The Challenge
How users on foot move from one virtual place to another within limited tracked space is one of the most persistent and difficult user interface problems for immersive virtual environments. Flying by pushing a button or joystick has none of the naturalness of really walking: flying doesn’t make you tired or stimulate your proprioceptive and vestibular systems, which is your body’s way of “feeling” motion. Really walking overcomes those problems, but introduces the problem of how to move in a virtual environment that is larger than the area covered by your trackers.

Since 1998 the Effective Virtual Environments (EVE) research team has been developing and evaluating locomotion techniques for use in virtual environments.

Comparing Walking, Walking-in-Place, and Flying
Our earliest work in locomotion was done in collaboration with University College London. We replicated their results showing that walking-in-place (standing still while marching the feet) induces a higher sense of presence than flying with a joystick. Because we have a 6.7m x 9m wide-area tracker, we were able to add a really walking condition to the study. The really walking results showed that really walking is also significantly better than flying, and showed a strong trend that it is better than walking-in-place.

This locomotion work was done in our “Pit” environment, Figure 1 (left), and the measures were post-experience questionnaires. This work led to later work establishing the validity of physiological measures as correlates of presence and the use of physiological measures to evaluate VE systems on several dimensions, e.g., frame rate, field-of-view, rendering quality, and audio quality.

Comparing Motion Paths
In our current work on locomotion, our goals are to develop metrics that let us compare motion paths—how the user moves in space and time—so that we can then apply those measures to see whether users move differently using different locomotion techniques. Our motivating issue is to determine whether or not locomotion interface adversely affects training and the transfer of skills learned in VR to the real world.
by interactively and imperceptibly rotating the scene about the user. This causes users to walk along an arc when they think they are walking in a straight line. When users are turning in place, it causes them to turn faster than they think they are. By continually rotating the visual and auditory scene, it causes users to continually walk towards the farthest wall of the lab (Figure 3).

Redirected Walking-in-Place: The vast majority of CAVEs® and CAVE-like systems, have three vertical display surfaces (walls) and an opening on the fourth, back, side. Having the open wall come into view reduces the user’s sense of presence in the VE. We have successfully applied the Redirection to locomotion in a 3-walled CAVEs. Users can turn naturally and in any direction in the virtual scene, using their body rather than a hand-controller. Compared to using a hand-controller, users see the open back wall less often and suffer less simulator sickness Figure 4 shows one user’s path in the virtual scene—she is able to walk in all directions without seeing the open back wall.

Future Opportunities: Simulations based on theory and user studies describe the minimum size tracked space needed to allow the user to walk along an arbitrarily long, straight, virtual path. Algorithms have been proposed for steering users away from the lab walls while they freely explore a large virtual scene. The hardware components to build a system which implements all of this are now available. This would enable testing and refining the theoretical work and deploying it in practical applications. Also the effects of Redirection on users’ spatial understanding, task performance and training have not been explored.