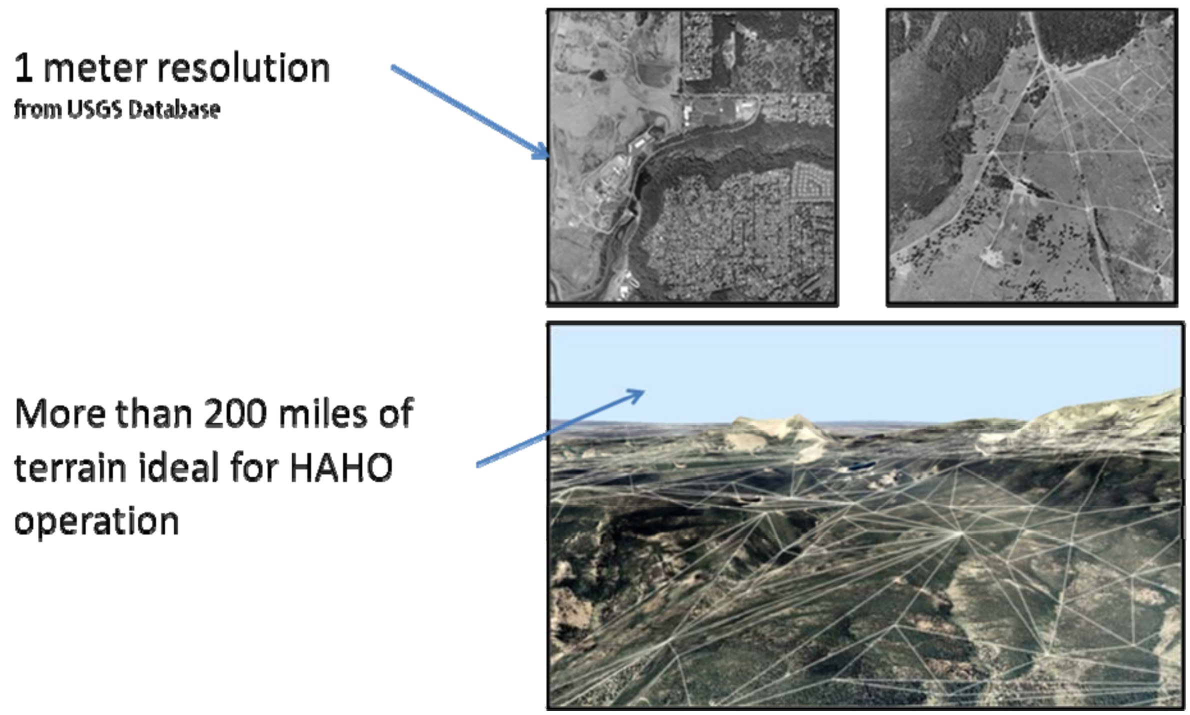


Figure 4 Generation of real world scenes

Real-world scenes have been generated to prepare jumpers for training missions. The parachute simulator currently has three real world DZs including Yuma Proven Ground (YPG.) Five target areas at YPG used by the Freefall School are included (Figure 5). The other two DZs are Joint Base Lewis-McChord and NBVC Point Magu. All of these target areas were selected specifically to match real training operations.

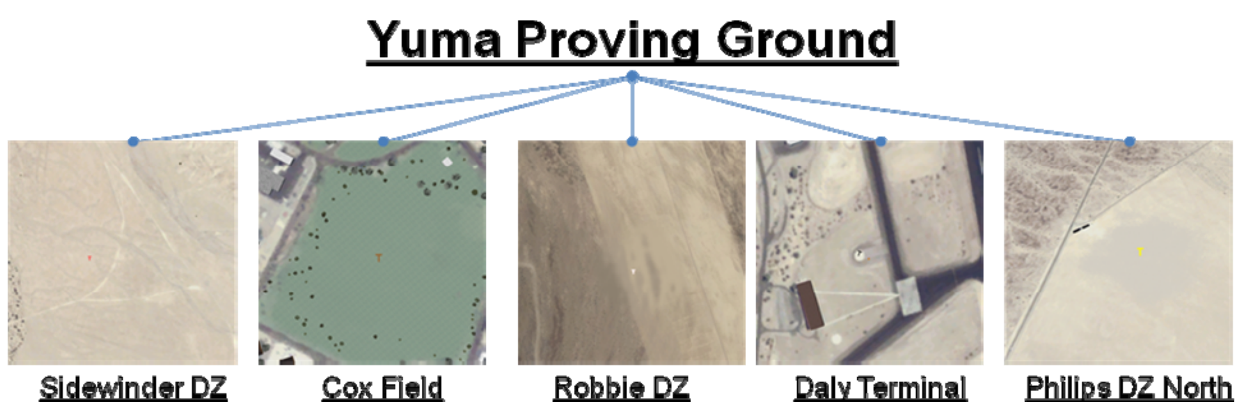


Figure 5 Five target areas at Yuma Proving Ground

Another major improvement is a new graphics engine that supports state-of-the-art shader code, skeletal and softbody animation, particle systems and more. The graphics engine provides greatly enhanced visuals, with scenes covering areas hundreds of miles wide, enabling HAHO canopy glide training, as well as animated water and new weather effects. Realistic lighting effects provide depth cues for landing. The view close to a water surface would be animated and water reflection would provide depth cues for landing (Figure 6).

The simulator graphics accommodate the effects of sun position to train for operation at different times of the day. In Figure 7 sky and sun reflection on water can be seen clearly and greatly enhance the realism of the training.

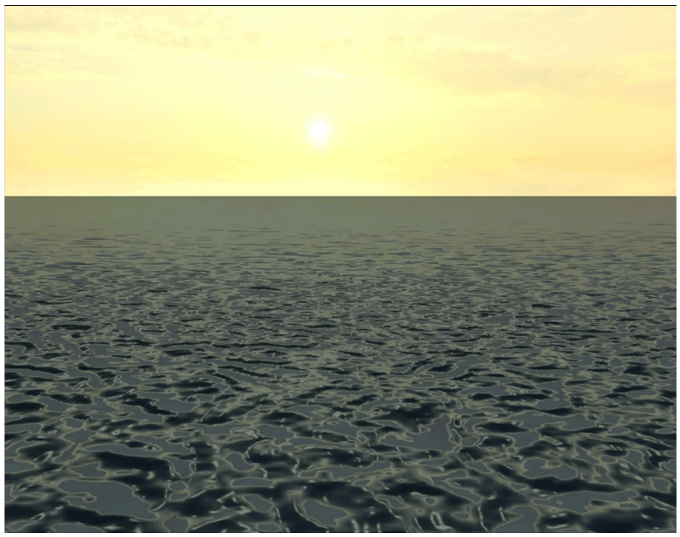


Figure 6 Wave animation

Figure 7 Sky/sun reflection on water

The shading on the parachute canopy (Figure 8) greatly enhances the realism of the training and makes the simulator more immersive.

Figure 8 T-II simulation scene

Jump Review helps identify maneuvering problems and confirm knowledge gained. For example, consider exit at 2000 ft. followed by careful maneuvering to 36 ft above the ground. Two frames are shown Figure 9 from the animated review video. Actually the entire jump can be recorded and reviewed over and over to identify any problems and confirm knowledge learned. This is a unique feature of simulation that is very difficult to do in real jump.

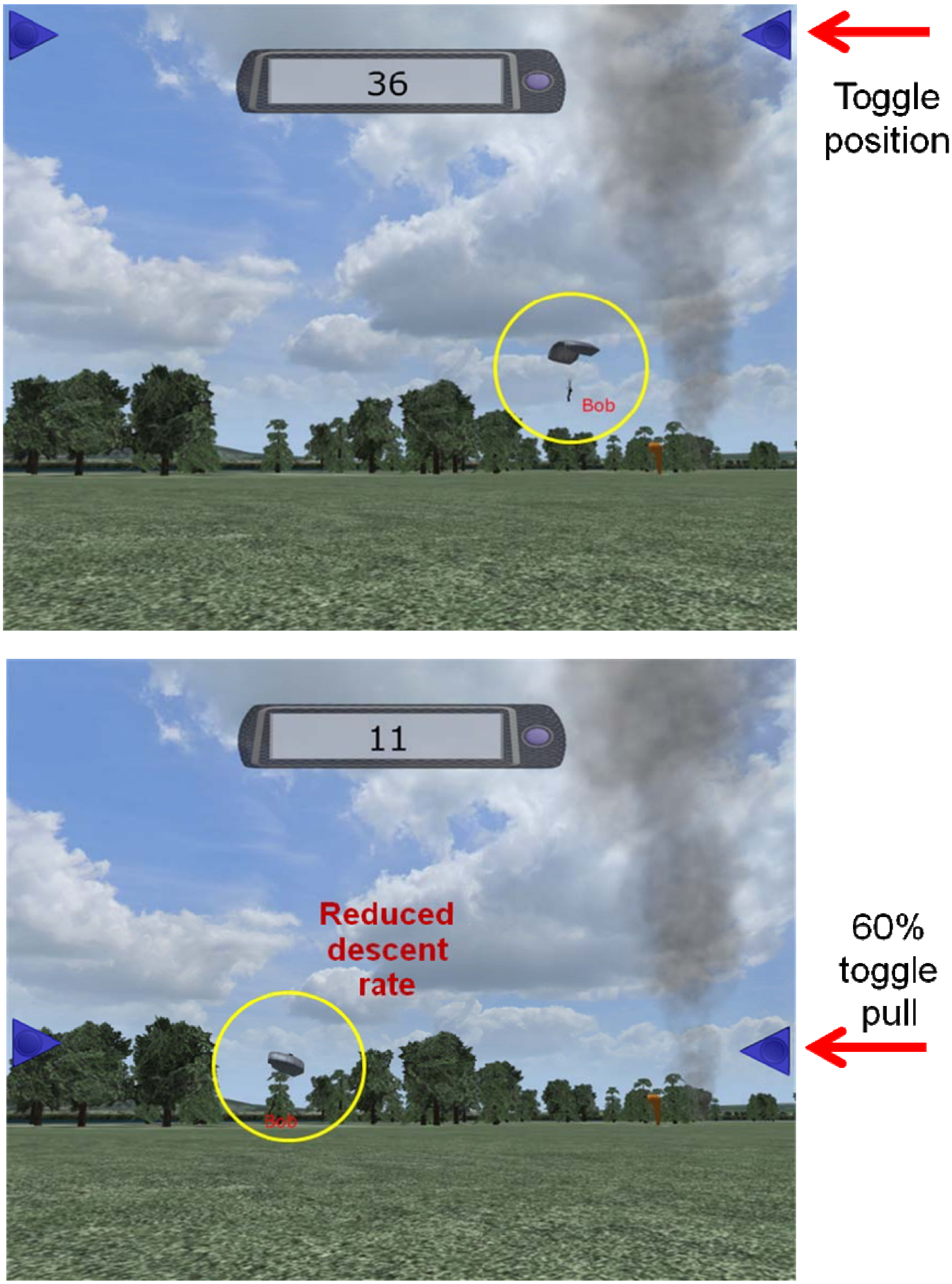


Figure 9 Two frames from a review animation

Networked jump: in network mode, one master controller controls multiple simulators to allow multiple jumpers to jump into the same virtual world (Figure 10). This allows units to plan and rehearse group operations. During jumps, the simulator environment provides features which allow observing, interacting with and avoiding collisions with multiple jumpers. After a jump the master controller station can produce reviews of the simulated jump from individual and group perspectives.

Figure 10 Networked parachute simulators

III. Improving Parachute Safety

The parachute simulator improves safety with three elements

1. Malfunctions recovery
2. Landing techniques
3. Jump log

Malfunction recovery: recognition and correction of a variety of malfunctions can be trained with the visually and dynamically correct canopy models for both square and round canopies (Figure 11). They include a variety of malfunctions and the list is growing. The student, using Virtual Reality Glasses, can look up at the canopy or perform controllability tests to identify a malfunction and react to it in real time. The student can be trained for the same malfunction repeatedly until the proper response is learned.

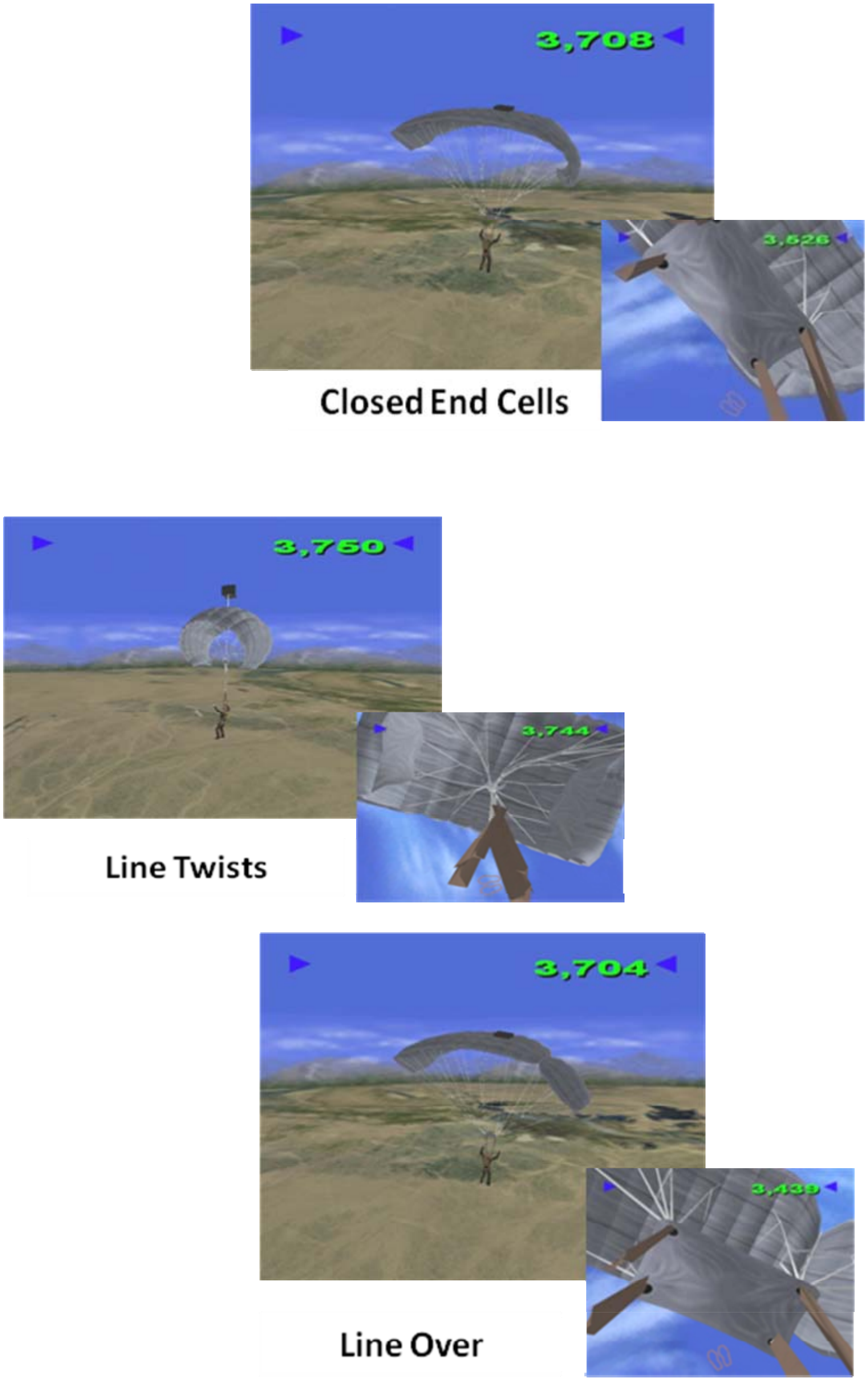


Figure 11 Three malfunction simulations

Landing techniques: Ground objects (Figure 12) are distributed across the terrain for landing training including:

1. Identify areas for safe landing if target is not within range.
2. Avoid collision with potential ground hazards.
3. Learn to use ground objects as references for landing maneuvering

Figure 12 Typical ground objects

Jump Log: Each jump can be saved to the Jump Log (Figure 13) for later review.

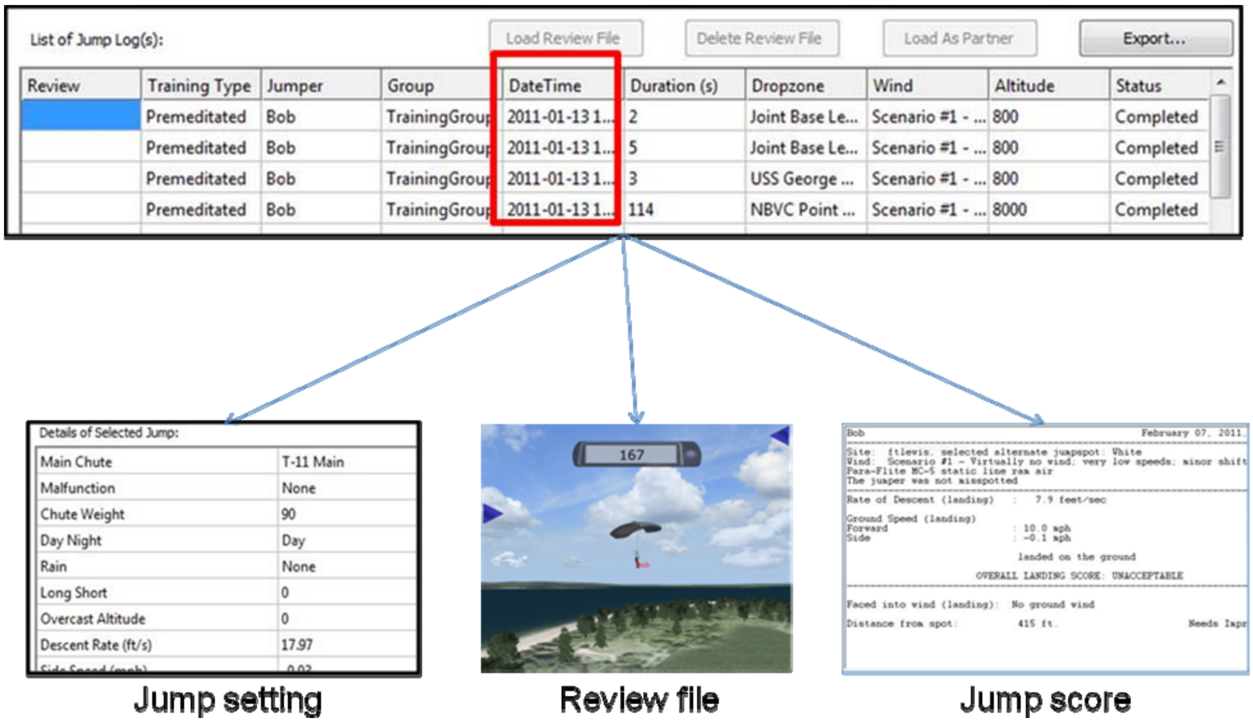


Figure 13 Jump log

IV. Emerging Technologies

Glideline, a personal navigation system, (Figure 14), has been integrated with the parachute simulator to facilitate Glideline development and testing. Glideline enables all-weather HAHO/HALO parachutist navigation. This facilitates clandestine insertion from distances in excess of 20 miles from altitudes greater than 25,000 feet (objective of 35,000 ft.) To date initial integration has been completed and two-way communication is enabled.

Figure 14 Glideline

Recently, for a separate project, virtual jumpers and cargo drops were developed for a CV-22 CPTT crew trainer. Multiple jumpers and cargo drops can be viewed from the rear of CV-22 (Figure 15). This will enable new capabilities for the parachute simulator.

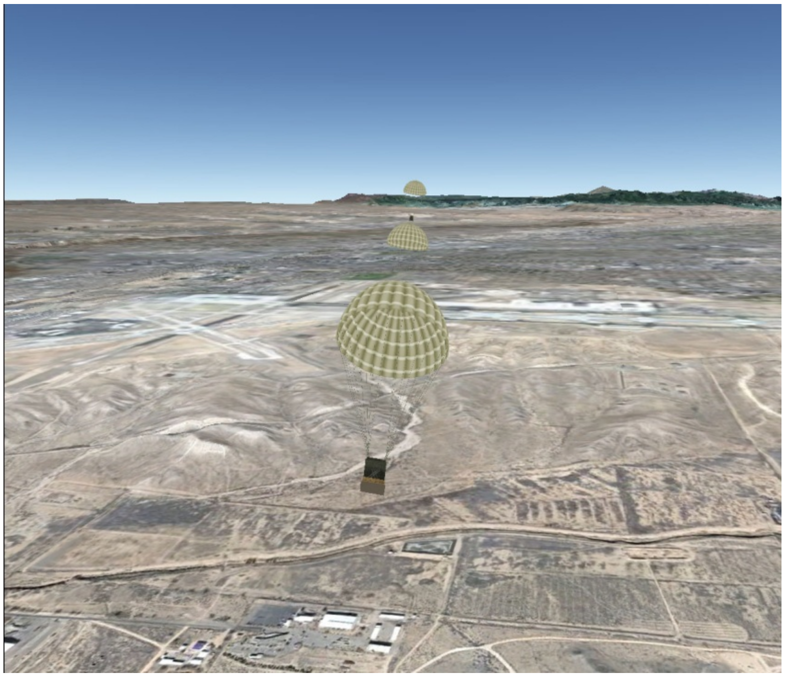


Figure 15 Virtual cargo drops seen from CV-22 simulator

V. Reducing Training Costs

The parachute training simulator has the capability to reduce training costs in three areas as shown in Figure 16.

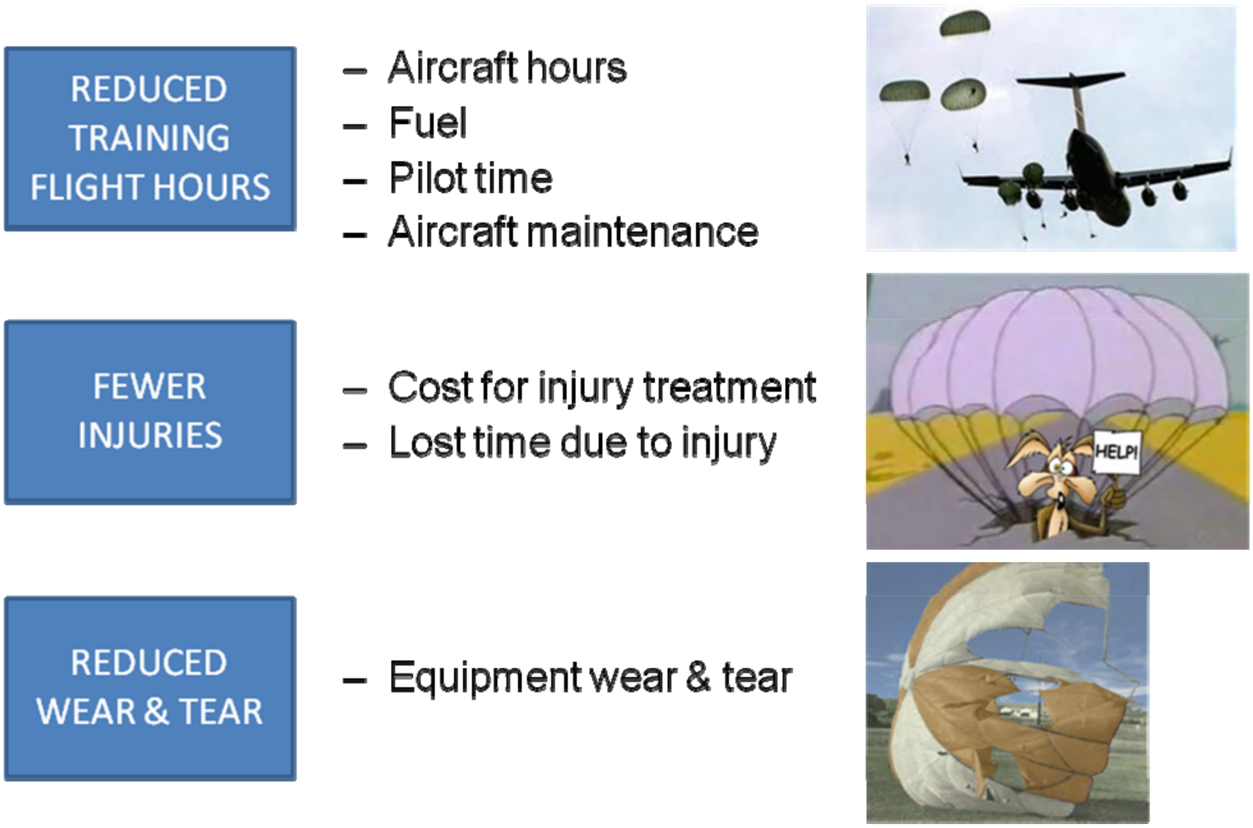


Figure 16 Parachute training cost factors

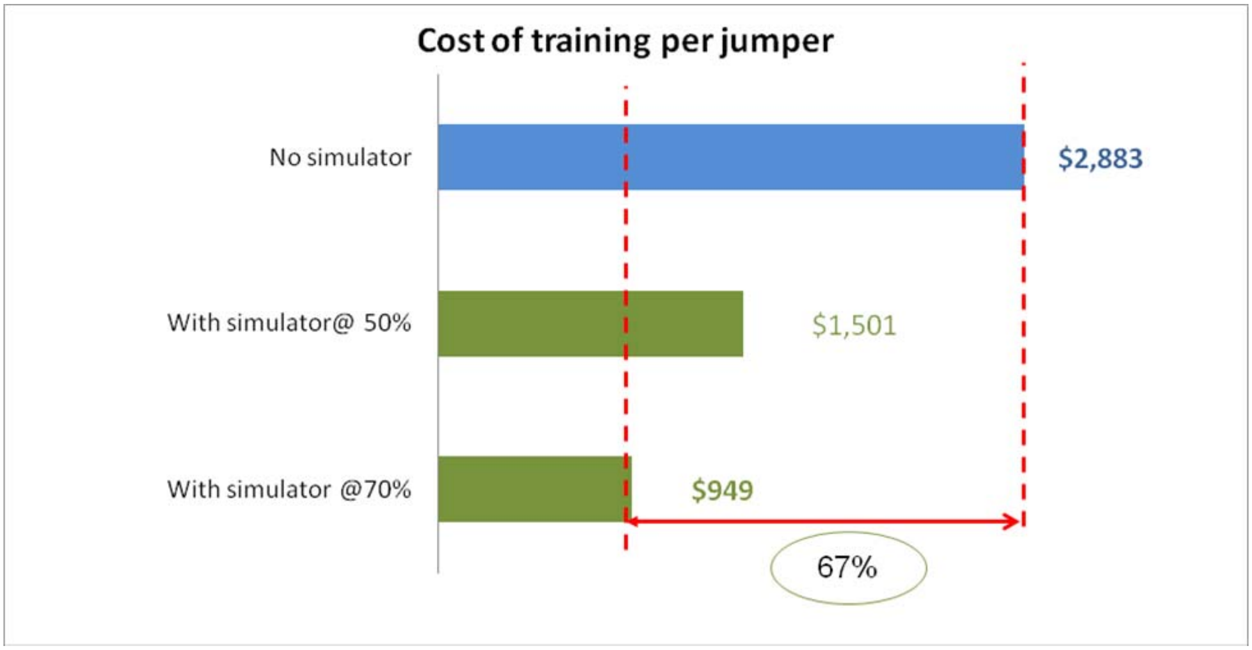
Estimated costs per jump per trainee are shown in Figure 17.

A. FLIGHT COST			
# of hours / flight		1.5	
	Unit	Cost / unit	
1. Aircraft	Aircraft Cost / hour	$ 1,600.00	$ 2,400
2. Fuel	Cost / hour	$ 1,000.00	$ 1,500
3. Aircraft maintenance	Cost / flight hour	$ 1,000.00	$ 1,500
4. Pilot/crew time	Cost / hour	$ 500.00	$ 750
TOTAL COSTS / FLIGHT			**$ 6,150**
Trainees per flight	**64**		
TOTAL COST / JUMP / TRAINEE			**$ 96**

B. SIMULATION COST			
	Total cost of simulator	**$ 120,000**	
	# of service hours	**10000**	**$ 12**
Number of jumps per hour on simulator		**3**	
TOTAL COST / JUMP / TRAINEE			**$ 4**

Figure 17 Parachute training costs per jump

Replacing flight jumps with simulator jumps can save up to 2/3 of jumper training cost compared to training without the simulator as shown in Figure 18.



Assumptions – Based on C-130 Hourly costs for flight: Aircraft:$1,600; Fuel: $1,000; Maintenance:$1,000; Crew: $500; flight time = 1.5 hrs; number of jumpers / flight: 64; Total 30 jumps

Figure 18 Parachute training costs per trainee

VI. Conclusions

The parachute simulator and related emerging technologies can now be the *mainstream training tools* to dramatically improve mission success and safety while meeting current budget constraints.

References

[1] Hogue, Jeffery R., Johnson, Walter A., Allen, R. Wade, Pierce, Dave, "A Smokejumper's Parachute Maneuvering Training Simulation," *AIAA 11th Aerodynamic Decelerator Systems Technology Conference*, AIAA-91-0829, San Diego, California, April 9-11, 1991

[2] Hogue, Jeffery R., Johnson, Walter A., Allen, R. Wade, Pierce, Dave, "Parachute Canopy Control and Guidance Training Requirements and Methodology", *RAes/AIAA 12th Aerodynamic Decelerator Systems Technology Conference*, AIAA-93-1255, London, UK, May 10-13, 1993