# Transition to Practice

In what follows, we describe the transition to practice option for the research proposal. We start with an articulation of the specific goals of the transition to practice, and follow that with a discussion of the execution plan. We conclude with the budget estimate.

## 1 TTP Goals

Specific goals we wish to accomplish as part of our transition to practice include the following.

1. *Revise the design of the catoptric surface so that it can be installed outside.*

   Our initial two surfaces (already in place), and those that we will construct as part of the research plan, are all intended for indoor installation (e.g., in an atrium or on or near a window. This simplifies the design in a number of ways, primarily enabling us to focus on the physical motion of the mirrors, without having to ensure that each component is also weatherproof.

   If the the system can be installed outside, that significantly increases the circumstances under which it can be used practically. When the mirror units can be located outside, then they are able to be exposed to daylight beyond any obstructions such as roof overhangs. An overhang can block some of the high altitude angle sunlight during summer months or in locations near the equator. An additional benefit is that the mirror units can provide some shading for the interior area just inside the window. This could benefit interior spaces in two ways. First, the solar heat gain on the floor or desks near a window may be unwanted and the mirror units can direct the daylight to where it is more useful. Second, direct daylight can cause too much luminous intensity or glare in the area around the window and our systems can redirect the light to bounce off the ceiling to diffuse the light before reaching the task height of the occupants.

2. *Design and implement a user-friendly interface to the open source software.*

   As part of the research plan, we intend to design and implement two levels of control software (one, low-level positioning control for a pan-tilt physical system, and two, high-level management software for Markov decision process optimization). All of this software will be released with an open source distribution.

   However, during the research phase, the user interfaces to this software will not be the primary focus of our effort. As part of the transition to practice, we will design and build an appropriate user interface that enables the architecture community to both use each component individually and to integrate them seamlessly. This user interface capability will also be released under an open source license.

3. *Investigate the commercialization options for the system.*

   We will explore two paths to assessing the potential for commercialization of catoptric systems. First, we will ask a number of practicing architects to evaluate the catoptric surface and provide us with their professional opinions (see letters). Second, we will work with the manufacturing firm that is our second prototype installation site, BECS Technology, to assess the commercial viability from the point of view of a manufacturer (see letter).

Our group has significant experience in commercialization efforts. PI R. Chamberlain has formed 4 companies over the course of his professional career, 3 of which are still in operation and collectively employ over 200 individuals in St. Louis, Chicago, New York, and London, UK. Co-PI C. Ahrens is a licensed architect with 22 years of professional experience, working on institutional, commercial, and residential buildings that focus on sustainable façade and mechanical systems. The projects have been located around the world in Europe, the Middle East, China and the United States. As an example, he was the main designer for the engineering building for Cooper Union, which was the first LEED Platinum rated laboratory building in the United States. Many of his completed buildings have won numerous awards for their sustainable technologies. He is currently the owner of an architecture firm and continues to employ sustainable technologies and techniques in his practice. Co-PI C. Gill has worked extensively with industry partners throughout his research career, including developing software in collaboration with Boeing, BBN Technologies, and Honeywell that was used in manned flight demonstrations.

## 2 TTP Plan

The duration of the transition to practice plan will be for 3 years. The first two years will overlap with the primary research plan (and are labeled years 2 and 3 in what follows). The third year will extend beyond the primary research plan and is labeled year 4.

### Year 2

- Design, prototype, and test several mirror elements aimed at outdoor installation. This will include protection of the metallic components, electronic components, and stepper motors. The assessment will include both the degree to which they can withstand the elements and whether or not there is any degredation in operational peformance (e.g., reduced positioning accuracy or other limitation).

- Perform initial user interface design for individual software components. For both the pan-tilt positioning control software and the MDP optimization software, we will develop visualizations of the state of the system. For the positioning control software, this will include a visual representation of the physical surface and the current positioning of each mirror (either as a whole system or a zoom-in option for a subset of the mirrors). For the MDP optimization software, we will explore various graphical representations that enable the user to easily comprehend the state space, $\mathcal{X}$, of the MDP.

### Year 3

- Assess manufacturability of physical system. In collaboration with the design engineers at BECS Technology, we will evaluate the ability and cost of manufacturing the catoptric surfaces in moderate to large volumes.

- Prototype component user interfaces. This will include the individual interfaces for the pan-tilt positioning controller software and for the high-level MDP model specification. In addition, we will explore an initial design that will allow users to specify the MDP models using a graphical interface. In effect, can we let them draw the visualization of the state space that is then presented as part of the MDP evaluation output?

**Year 4**

- Integrate unified user interface. We will integrate both the MDP model specification software and the pan-tilt control software with the Grasshopper plug-in to Rhino3D. As a visual programming language, Grasshopper is considered by the architecture community to be user friendly (i.e., it is both familiar and in common use).

  While the above integration is well suited for architects, we will also develop an easy to use method that allows occupants of a building to be able to vary the intensity of daylight within their space according to their needs. This will likely be in the form of an app that executes on the occupants' mobile devices. Alternatively, it could be via a web interface.

- Assess commercial viability. The assessment of commercial viability will comprise two primary elements: evaluation of the demand for catoptric surfaces and evaluation of their manufacturability. For the former, we will survey a number of specific architecture firms that have a proven record of using technology to improve energy efficiency in their designs for buildings or renovations. Interfacing with key figures in the firm can provide valuable feedback on the market for our system.

  For the latter, we stated above that we will work with the design engineers at BECS Technology. While that effort will be initiated in year 3, it will have to continue into year 4 as the surface designs evolve, potentially changing the manufacuring assessment.

- Seek commercial partners. Ultimately, if this system is to be put into practice, we must interest a manufacturing firm in making catoptric surfaces and architects in utilizing catoptric surfaces either in new construction or as a renovation option. As indicated above, as part of the project we are collaborating with firms that are qualified to do each of these things.

  Clearly, we will explore the options for commercialization with these organizations; however, we will not limit our investigation there. A major task towards the completion of the project will be to seek out additional potential partners for a commercialization effort.

At the completion of the transition to practice period, if we can attract commercial partners to manufacture and market catoptric surfaces, the design will be very close to "market ready." The bulk of the work that would be remaining is the development of marketing and sales strategies and materials.

## 3 TTP Supplemental Budget

The execution of the TTP plan will extend the duration of the research project for 1 year, and will involve the addition of one more individual to the team. Ed Richter, Professor of Practice in Electrical and Systems Engineering, will join the team in years 2 through 4 and will have a substantial role in executing the transition to practice activities.

| | | Year 2 | Year 3 | Year 4 |
|---|---|---|---|---|
| Personnel: | | | | |
| | Chamberlain | | | 16,587 |
| | Gill | | | 18,920 |
| | Ahrens | | | 10,634 |
| | Richter | 19,800 | 20,394 | 21,006 |
| | GRA (3) | | | 104,297 |
| | fringes | 4,752 | 4,895 | 16,155 |
| Travel: | | | | 6,000 |
| Supplies: | | | | 10,000 |
| Total Direct: | | 24,552 | 25,289 | 203,559 |
| Indirect: | | 13,995 | 14,541 | 117,046 |
| Total: | | 38,547 | 39,830 | 320,605 |
| | | | | 398,982 |

## TTP Supplemental Budget Justification

### Personnel

We request one month of support per year for PI Chamberlain and Co-PIs Ahrens and Gill in year 4. We request 20% time per year for Professor of Practice Ed Richter in years 2, 3, and 4. We request support for three GRAs in year 4. Salaries are assumed to increase 3%/year.

### Travel

We request $6000/year for senior personnel and student travel to present our work at academic conferences and to attend the PI meetings. This is based upon a plan for 4 individual trips each year, with an expected cost of $1500 per trip. Candidate conferences include ACADIA, ICCPS, RTAS, etc. We will also ensure that at least one PI/Co-PI is at the annual PI meetings that are arranged by NSF.

### Materials and Supplies

We request $10,000/year for miscellaneous components to both keep the experimental catoptric infrastructure operational and to make alterations to it for experimental purposes. This will include additional computational components (e.g., microcontrollers, etc.) as well as physical components (e.g., mirrors, structural elements, motors, etc.).

### Indirect costs

Indirect costs are requested at Washington University's standard rate of 55.5% of MTDC (starting 7/1/2018), 57% of MTDC (starting 7/1/2019), and 57.5% of MTDC (starting 7/1/2020).