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## **Office Level Lighting Controls Report**

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# Office Level Lighting Controls

## Introduction

The stated goal of this research is to “*design, develop, and prototype portable energy-efficient office luminaires that integrate occupancy-based controls to provide users a higher level of control and visual quality than they currently receive from traditional overhead lighting systems.*” Prior reports (including deliverable 4.4.2 - *Workstation-Level Lighting Systems Report*) have described potential luminaire designs that could be developed to achieve this stated goal. These reports have focused on the optical, mechanical, and electrical characteristics inherent to the luminaires themselves, and not necessarily on the overall lighting effect that results from utilizing several of these luminaires in a given application.

This report focuses on the office-level integration of the proposed new luminaires and the control strategies needed to ensure their proper function and integration. As these luminaires are controllable separately from each other, systems and strategies must be established to appropriately link these luminaires together to produce an overall lighting effect in the office that is coherent and functions logically. This task is made more complicated by the fact that some proposed designs have multiple, independently controllable lamps (task, ambient, etc.), and in some situations it may be desirable to integrate the existing hardwired overhead lighting systems. This report will discuss the complexities of these scenarios and present several possible solutions and approaches.

## Part 1: Approach and Background on Luminaires

### *Task/Ambient Lighting Design*

Traditionally, office spaces rely on ceiling-mounted luminaires for both task and ambient lighting. The target illuminance levels have been dictated by task requirements, which is the equivalent of providing task lighting throughout the workplace. This can be an inefficient approach, as illumination levels drop by the square of the distance from the light source. Ceiling-mounted luminaires are relatively far away from the work plane, which makes them inefficient for providing task light, as compared to task lighting luminaires that are located closer to the work plane.

Studies at the Lawrence Berkeley National Laboratory have shown that separating task and ambient lighting systems can result in significant energy and lifecycle cost benefits by reducing the light levels produced by the ambient system to significantly lower levels and by providing separate lighting fixtures for task lighting. By being closer to where the light is needed, task lighting fixtures offer a significantly more efficient and effective way of delivering task lighting than ceiling-mounted fixtures.

Perhaps the greatest benefit of this approach, though, is that it provides light where it is actually needed. This saves on energy by decreasing the overall illuminance in spaces where detailed visual tasks do not typically occur, such as hallways and circulation areas.

This also can improve the overall visual quality of the spaces by reducing high angle glare that is commonly caused by overhead lighting.

### ***New Construction vs Retrofit***

While a task-ambient portable luminaire approach could be appropriately applied to new construction applications, it is more easily applied to retrofit environments for a variety of reasons. For example, local building codes often require that a minimum level of illuminance (generally 10 fc or greater) be maintained in a space to provide for egress. In new construction, it may prove difficult to obtain building permits without providing for egress lighting from hardwired lighting systems. In retrofit applications, the hardwired overhead lighting system may no longer be utilized or may be partially delamped, but it likely will remain in place to satisfy code requirements for egress lighting.

The application of the portable luminaire approach could represent a significantly simplified retrofit solution in many environments. Portable luminaires could be distributed throughout a space and the existing hardwired system can be turned off (or delamped) without the services of electricians. This approach has the potential to significantly limit both disruption to the office work environment and the expense to the building owner associated with standard retrofit practice.

This approach will likely be utilized initially in owner-occupied applications. The owner-occupants will benefit directly from the energy savings and the increase in lighting quality. This approach should interest property managers for the inherent flexibility the application offers for use in rental units, but they may have concerns about utilizing an alternative approach to standard practice.

### ***Finelite Prototypes***

The luminaire designs described in the *Workstation-Level Lighting Systems Report* were developed in cooperation with our industrial partner, Finelite. These designs were developed with the task-ambient approach in mind. Most of these designs allowed for independent user control over the task (downlight) and ambient (uplight) portions of the luminaire's output. Due to cost considerations related to the independent operation of multiple lamps (discussed in detail below), Finelite determined that their initial prototype would utilize a single lamp in a luminaire that has a fixed (non-controllable) task-ambient distributional output.

In June 2004, Finelite constructed a prototype luminaire based on this fixed task-ambient approach. This luminaire included a single 55W, long twin tube CFL in a design that provided the user with both task and ambient lighting. The luminaire also included a feature that allowed users to dynamically reconfigure its optics by allowing the optical head to be reoriented from its standard horizontal position to a vertical position via a 90° pivot joint. This allowed users to utilize sidelighting, rather than uplighting, if this would be more appropriate for particular photometric needs in their workspace. (Figure 1)

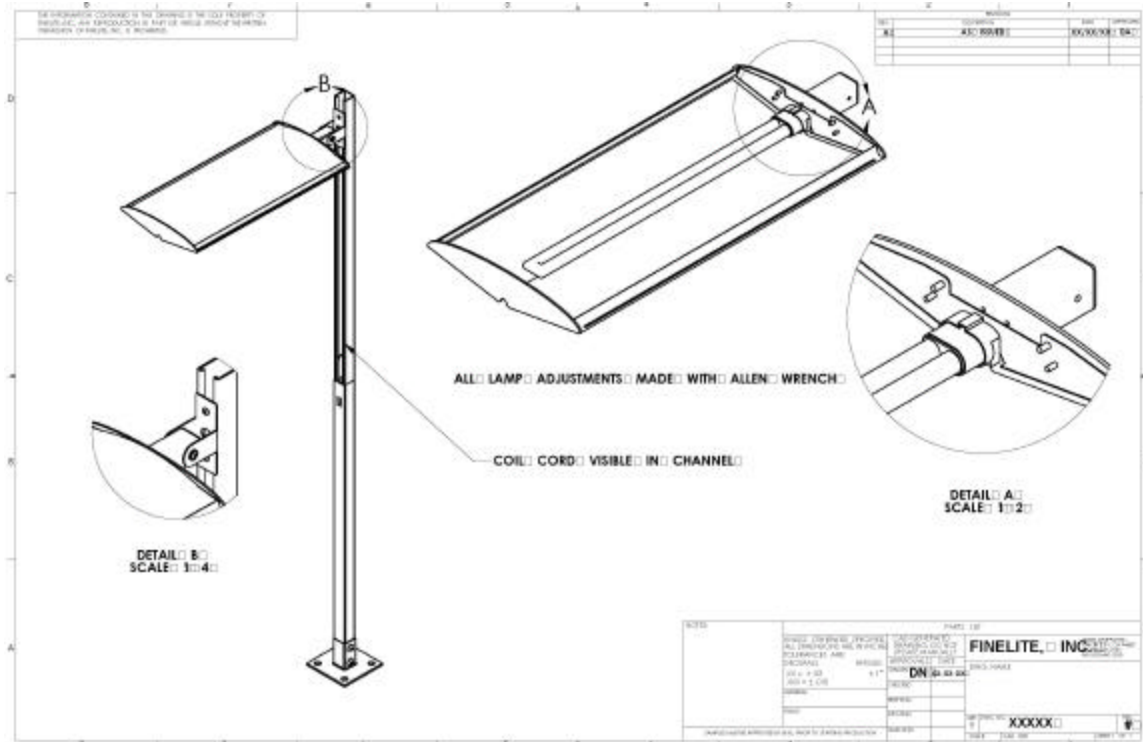


Figure 1: Mechanical Drawing of Finelite Prototype Luminaire

This prototype was demonstrated to personnel at PG&E, SCE, and SMUD, at which point they were asked to provide feedback on the changes they would recommend. The utilities were also asked to support a limited demonstration in their territories by procuring and placing approximately 20 luminaires each. To date, SCE and SMUD have agreed to sponsor demonstration efforts and PG&E is considering a demonstration as well.

Based on the utility feedback and further testing and refinement at CLTC, several design modifications were suggested to Finelite in July 2004. These suggestions included the integration of an occupancy sensor and a modification to the 90° pivot joint so the optical head could be moved horizontally instead of vertically. Also, based on detailed testing at CLTC, it was suggested that the 55W lamp be replaced by either two 40W lamps or one 80W lamp. Researchers at CLTC constructed and characterized several prototypes that included these design modifications and demonstrated these systems to Finelite (Figures 2, 3). Finelite is currently considering these modifications and developing price quotes for the utilities based on these final modifications.

While these prototypes were constructed as single lamp systems, the luminaire profiles can potentially be utilized using two or three independently controllable light sources.

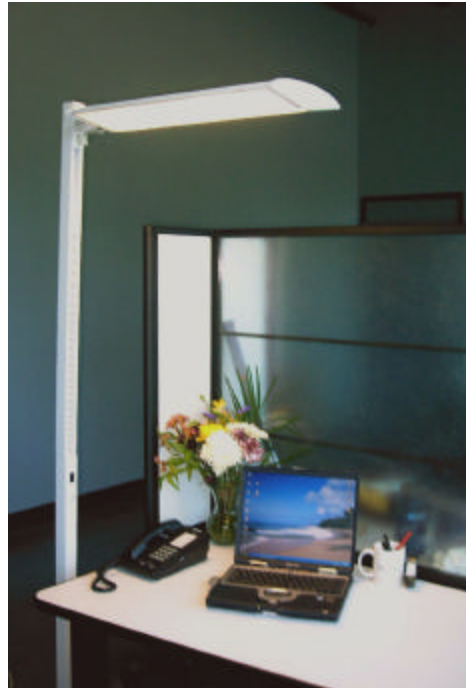


Figure 2: The CLTC relamped a Finelite prototype with an 80W lamp and added an integrated occupancy sensor

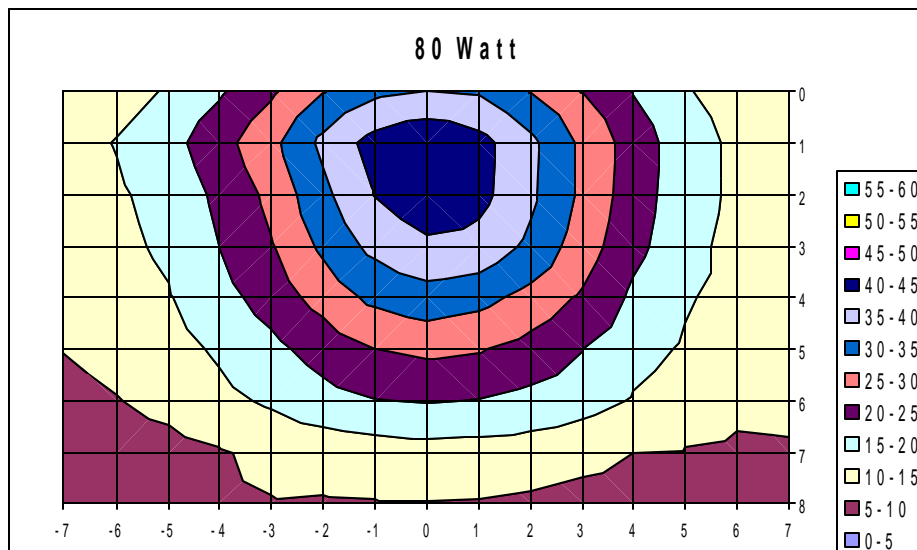


Figure 3: Illuminance maps were collected for all prototypes constructed, such as this map for the 80W prototype system.

**Limitations to Independently Controllable Multi-lamp Luminaires**

Two main factors have limited the development of portable luminaires with fully independent task and ambient elements. The first is the relative increase in the cost of ballasting to handle the independent switching of these systems. The second factor is the lack of control strategies and systems to take full advantage of the added control offered

by these systems. These factors played heavily into Finelite's decision to prototype a single- rather than a multi-lamp system.

Fortunately, solutions are emerging that will address these barriers. A number of bi-level switching ballasts are entering the market that allow for independently controllable switching to be achieved much more economically than by utilizing several single lamp ballasts.

We will present and discuss a control solution that utilizes existing and emerging technologies that is relatively simple to integrate, yet offers unprecedented user control when utilized with multi-lamp luminaires.

### ***Bi-Level Switching Ballasts***

One of the drawbacks of the independently controllable multi-lamp luminaire is cost. More significant than the cost of extra lamps is the cost of the added ballasts. Traditionally, if a luminaire has two lamps that are to be switched separately, it would require two separate one-lamp ballasts. This represents a significant additional cost that luminaire manufacturers have been unable to justify.

Recently, a growing number of bi-level switching ballasts have entered the market. These ballasts typically have a high level in which they operate a specified multiple of lamps, as well as a low level in which they operate a single lamp (or smaller multiple of lamps). These ballasts are relatively more expensive than standard ballasts, but not twice as expensive, so they represent an attractive alternative for achieving independent lamp switching control.

These ballasts are particularly well suited for applications where one lamp is operated continuously, while another lamp may be turned on and off. For example, in a task-ambient portable luminaire a single bi-level switching ballast might be applied so that one lamp is utilized for an ambient light and another lamp for task light. In such a system the ambient light could be left on for extended periods of time for general room-wide illumination, while the task light could be turned on and off (manually or with controls) as needed.

Bi-level switching is available in a number of different combinations for many different lamp types. For the lamps that have been the focus of consideration for most of this project, the long twin tube CFLs, there are a number of available options. In addition to the 2-1 ballasts described above (high = 2 lamps, low = 1 lamp), there is also bi-level switching that will operate in the following configurations: 4-2, 4-1, 3-2, and 3-1. These systems were closely evaluated and considered during this phase of the research project as a mechanism to increase the luminaire's functionality and controllability while containing overall material costs.

## **Part 2: Approach and Background on Controls**

### ***Overview of Controls Approach***

The overall vision of a control system for a portable lighting system is one that allows for a dynamic, automatic, and appropriate modification of a room's illumination as a function of changing user needs and room occupancy. This effectively translates to "putting light where it is needed, when it is needed." When done properly, the result should be an increase in lighting quality and a decrease in energy usage.

Considering this control approach in combination with task-ambient portable luminaires, the broad vision is an environment in which the ambient components of the luminaires in the room combine to create a uniform general ambient lighting effect for the space, while the luminaires' task components serve the local task illumination requirements. Given this vision, the first problem is determining the conditions under which the luminaires' task and/or ambient components should be turned on or off. Then, we must determine how to turn these components on or off.

### ***Two-Level vs. Three-Level Control***

Through our development of the task-ambient lighting strategy and the refinement of specific prototype luminaire systems, we have established some specific strategies for the integrated controls of portable office luminaires. At the most basic level, these systems require two levels of control: one for the task lighting and one for the ambient lighting. However, we have determined there may be great added value in a system that provides three levels of control: task, ambient, and local ambient.

Local ambient refers to an indirect (reflected) lighting that primarily illuminates the local environment. An example of local ambient is an open office application when users utilize torchieres (uplights), which have a fairly focused upward beam spread, to provide a controllable level of indirect light in their personal workspace. In this application, some of the flux from the torchieres reaches spaces outside the user's cubicle. However, because of the focused beam spread the effect of the luminaire drops off significantly outside its immediate area. This is in contrast to what we have generally referred to as ambient lighting, in which a fairly uniform level of illumination is present throughout the space. We will refer to this as "general ambient". The three levels of lighting for the control system to consider are task, local ambient, and general ambient.

In most applications, the task and local ambient components are best satisfied by portable luminaires. The general ambient, on the other hand, can be addressed either by portable luminaires or by overhead fixtures. We explored both of these approaches for general ambient illumination.

The initial focus of this research was on systems that provided two-level control solutions. These systems have certain advantages over three-level control systems. One of the main advantages of two-level control systems is they are potentially simpler and cheaper to apply. A two-level system may still be the best approach for private offices,

but shortcomings of this approach begin to surface when considering multi-person spaces. It became increasingly clear that two-level control solutions often had significant limitations.

Initial resistance to adding a third level of control was due to concern over the added complexity this would bring to the control system. One of the primary goals of this project was the development of a simple lighting control system that would not require the type of commissioning by lighting professionals that is common on more complicated lighting control systems. As we examined this more closely, the addition of a third level of control actually simplified the controls equation by offering maximum energy savings with increased occupant acceptance. In such an approach, a general ambient lighting component (whether from the portable luminaires or the overhead fixtures) would be left “on” if there was occupancy anywhere in the space. This would ensure that a minimum low-level illuminance would be present in all occupancy scenarios.

### ***Luminaire vs. Controls Solutions***

There are many different avenues to achieve the three-level control. It is important to note this is neither purely a “luminaire” nor a “controls” issue, but really a combination of both. There is a continuum of possible approaches. On one end of the spectrum is a luminaire-heavy approach in which a portable luminaire is developed with three independent light sources: a task light, a focused uplight or broad downlight (local ambient), and a broad uplight (general ambient). On the other end of the spectrum is a controls-heavy solution in which a control component is developed where different luminaires (task lights, uplights over various distributions) can be plugged in and automatically turned on or off. There is no simple answer as to how to achieve this level of control. The problem revolves around the integration of control and luminaire issues rather than a search for a luminaire solution or a control solution.

## **Part 3: Control Scenarios**

### ***Discussion of Specific Solutions***

Several control strategies are presented in this section, which describe and highlight the advantages and disadvantages of various approaches, as well as exploring in greater detail how these systems might operate.

#### ***1. General Ambient from Existing Overheads, Task from Portable Luminaire***

Luminaire requirements: This case presents a task-ambient lighting system at its most basic level. In such a system the overhead lighting system is utilized to provide an overall level of illumination that allows for general circulation and other tasks which are not visually demanding. This is generally accepted to be in the range of 25-35 foot candles (fc). Task lights are then used at the workstation level to supplement the overhead lighting to reach levels appropriate for more visually demanding tasks, such as reading or writing. Fluorescent and halogen task lights in the 13-50 Watt (W) range are often used in this scenario.

Controls integration: Because the luminaires used in this scenario are relatively basic, the control system options for the system are also fairly basic. Generally speaking, the vast majority of the energy usage from a lighting system such as this is from the overhead lighting system. This system should clearly be controlled by an occupancy sensor that automatically turns off the overhead lighting system when the entire office is no longer occupied. The task lights would be controlled at a local level by the users, and may also be controlled by occupancy sensors (either luminaire integrated or power strip integrated). The cost effectiveness is dependent on the amount of electricity saved by using a lower wattage overhead system with energy efficient task lighting.

Discussion: This is the simplest solution and can easily be realized with technologies that are on the market today. While offices are generally not lit to these lower lighting levels (25-35 fc), they can be retrofitted, de-lamped, or re-lamped to achieve these levels. Occupancy sensors are typically connected to the overhead lighting in these applications, but could be readily added if not present. A wide variety of task lights are available for offices, including many fluorescent systems. The available task lighting generally has a relatively small area of influence. If users have a large area that they need to illuminate at a higher level, they may need two (or more) task lights. In applications in which significant areas require visual task performance (file cabinets, common areas with printers, copiers, etc.), this approach may be unworkable.

## ***2. General Ambient from Existing Overheads, Task and Local Ambient from Portable Luminaire***

Luminaire requirements: This scenario adds a third level of control to the two levels described above. In addition to the ambient from the overhead and the workstation level task lighting, we now also have a workstation level local ambient lighting system. The local ambient is intended to provide general, indirect lighting uniformly in the local workstation environment. The local ambient system could have one of the following relationships to the task light: (1) fully independent from the task light (i.e., stand-alone torchiere uplight); (2) fully integrated with the task light (i.e., a luminaire with a fixed distribution that is partially uplight, partially downlight); or (3) partially integrated (uplight and downlight in same luminaire, but independently controllable).

Controls integration: Option (2) with the task light and ambient light fully integrated is essentially a two-level control system analogous to the control scenario previously described. Options (1) and (3) are three-level controls that might require a new control scheme. In these applications, the user would have direct, independent control over the local ambient and task light in their area. A workstation level occupancy sensor can be connected to the local ambient and task light. Because there are now two light sources, the load connected to the local occupancy sensor will likely be higher than in scenario 1, thus making it more likely to be cost effective. As in scenario 1, the general lighting still must be on if there is occupancy anywhere in the office, so there is little advantage in tying the control of the general overhead ambient lighting system to the workstation-level control system.

Discussion: While very similar to scenario 1, this scenario has several distinct advantages. First, because individuals now have the ability to increase the ambient lighting in their local areas, it may be possible to decrease the general overhead illuminance even further for increased energy savings and reduced glare. General ambient lighting levels of 10-25 fc may be possible. Also, this system may be more generally applicable, as spaces that need larger areas with higher levels of illumination (common area for printers and copiers) can now have a local ambient luminaire at a maximum output level. The controls for this system remain relatively simple, with an occupancy sensor on the overhead fixtures and workstation-level occupancy sensors (working independently from the overhead occupancy sensor) connected to the task and local ambient luminaires.

### ***3. General Ambient and Task from Portable Luminaire***

Luminaire requirements: This scenario is quite different from the previous two, as we are no longer considering utilization of any overhead lighting. The task light is similar to the earlier examples, but the uplight component of the portable luminaire must be capable of providing enough flux to satisfy the general illumination needs of the office, approximately 25-35 fc. As in scenario 2, there are three options for integration between the task and the ambient light: (1) fully independent (i.e., stand-alone torchiere uplight and stand-alone task light), (2) fully integrated (i.e., a luminaire with a fixed distribution that is partially uplight, partially downlight) or, (3) partially integrated (uplight and downlight in same luminaire, but independently controllable). Option 2 is fairly limited from a control perspective as there is not much that can be done to this system aside from connecting it to an occupancy sensor. This solution is less than ideal as it may lead to circumstances when the ambient component of a system is turned off inappropriately when a cubicle is unoccupied, but the light may be needed by an adjacent space. Options 1 and 3 offer configurations with the flexibility to provide more creative control solutions.

Controls integration: This application represents great challenges and opportunities for control solutions. An overhead lighting system, which has been considered to have a single switch which either turns the lights in the entire space on or off, has now been replaced by several ambient luminaires which could be independently switched. This added flexibility creates opportunities, but presents challenges. On the most basic level, this system can be treated much like the overhead systems by tying together the operation of all of the ambient light components. Whenever the room is occupied, all of the ambient sources are turned on. While this would be relatively simple, this approach does not take full advantage of the added flexibility of the independently switchable ambient fixtures. For maximum energy efficiency, it would be advantageous to switch off some of the ambient sources when possible (for example, turning off several of the ambient sources on the northeast side of an office when only one person in the office is in the southwest corner).

Discussion: This system requires a level of integration that has not been required previously. Now that we propose turning off specific general ambient sources, we must know which portion of the room is occupied. The hardware infrastructure to make this

determination is provided by the inclusion of local-workstation level occupancy sensors. At a primary level, these occupancy sensors can turn off the task light when the workstation is unoccupied. It is also conceivable that this occupancy information can be shared with the surrounding spaces affected by the light output of the ambient source so the system acts “intelligently”. For example, consider a scenario where an occupant is in cubicle 1, while all of the other cubicles are vacant (Table 1). An intelligent and energy efficient solution would be to leave on the ambient sources in cubicles 1, 2, 4, and 5, while turning off the ambient components in cubicles 3, 6, 7, 8, and 9. This system can be modified for the specific needs of each application. For example, if the exit was located near cubicle 9, the ambient component of cubicle 9 might be left on if there is any occupancy in the space.

This type of intelligence now requires individual occupancy sensors (or their controllers) to “talk” to each other. This can be handled either with wires or, preferably, with a wireless system. There are a number of wireless systems and protocols, including emerging systems by our controls industrial partner, The Watt Stopper, which could be capable of offering this level of communication. In this scenario, a straightforward commissioning protocol is envisioned in which occupants define which ambient sources they would like to be “linked” to. This link could be made by running wires between the ambient source (or occupancy controller) and the devices to which they wish to link, or, with a wireless system, by entering the IP address (or equivalent) of the sources to which they wish to link. After these links have been established, if there is occupancy in a cubicle, the ambient component of that cubicle and all of the cubicles that the system is linked to will remain on. Consider an example where cubicle 1 is linked to 2, 4, and 9, while cubicle 7 is linked to 4, 5, and 9. If cubicle 1 and 7 were the only occupied cubicles, then 1, 2,4,5,7, and 9 would remain on while 3, 6, and 8 would be off.

Table 1: Occupancy State Diagram

1	2	3
4	5	6
7	8	9

#### ***4. General Ambient, Local Ambient and Task from Portable Luminaire***

**Luminaire requirements:** This application is an extension of scenario 3, with a local ambient component added to the local workstation luminaire or luminaires. Again, no overhead lighting system is present and these various components (task, local ambient, general ambient) would be fully integrated, fully independent, or some combination. The general ambient lighting component will have a broad candlepower distribution, so it can be shared with the room as a whole. The local ambient will have a more narrow candlepower distribution, so it primarily affects the space in which it is placed.

Controls integration: The complexity of adding a third level of control to this application actually serves to simplify the controls of the system. This approach is very analogous to scenario 2, except now the general ambient component is provided by the portable luminaire rather than the overhead lighting system. Each workstation must have local occupancy sensors to turn off the task light and local ambient light when the workstation is unoccupied. When all of the spaces are unoccupied, then the system must turn off the general lighting components of all the portable luminaires.

Discussion: This scenario presents a very flexible system that should allow for maximum user control and enhanced energy efficiency. It represents a completely portable solution that could be integrated into a space that has no lighting or problematic lighting. It may represent an easier and potentially cheaper alternative to retrofitting the overhead lighting in a space if the users know that they only desire a low-level, general ambient lighting system. In this portable luminaire approach, the general ambient lighting systems would provide a uniform 10-25 fc whenever there is any occupancy in the space, while the task and local ambient controls could respond to the particular needs of the individual workstations. While the local ambient and task sources are controlled very simply by the local occupancy sensors, the operation of the general ambient components is more problematic. While these sources are powered separately at the various locations around the office, they need to be switched together. This can be achieved in a variety of ways, including communication between the local occupancy sensors (if any = occupied, stay on, if all = unoccupied, turn off), a central room occupancy sensor communicating via a wireless connection to the general ambient sources, or a central room occupancy sensor controlling a power breaker in which all general ambient sources are connected.

## Conclusions

Of these control scenarios, we feel that options 2 and 3 are the most promising and most worthy of further investigation. Option 2 might be very attractive in retrofit applications, while option 3 has promise in new construction as cost savings could be realized by not installing any overhead lighting system. For situations in which the overhead lighting system can easily be utilized to provide very low level general ambient light, the addition of a highly flexible local ambient and task lighting system can provide users with a very high level of flexibility to satisfy most of their illumination needs. This system has very simple controls, as the general lighting controls and the local lighting controls need not communicate with one another and can operate independently. The current Finelite prototype design could be modified to serve as the local ambient and task needs control in such an application.

For situations in which it is undesirable to utilize the overhead lighting system, a system that relies on portable luminaires to provide task lighting as well as general ambient illumination that is “linked” to surrounding space is very appealing. While this approach is more complex than the overhead fixture approach, there are advantages in the greater degree of flexibility from portable luminaires. There is also the potential for even greater energy savings by taking advantage of the fact that these general ambient systems are not

on a single lighting bank, and can be selectively turned off in response to a specific occupancy scenario.

We plan to explore both of these scenarios in further detail with our industrial partners, as well as with local California utilities. The utilities have indicated their interest in becoming involved in this research project by supporting a field test of portable luminaire office lighting applications which will likely initiate in the Fall of 2004. We plan to work with our partners to refine a field test plan to study the merits of these approaches.