Mad Scientist™

L2K Owner's Manual

Part No. L2K-00E10000000
June, 2001

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For further L2K information, visit the Quantalink Web site at **http://www.quantalink.com**.

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Open Letter to the Burning Man Community

July 14, 2002

This guide was written over a year ago as a how-to for maintaining the L2K harnesses and light pods. Since last year, the project has been handed off to a new caretaker who is working with Burning Man to ensure the safe return of L2K each year.

Creating L2K was an act of love undertaken by many committed (and boy should they be) individuals. We all put a lot of hard work into this project so that everyone at Burning Man could enjoy it. The most wonderful thing in the world is to hear stories about how L2K has inspired other artists to bring their own creations to life. We hope L2K continues to inspire and amaze people year after year.

We designed L2K to be rugged enough to survive the playa in 1999. We were amazed that it worked flawlessly that first year, especially since installation on the playa was the first full system test of all the components. We were even more amazed that it survived two more trips to the playa in 2000 and 2001. Over the years, we retrofitted the wiring harnesses for even more durability and continued making pods to replace those that had been lost or broken. We hope L2K will continue to be a fixture at Burning Man for many years to come.

However, L2K's survival does depend on the help from the citizens of Black Rock. Each year, we lose around 300-400 pods. Some of the pods are broken during transport, others break due to exposure on the playa. However, by far the vast majority of pods simply disappear without a trace, most likely ending up as souvenirs in someone's home.

While we understand the attraction to the bright shiny lights on the ground, we ask the citizens of Black Rock to remind folks that L2K is an art project. If you see someone taking a pod, just let them know that a lot of hard work went into making this thing. And while taking a pod might not seem like a big deal, the cumulative effect of several people taking them threatens our ability to bring L2K back each year. Pods aren't cheap to make, especially when you have to make a lot of them. Besides, a pod by itself is just a hunk of concrete and plastic. But a pod hooked into L2K is a magical light show for everyone to enjoy.

Thank you all for your continued support of L2K over the years. We hope you continue to enjoy L2K for many years to come. And if you see somebody out doing maintenance on the ring, please don't hesitate to say "Hi". We're all very proud of our project and love to talk about it.

- The L2K Team

Introduction

This chapter includes an introduction to L2K and notes from the Wizard on how it all started.

About Your L2K System

Congratulations on your acquisition of a Mad-Scientist™ brand, L2K™ computer-controlled, pod-based lighting system. Your L2K system is self-contained and portable, giving you 2000 programmable lights, anywhere, at any time. Using the latest in Playa-Prufe™ technology[1], it can withstand the harshest indoor and outdoor environments.

1. Note that Playa-Prufe technology does not fully protect the system from the following: alkaline corrosion found in some geographic regions, damage from heavy machinery, deliberate or accidental mistreatment, or naked tripping people doing stupid things.

Your new L2K system will provide years of enjoyment. Use it to:

- provide emergency runway lighting
- signal UFO's
- keep naked, tripping people out of harm's way
- amuse the kids
- hypnotize the neighbors
- decorate your house
- become president of Antarctica
- get past security roadblocks
- or perform any of a hundred other common household tasks...

The following document provides information needed to install and maintain your new L2K system. Please make sure you read through this manual thoroughly before unpacking any L2K materials.

A Word from the Wizard

The following section contains an excerpt from an interview with Tim Black (aka the Wizard) about how L2K came into being. The complete text of the interview is available in Thanks to Rebecca Firestone and Tim Black for supplying this text.

How It All Started

I enjoyed the art and performance of the Nebulous Entity last year (Burningman 98). I was basking in the glow of last year's success and expecting to just go and enjoy other people's art, take it a little easy after the overcommitment of '98. Then Larry called me up and asked, "What are you going to do for the Wheel of Time?"

Being a somewhat literal-minded engineer, I though: Wheel... Circle... 2000... OK, what about 2,000 lights in a circle... individually addressable... at a speed of 2,000 times a second... a Ring, artwork consisting of patterns and light!

Why am I doing this? Why turn my life upside down to create acres of art in the desert?

It's not a logical thing, My head says I must be completely nuts, but it just feels like I should do this. It's somehow a heart thing. There are a lot of invisible people working on this, people who do science and technology in cubes and other hidden places. People who are extremely creative, but normally their work is not directly seen. I'm one of them, and this project is about that somehow. About how the hard core tools of engineering, circuit boards and software debuggers, are valid tools for art. That technology can be a medium, used like paint or marble, and formed into things delightful and unexpected.

It just matters in ways that I can't begin to explain, and I deeply thank everyone who is helping make this happen.

- The Wizard

Installing Your L2K System

This chapter covers installation, setup, and configuration of the L2K system. Please read through all instructions in advance before your first installation. Installation is a relatively simple process but requires a good amount of coordination and up-front planning to execute well.

Installation

Installation on the playa involves several labor-intensive steps. In 1999, it took a crew of people 3 full days to install L2K. By 2000, we were able to get the amount of time down to 10 hours. This section will provide you with a summary of the installation, with subsequent sections providing more detailed information.

L2K installation can be broken down into the following steps:

1. Survey
2. Loadout
3. Distribution
4. Trenching
5. Unpacking
6. Installation
7. Testing
8. Burial
9. Cleanup

The first step in installing the system is to **survey** your site and figure out where you want L2K to go. Burning Man has taken care of this step in the past by marking the safety circle around the man with small flags. The flags were placed at a preset distance by DPW in advance of the L2K crew arrival. In general, you need to have enough markers to be able to establish a sight line for the ring as you walk around it.

The **loadout** step simply involves transporting all of the L2K equipment to the site. A Burning Man-sized installation uses all of the L2K pods, harnesses, and batteries. The total weight of all this gear is nearly 3 tons (yes, 6,000 pounds!). The L2K pods make up the bulk of the weight. They are, after all, made from cement. The batteries are the next heaviest load. The harnesses do not weight as much relative to the pods and batteries but they are more delicate and therefore require more packing space to prevent damage.

NOTE: In 2001, 8 towers have been added to the L2K installation. These towers are installed in pairs so that they define four gateways into the center of the ring. Each gateway will consist of a controller tower and a dummy tower. The controller towers will contain a battery and an interactive system for manipulating the ring speed, pulse width, and individual pixels. The other towers will contain dead weight.

It is generally a good idea to distribute the L2K equipment before you begin trenching. **Distribute** the pod buckets and batteries at regular intervals around the area to be trenched. Pod buckets need to be spaced approximately every 20 feet. Harness buckets should be distributed evenly around the ring. At each of the 4 cardinal points (12, 3, 6, and 9 o'clock) place a single controller tower and a single dummy tower. (These towers will designate the gaps in the ring through which vehicles can pass). Make sure that all equipment is far enough from the line of the trench that the trenching equipment has room to operate.

Four of the batteries are encased in the wooden towers that define the gateways into the center of the ring. The remaining batteries are encased in durable plastic containers. The batteries in the plastic containers should be placed halfway between the gateways. When you connect up the ring, the number of harnesses between each pair of sequential batteries should be roughly the same.

IMPORTANT! It is imperative that the batteries are distributed evenly around the ring. The current sources need to be distributed evenly for everything to work. Failure to distribute the batteries could result in blackouts during heavy pattern loads or it could damage the ring!

Trenching is the most critical step. Our lesson from the year 2000 was to use a real trench digging tool, such as a Ditch Witch trencher. Do not try to dig a furrow using a plow or plow-like attachment (such as forklift forks). A real trencher will leave you with a nice hole in the ground and a pile of dirt along the side. The advantage of this type of trench is that it makes the final burial step go significantly faster.

The best place to start the trench is at 12 o'clock relative to the man. The next best place is 6 o'clock. Start at the edge of the gap left for through traffic and begin trenching clockwise. (If you're part of the counter-culture, feel free to trench counter-clockwise instead.) Dig the trench about 3-4 inches wide and 6-8 inches deep.

NOTE: The first year we did L2K, we used forklift blades as a plow in the playa. With this type of trench, the harnesses had to be buried and backfilled by hand, which increased installation time by a full 2 days and resulted in some exposed circuit boards. Get a clue, use the trencher.

Once you have a section of trench dug, you can begin **unpacking** the harnesses and pods. Place the pods at 1-foot intervals on the ground next to the trench. Unroll the harnesses carefully, placing them in the actual trench. The male plug of each harness marks the beginning of the harness.

Installation is a simple matter of plugging everything in. The harnesses and battery towers are delicate parts of the system so have the crew leaders work with them as opposed to volunteers. Everything else is well suited for large numbers of volunteers. Grab as many people as you can and have them start plugging pods into the harness wires. There is only one way to connect everything together so you do not have to worry about people making mistakes.

Connect a controller tower to the lead harness and start **testing** the system as soon as you can. As soon as pods are plugged in, you want to see data running across all of the connected harnesses. If it is, you can go ahead and have volunteers **bury** the completed harness sections. After burying the harnesses, place the pods on top of the backfilled trench. Twist each pod a few times to bunch the pod wires up underneath the pod.

NOTE: If you dovetail the work, you can have the trencher digging the trench, the crew chiefs laying out harnesses and connecting them to the towers, and the volunteers plugging in pods all at once. Once you have verified that a section of harnesses is working, you can then have a crew backfill that section of the trench.

Once the last pod is plugged in and the entire set of harnesses is tested and buried, congratulate yourself on a job well done. Then, you can begin the installation **cleanup** process. Cleanup simply involves gathering the pod and harness buckets and moving them someplace safe.

Preparing the Site

The following sections provide more detail about each of the installation steps. If you helped install L2K during 1999 or 2000, you will notice that some of the steps have changed, particularly with regard to connecting the batteries and controller computers. However, most of the rest of the process is exactly the same.

Surveying the Site

Up until now, Burning Man has handled the surveying of the L2K ring. Prior to our arrival, members of DPW would mark a circular ring around the man using range-finding binoculars. To mark the ring, they would place flags at the appropriate distance from the center of the man. These flags would demarcate the future placement of the ring.

During trenching, the more flags placed on the ring, the better the trench. Digging a curved trench takes a certain amount of skill. You have to be able to walk backwards slowly and follow an imaginary arc while guiding a very large machine. Try to space flags as frequently as possible to get a good approximation of the ring.

Transporting the L2K Components

The L2K components are packed in sturdy containers to protect them during transit. However, even with this protection, there are additional safeguards you should follow when transporting L2K materials.

Transporting pod buckets

Do not stack pod buckets more than 3 high. If you have the space, stack them only 2 high. Pod buckets contain nearly 60 pounds of cement each. You do not want that much weight stacked at a height if you can avoid it. If you do have to stack them high, make sure they are secured very well.

Transporting battery towers

Due to their shape, you will not be able to stack the 8 towers. Regardless, make sure you take great care when transporting them. Four of the towers contain a 6 Volt lead-acid battery, control circuitry, and gadgets on the pyramid top. The batteries are secured inside the towers but you should always be careful when transporting them. Do not let a tower fall on its side. This can spill some of the acid from the battery, which both reduces the battery life and damages the tower.

Stacking things on top of the towers can damage the controllers and gadgets on the outside, so just don't do it.

Transporting harness containers

The current harness containers do not weigh very much. As such, feel free to stack them as high as space allows. However, make sure to secure them so that they do not spill.

Trenching

The only thing to say about trenching is that you REALLY want to use a trench-digging machine such as a Ditch Witch. The first year L2K appeared at Burning Man, DPW dug a trench for us using the forks of a forklift. This made for a nice circular trench, but meant that we had to remove a whole bunch of dirt by hand before we could bury the harnesses. Not fun. A Ditch Witch will dig a perfectly square trench and place the dirt in a neat pile to one side. This makes both placement of the harnesses and backfilling of the trench trivial operations. We saved 2 days of backbreaking manual labor by digging a real trench.

The trench you dig should be about 3-4 inches wide and at least 6-8 inches deep. You want the harnesses to be deep enough where people will not disturb them but shallow enough for you to get at them for maintenance. You also want them reasonably shallow so as not to damage the harnesses during the uninstall.

Connecting It All Up

Once you have a section of trench dug, you can begin the installation process. In fact, trenching and installation can happen in parallel for most of the operation. Digging a trench takes time, but so does installing the harnesses, testing them, and then backfilling the trench.

The best time to install L2K is late in the afternoon. You want to have enough time to dig the trench during daylight but still be able to see the pods when you run your tests. If you plan to do a night installation, make sure there are plenty of portable lights for volunteers since plugging in the pod wires requires the ability to see them.

Gathering Your Volunteers

The more hands you have helping you install L2K, the faster it will go. Gather as many folks as you can to help carry buckets, plug in pods, and bury harnesses.

Useful Tools to Provide to Volunteers

- Gloves
- Kneepads
- Push brooms (used upside down) or snow shovels for pushing dirt back into the trench
- Water cooler (it's thirsty work)

Plugging Everything Together

Installing the harnesses is as simple as unrolling them and plugging them in. The male plug denotes the beginning of each harness. Once you have the first harness in place, there is only one way to plug in the rest of them, so get it right the first time. Stretch the harnesses out to their full length, removing any kinks you find in them. When you plug two harnesses together, make sure to twist the plugs so that they lock. Locking the plugs prevents the harnesses from disconnecting accidentially. It also simplifies the uninstallation process.

Figure 1 shows the L2K trench, pods, and volunteers during the installation process. This trench was dug by a Ditch Witch trencher, seen near the lamp post.

Figure 1 Installing L2K

Plugging in the Pods

Plugging in the pods is a perfect job for your volunteers. You should start by having the volunteers pull the pods out of the pod buckets and place them next to the trench. The wires for the pods are spaced 1 foot apart, so you want the volunteers to space the pods as close to that mark as you can. With the pods and harnesses in place, have people start plugging everything together.

Have them place the pods on the opposite side of the trench as the mound of dirt put their by the trencher. That way, the dirt can be pushed in quickly without the pod being in the way. Do not have them push the dirt in until the section of harnesses has all its pods connected and has been tested.

Setting up the Towers

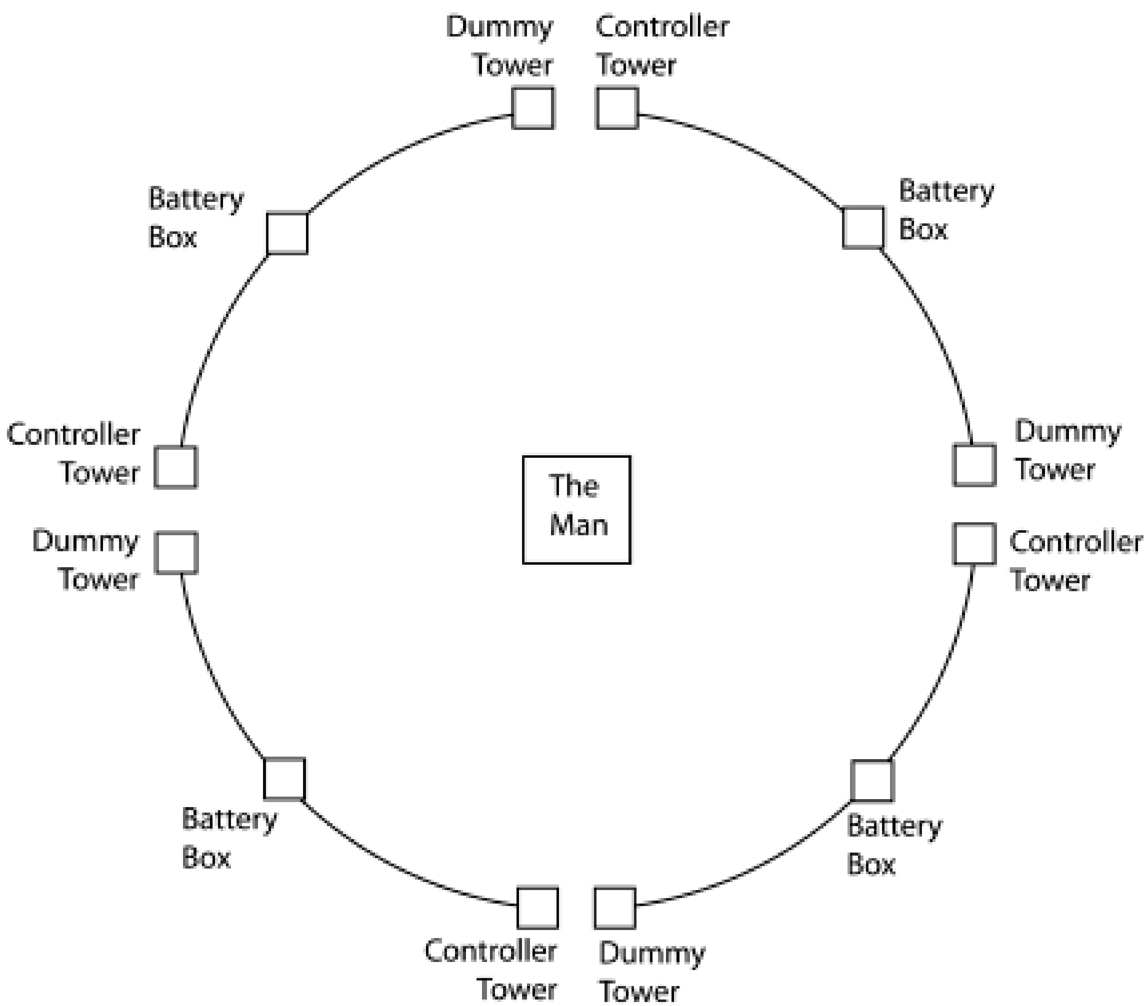
Beginning in 2001, L2K will use 8 towers, shaped like obelisks, to power the ring and control its patterns. There are two types of towers: controller towers and dummy towers.

The controller towers will have a battery and a computer for controlling the ring. These towers will change the primary characteristics of the ring, such as the width and speed of pulses. Passers-by will be able to modify the ring pattern using input devices found in these towers. The dummy towers will contain dead weight. These towers help define the gateway into the center of the ring.

In addition to the towers, there will be four durable plastic containers containing batteries. Each of these boxes must be placed roughly halfway between two gateways.

Figure 2 shows the approximate placement of the towers around the ring. This diagram also shows the gaps to be placed in the ring at the main compass points to allow for vehicular traffic through the ring. The exact placement of the towers will depend on where the immediately preceding harness ends. The gaps between towers must still be trenched to allow for the completion of the ring.

Figure 2 Tower placement along the ring



In order to prevent brown-outs or other low power situations, the batteries must be distributed evenly over the length of the ring. Exact placement of the towers depends on the size of the ring. The exact size of the ring is difficult to calculate in advance because of the natural variations that occur during the trenching process. However, knowing the intended size of the ring can give you a rough idea of where to place the towers.

Example:

Suppose you are setting up L2K in a 600 foot diameter circle in the configuration shown in Figure 2. In this configuration, there are 4 gateways, each with a 20 foot gap. There are also four uninterrupted arcs. The leading edge of each arc starts with a controller tower while the trailing edge ends with a battery tower. There is also a single battery tower midway along the arc

A 600 foot diameter ring has a circumference of approximately 1884 feet. This means that you will need approximately 38 harnesses for the entire ring. L2K comes with five 10-foot long segments to let you generate the size of ring you want to within a very close approximation.

To make sure the batteries are distributed properly along each quarter arc, place the midpoint battery towers 4 harnesses from the previous controller tower. the remaining gap should be exactly 5 harnesses. Repeat this process for each quarter arc, making sure you always have either 4 or 5 harnesses between batteries.

If you find yourself using more or fewer harnesses for an arc, adjust the placement of battery towers as needed. Setting up the ring is not rocket science but it does require the attention of someone to make sure everything is balanced.

Running a System Test

Before you backfill any trenches, make sure the harnesses you are burying have been fully tested. If a harness is not passing data further down the line, you may have to replace it, so save yourself some trouble by testing.

The first stage of testing involves applying power to the ring. Once you establish power to the L2K ring, each ring board will initialize itself and begin running a simple test pattern. This test pattern will tell you that the boards are OK and ready for commands.

The second stage of testing involves running patterns. It is important to run patterns over the entire ring to make sure each board is receiving and sending the pattern data. A failure to receive or transmit this data will result in failures of all the downstream boards.

Running the Self-Test Pattern

By default, whenever you apply power to an L2K circuit board, the board begins running a self-test pattern. This self-test pattern provides visual feedback that the board has power and its pods are working. Self-test mode does not provide any indication that the data lines between boards are working.

In self-test mode, each circuit board turns all of its pods on in sequence. Only one pod remains lit at any given time. (The effect is a 10-light tracer pattern.) If a pod does not light, check to make sure the pod has a good connection. If the connection looks alright, try replacing the pod or checking the wiring on the harness for loose connections.

Running Patterns

Once you have established power to the L2K system, you can begin running patterns from one of the L2K controller towers. In previous installations, L2K was originally powered by a single master computer. However, starting with Burning Man 2001, the L2K system will come with a new set of controllers to run the L2K ring. During the event, multiple pattern-generating computers will be distributed around the ring vying with each other for control.

When you begin installing the ring, place the first controller at the head of the ring and turn it on (See *Enabling the Controller Towers* on page 66 for information on how to do this.) The first thing the controller does is quiet the ring and initialize it. Quieting the ring pulls the boards out of self-test mode and tells them to wait for instructions. The controller then starts generating patterns. If the boards are communicating properly, you should see patterns start running along the ring.

Leave the controller enabled for the duration of the installation. Most controllers will reinitialize the ring after a preset interval. This reinitialization should activate the circuit boards on any recently added harnesses. If it doesn't work the first time, try waiting for another initialization cycle. If the new harness still doesn't work, remove it from the ring and diagnose the problem later.

You can plug additional controller towers into the ring at any point. Because the original tower will not have data until you close the ring, it should retain control for the entire installation. The other controllers will pass data through until they are given the opportunity to take control.

Troubleshooting

If you tested all of the L2K gear prior to your arrival on the playa, you should not run into too many problems during installation. However, problems still occur and the most likely things you will run into are pods that do not light up and harnesses that do not pass data. When you encounter either of these problems, simply replace the component and move on.

During installation, the most important thing is to get the ring working and BURIED! Leaving an open trench on the playa is just asking for trouble so do not try to diagnose problems on the spot. Replace the component with one that works and spend time later trying to figure out why the original one broke.

Backfilling the Trench

If you used a Ditch Witch trencher, backfilling is a simple process of pushing the dirt back in place. This is best handled as a two-person job. The first person should have a push broom turned upside down so that the wood is scraping the ground and the bristles are in the air. (Alternatively, the person can also use a large snow shovel to push the dirt.) Have that person push the dirt back into the trench. The second person should be opposite the first, holding the harness wires down in the trench when the dirt is pushed in. Both people should have a pair of gloves for this operation.

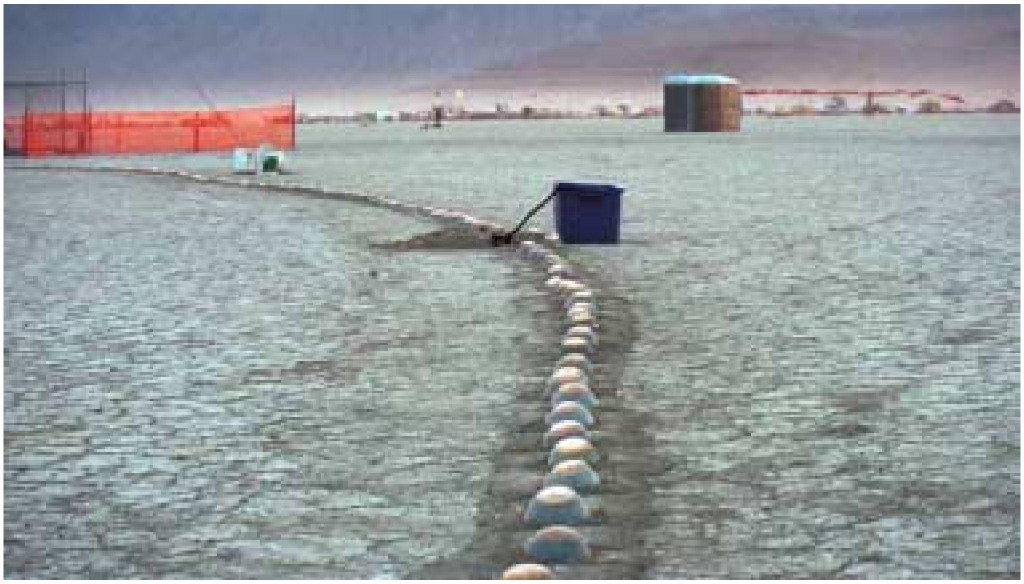
Once the trench is filled, have another person come along and place the pods directly on top of the backfilled trench. When placing pods, the important thing is to make sure the pod wires are not exposed, as this will lead to people tripping on the wires and possibly damaging them. Gather the wires underneath the pod and squish the pod slightly into the soft dirt of the trench so that the base portion is slightly submerged.

NOTE: The best way to gather the wires underneath a pod is to do the pod twist maneuver. In this maneuver, you simply twist the pod clockwise or counter-clockwise for several revolutions. This curls the wires up underneath the pod very nicely.

Once all of the harnesses are buried and the last pod has been placed into position, you are done with the initial installation phase. Collect any tools and remove any buckets and equipment and you have a nice ring of lights for people to play with.

Figure 3 shows the L2K ring after installation.

Figure 3 L2K installed



Nailing Everything Down

Once everything is installed, you should go back and retrieve the pod and harness buckets and store them somewhere safe. With nothing in them, all of the buckets will easily blow away in the playa winds.

In order to keep the towers from being blown over in the wind, each tower is outfitted with metal bars along the bottom. After you have the tower positioned where you want it, pound some candy-caned rebar into the ground over these bars, getting the rebar as close to the ground as possible. Make sure to put at least one piece of rebar on each side of the tower to prevent it from sliding out from underneath the rebar (or to keep somebody from sliding it out from underneath the rebar).

Maintaining the Ring

Regular maintenance of the L2K ring is important to keeping it looking nice. Because the pods are just sitting on top of the ground, they have a tendency to get knocked loose when people kick them or ride their bikes over them.

Most of the time, the pods just slide a little to one side and continue to light up. If a pod gets knocked too far, it will disconnect itself from the harness and not light up. When you discover a disconnected pod, you should try to find the place from which it came and plug it back in. This will naturally require digging down into the trench to find the harness wires. For this, a pair of sturdy gloves or a small plastic shovel is usually sufficient to dig up the wires.

IMPORTANT! Do not use a metal shovel to dig for harness wires. Metal shovels tend to have sharper edges and can cut the wiring of the harness.

If you notice a point along the ring where data is no longer flowing, you may have to go out and dig up one or more circuit boards or the entire harness. The main reason the ring will stop passing data is that the dirt surrounding a ring board will compress so tightly as to press the data line against a sharp edge on the board. This causes a short circuit in the data line and prevents data from flowing further down the line. To fix the problem, you need to remove the short circuit.

For more information on troubleshooting problems, see *Troubleshooting* on page 55. Figure 4 shows Podmeisters T.J. and Bob digging up a malfunctioning harness.

Figure 4 Fixing a broken harness

Uninstalling L2K

Uninstalling L2K is a relatively simple process since L2K was designed for quick removal from the ground. The first thing you need to do is extract the harness from the ground. This is accomplished by starting at the computer and gently pulling the harnesses up out of the ground.

Each harness includes a length of rope as part of the harness cabling. This rope provides some strength for simply tugging on the harness wires to pull them out of the ground. However, this does not mean that you should yank the wires suddenly. They can still break if you pull on them too hard.

The plugs at the end of each harness are 3-prong twist-lock plugs. If the plugs were locked during installation, the harnesses will all come up as one large harness.

Once the harnesses are exposed, unplug the pods and start the repacking process. Each 5-gallon pod bucket is capable of holding 21 pods. Make sure your volunteers use the layering strategy described in *Pod Storage and Handling* on page 37. Once a harness is free of its pods, go ahead and coil it back up and place it in its protective storage container.

As with any playa project, make sure to smooth over the trench after everything is uninstalled so as to leave no trace of its existence. Figure 5 shows the L2K team removing the harness wires from the ground.

Figure 5 Uninstalling L2K

Working With Pods

This chapter describes the L2K pod lights, and shows you how to make new ones. This chapter also covers some of the basics of pod maintenance, such as proper storage and handling.

Pod Construction Basics

Pods are a combination of cement, plastic, and electronics. They were designed to be durable ground-based lights, capable of surviving for over a week out on the playa. Much thought went into the basic design of the pods. The main design factors we considered were as follows:

- **Durability -** Besides playa dust, the pods have to withstand vehicles driving over them, people tripping on them, and people just plain stepping on them. They have to be heavy enough not to blow away or get knocked out of position too easily.
- **Visibility -** The superbright orange LEDs chosen for the pods gave out the most light of all the ones we tested. Although the LEDs provide a point source of light, the plastic lens surrounding them diffuses that light. With a straight line of sight, you should be able to see these pods from nearly a mile away, which is pretty impressive for LEDs.
- **Safety -** The pods are rounded so as not to cut pedestrians or tires. The pods are also equipped with quick-disconnect plugs to prevent someone from tripping over one. We don't want the pods to be fixed hazards in the playa. We also don't want to damage the wiring harness buried underground. Since pods are cheap, they become more expendable than any other part of L2K, absorbing damage so nothing else has to.
- **Simplicity -** We had to make 2000 of the blighters. They had to be reasonably simple to make otherwise they would have taken too long to make and would be prone to more problems.
- **Cost-effective -** In bulk, our pods cost around $1/each for the materials. Of course, this meant we had to put a lot more labor into their construction, but that's where volunteers come in handy.

Figure 1 shows two close-up views of an original L2K pod. The diameter of the base is approximately 5 inches. The diameter of the lens is approximately 3 inches.

Figure 1 Top and side-view of an L2K pod

To make a pod, you basically cast a super-bright orange LED in fast-setting plastic. Attach wires to the LED and mount the whole unit on top of a cement base. Sounds simple? Think again.

The following sections document the process for creating new pods. Most of the initial manufacturing processes can happen in parallel, and we recommend you exploit those possibilities whenever possible. Most of the laborious work requires only minimal skills, so if you have an inexperienced crew, you can probably train them without too many problems.

IMPORTANT! Although pod making involves some relatively straightforward processes, the devil is in the details. The more careful you are during their construction, the fewer problems you'll have when you actually deploy them out on the playa. The pod's electrical connections are especially delicate and require a certain amount of skill. Of course, if you have a dedicated crew working on them, they'll get pretty good after the first five hundred or so.

Materials List

Pods use a variety of different materials. Table 1 lists the materials you'll need and guidelines for how much to buy. Remember that the quantity estimates are only guidelines. It's always best to buy extra to handle the inevitable throw-away work.

Table 1 Pod materials list

Material	Guidelines
Portland cement	Used for cement mix. See *Calculating Your Cement Needs* on page 27 for advice on quantities.
Aggregate (sand)	Used for cement mix. We used 30 mesh washed sand, available from any cement supply store.
Lime	Used for cement mix. This is lime the mineral, as opposed to lime the fruit.
Fiberglass reinforcement	Used for cement mix. (Note, this ingredient was not used in the original pods, but has been added to improve pod durability.)

Table 1 Pod materials list

Material	Guidelines
Styrofoam cereal bowls	Used for bases. We used Costco styrofoam bowls for casting the bases. You'll want to use fresh bowls each time since they get destroyed easily. Bowls should be 3' diameter at the bottom and 5" diameter at the top.
Straws	Used for the bases. Straws provide a starter hole in the base through which the wires can be fed. You don't strictly need straws, but if you don't use them, you'll have to drill through a lot more cement, which is time consuming. Get Costco straight straws (no bendie-straws).
Liquid Plastic Resin	Used for lenses. We originally used an acrylic mixture that came in two parts: the resin and a catalyst. For 2001, we are investigating the use of resins designed for surfboard and windsurfers. The resin characteristics are nearly identical, except that the new materials are more pliable and appear to be less prone to shattering. The cost of the new materials is nearly identical to the original plastics. The mixing of the catalyst and resin is a scientific paper in its own right and is discussed in *The Science of Plastic Resins* on page 31.
Mold release	Used for lenses. This material is critical for getting nicely shaped lenses.
Superbright LEDs	Used for lenses. Best to buy these in bulk from the manufacturer. Each pod needs only one LED.
Wire	Used for lenses. This is 22 gauge stranded wire. For each pod, you'll need two 1-foot lengths, preferably of different colors. Thus, for 2000 pods, you'll need at least 4000 feet of wire (2000 feet per color).
Molex pins	Used for lenses. Molex pins are quick-disconnect plugs. You'll need to make sure you get Molex pins that match the ones on the harnesses. You'll need a male and female pin for each pod. Plus, you'll want plenty of extra pins for those inevitable bad crimps.
Heat-shrink tubing	Used for lenses. You'll need two 1-inch lengths of 1/8" heat-shrink tubing to fit over the Molex pins. So, you'll need at least 2 inches per pod.
Hot glue	Used for lenses. You'll need this to seal up electrical connections. Hot glue is cheap and useful so buy plenty.
Silicone sealant	Used for pod assembly. Use good quality silicone sealant if you want long-lasting pods. Cheap stuff will result in lens/base separation at some point. We used several cases worth of sealant to do the original pods.

Table 2 lists the tools and equipment needed to build the pods. Many tools on this list can be duplicated to increase production capacity. Read the instructions in later sections for guidelines on which parts of the process can support duplication.

Table 2 Pod tools

Tools	Description
Casting Oven	You'll need some sort of rack for holding the plastic resin. This oven needs to be able to suspend the LED's in the plastic. See *Casting the Lenses* on page 28 for more information.
Drying racks	You'll need space to let the pods dry. We used 2x4s with a gap between them to allow for wires to dangle down.
Paperweight molds	These molds are used to cast the lenses. We used Tap Plastics paperweight molds with a 3" diameter. They can be reused but you should by extras since they get filled with gunk pretty quickly.
Mixing sticks	Have some tools for mixing the plastic resin.

Table 2 Pod tools

Tools	Description
Wire stripping tools	If you're stripping a lot of wire, you'll want to get a dedicated wire-stripping tool. Bob recommends the StripAx Professional wire stripper.
Wire crimping tools	Get a crimping tool capable of handling Molex pins and 22 gauge wire.
Testing gear	Make a small battery pack with a 220 ohm resister in series to handle quick testing of the lenses.
Caulking Gun	For final pod assembly, you'll need something with which to apply the silicone sealant.
Wire cutters	For trimming LED leads and general wire work.
Needlenose pliers	For additional crimping and wire work.
Solder pot	For tinning wires and leads
Soldering iron	For attaching wires to leads.
5-gallon buckets	Used for mixing cement. We've been told that mechanical cement mixers also might be capable of doing the job.
1/2" drill	Used for mixing the cement, if you don't use a cement mixer.
Cement mixing paddle	This mixes cement, duh. Make sure it fits a 1/2" drill or your arms are going to get awfully tired.
Latex gloves	For casting both the lenses and the bases. Always make sure to where your digital condoms.
Respirator	For casting the bases. Cement dust is nasty. Use a respirator. If you do, your lungs will reward you with some nice oxygen later.

Casting the Bases

One of the major components of a pod is its base. The bases are made from cement to give the pod both strength and mass. The mass keeps pods from blowing away in the wind and from being kicked too far out of position. The strength of the cement also keeps the pods from getting totally destroyed by people driving over them on bicycles or other vehicles.

To make the bases, you need to mix up some cement and pour it into forms. We used Costco styrofoam cereal bowls to make our bases. The styrofoam is handy because it comes free from the cement pretty easily. In the rare case that a bowl actually stuck to the cement, you can just destroy the styrofoam. Figure 2 shows some of our bases drying.

Figure 2 Casting the cement in styrofoam cereal bowls

Calculating Your Cement Needs

The first step in casting the bases is getting your materials together. The final weight of each pod was approximately 2.5 pounds. Thus, for the original L2K project, we used approximately 5500 pounds of cement mixture to make 2211 pods. Once you know your approximate tonnage needs, you can use the following proportions to calculate the amount of raw materials you will need:

- 1 part - Portland cement
- 3 parts - 30 mesh washed sand
- 1/4 part - lime
- 1 healthy pinch of Stealth fiber (see package for more usage instructions)

NOTE: The fiberglass reinforcement material was not included in the original design. We added this material to make for stronger future pods. Its weight is negligible.

To the above proportions, you will also need to add a little water to get the consistency just right. Like the Stealth fiber, do not worry about including this in your raw materials calculations.

Preparing Your Mix

Before you mix the cement, make sure you have an open area to work and plenty of space for drying bases. Ventilation is important when working with cement because of the dust involved. Personal protection is also important. Make sure you where latex gloves and a respirator when mixing the cement.

The tools you will need for mixing the cement are pretty simple. If you have a cement mixer already, you probably do not need us to tell you too much more. However, if you are new to this, you can mix the cement in any large container. We used 5 gallon buckets for L2K. We stirred the mixture using a 1/2 inch drill with a mixing paddle drill attachment.

Once you get the cement going, make sure you have a place to put the styrofoam bowls. An 8’x4’ sheet of plywood makes a fine table for stacking lots of styrofoam bowls. Whatever kind of table you set up, make sure you can reach any point on the table. While the cement is setting, you will need to check it and make minor adjustments, which means you need to be able to reach every bowl.

Mixing it Up

Combine the dry cement ingredients according to the proportions listed in *Calculating Your Cement Needs* on page 27. Add water as needed until the consistency of the cement is similar to well blended cake batter. It should have a somewhat slurpy consistency. Use the drill and mixing paddle to make sure the ingredients are well mixed together.

Once your batter is looking all yummy, get out some bowls and start pouring. Use a 4-cup measuring device to transfer the slurry from its container to the cement. Do not try to dunk the bowls or lift the container. It would be bad.

As you fill the bowls, make sure to pop any air bubbles. Stir the slurry in the bowl gently to release any air pockets and pop any air bubbles you see on the surface of the slurry. Air bubbles make for uneven surfaces, which is also bad.

After 30 minutes, the cement should be cured enough to insert the a straw into the mixture and have it stand up. If the cement is still too runny, wait until it is a little more firm. Place the straw at the center point of the bowl. Push it all the way into the cement until it reaches the bottom of the bowl.

Every 30 minutes thereafter, rotate the straws with a slightly wobbly motion. The goal is to make the hole at the top of the bowl a little larger than the one at the bottom of the bowl. Continue this procedure every 30 minutes until you can remove the straw without affecting the structural integrity of the rest of the cement.

At this point you are done for the day. Let the bases dry for at least 24 hours. Once they are fully hardened you can flip over the bowls (carefully) to retrieve the newborn cement base. Use a drill to remove any lingering material in the hole where the straw was. Typically, we had to drill through just a small amount at the top of the base.

Our 2-person L2K crew averaged about 300 pods per 4-hour session. The primary limiting factor for our crew was drying space for the bases. The more space you have the more bases you can make in a single session.

Casting the Lenses

The other major component of a pod is its lens. The lens is a solid plastic hemisphere with an LED embedded at the focal point. The plastic diffuses the LED light and spreads it out in all directions. This is important because most LED's are point-sources of light, that is, they are brightest when you look at them directly. Casting the LED's in plastic helps spread out some of that light, making the pod visible from all directions.

The lenses themselves are cast using a two-part liquid resin that hardens into a tough plastic when combined in the right proportions. The liquid plastic was purchased from Tap Plastics in bulk. The shape of the lens was obtained by using a Tap Plastics paperweight mold.

The process for casting the lenses can be broken down into the following steps:

1. Prep the casting oven and molds for use. (Make sure to apply mold release to the molds.)
2. Position the LEDs as best you can in their holder.
3. Mix the plastic and pour it quickly.
4. Position the LEDs in the plastic and adjust as necessary.
5. Set the entire assembly aside so that the resin can harden.
6. Remove the lenses and clean them up.

About the L2K Casting Oven

To embed the LED in the plastic, we created a casting oven specially for the job. The casting oven allowed us to raise the temperature at the time of casting and lower the amount of catalyst in each batch. This was important for us because the catalyst component is pretty expensive compared to the cost of the resin.

The LED's were suspended from clothespins down into the casting molds. A system of removable inner chambers allowed us to fill the molds with liquid resin, affix the clothespinned lid into place, adjust the position of the LED's, and then place the entire assembly in a black box for baking.

Figure 3 shows the casting oven we used for building the original L2K pods. This oven could make 32 lenses at a time. Paperweight molds with liquid resin were placed in the grid. Clothespins held the LEDs in place over the paperweight molds while the resin hardened. The box was painted black to add heat to the process. The temperature of the box was controlled by a fan connected to a temperature sensor.

Figure 3 L2K lens casting oven

IMPORTANT! One thing that was discovered during the lens-making was that liquid plastic is extremely messy. After much use, the old paperweight molds became more problematic to work with. It's advised to have a steady stock of spare molds on hand, since Tap Plastics does not stock them in any great quantity. (We found this out after scouring every Tap Plastics in the San Jose area.)

Prepping the Oven

Prepping the oven is a critical step to turning out good lenses. You really want to make sure everything is ready to go before you even think about mixing the liquid plastic components together. The reason is that once you mix the plastic, you're working against the clock to get everything in place before the resin hardens. The plastic we used had a set up time of around 8 minutes.

Apply the Mold Release

One of the first steps in prepping the oven was to apply mold release to each of the paperweight molds. This thin film makes it much easier to separate the hardened resin from the plastic paperweight molds. However, since the paperweight molds have to be reused over and over, this is very important. Once you have applied the mold release to the paperweight molds, place them in the casting oven.

IMPORTANT! Podmeister T.J. says that a good mold release was critical to lens casting. Don't forget this step or you'll end up using up your paperweight mold supplies fast.

Prepare the LED Array

You need to prepare the LEDs for their eventual suspension into the liquid plastic. In our original casting oven, this meant putting LED's in pre-positioned clothespins. Later revisions of the oven used styrofoam and other block materials that you could stick LED's into. Regardless of your oven design, you'll want to position the LED's so that they will be close to the proper depth when you eventually dunk them in liquid plastic.

Figure 4 shows a side-long view of our original casting oven. In this view, you can see the clothespins used to hold the LED's in place. The LED array was fixed in place with the paperweight mold array by four bolts (two of which can be seen in the figure). As soon as the plastic was poured, the LED array would be bolted into position. The entire assembly could then be lifted up and set inside the casting oven.

Figure 4 LED array of the original L2K oven

NOTE: Marking the side of the paperweight molds with a “fill line” makes it easier to see if you have poured the correct amount of plastic. Finding the appropriate position for this fill line is an experiment left up to the reader.

Performing the Cast

The difference between plastic and theatre is that with theatre you cast the performers. The following sections contain notes on the casting process for the lenses. Speed is of the essence when you are working with plastic resins. So is safety. Make sure you read the instructions in this section and follow all of the safety precautions.

Plastics and Safety

Plastic resins are pretty nasty substances. You should always be very careful when working with these substances and take every precaution to protect yourself from their effects. You should always have the following protective gear when working with plastics:

- A respirator
- Latex gloves
- Protective covering for any exposed skin

If you must work with plastic resins indoors, make sure the area you are working in is very well ventilated. The fumes given off by hardening plastic are strong, even when they are being used outdoors. Indoors, the fumes can quickly overcome you or unprotected co-workers. Always make sure to wear a respirator or gas mask, regardless of whether you are working indoors or outdoors.

Anyone working directly with the resins should always wear latex gloves and protective clothing to keep the resin from coming in contact with your skin. The liquid plastic is hard to get off skin and not very fun to wear once it has hardened. You will need gloves whenever you are working with the plastic in its liquid or near-hardened form.

The Science of Plastic Resins

To cast the lenses, we went to our friendly, neighborhood Tap Plastics for materials. We used a 2-part liquid casting mix that contained a resin and a catalyst. The resin is the largest component and as such was purchased in bulk drums. The catalyst was a much more expensive component but much less of it was required.

We used the proportions of resin and catalyst recommended by Tap Plastics. Changing this ratio too much caused the lenses to cure incompletely or crack. We used an oven to speed the curing of the lenses. The casting oven kept the plastic resin at approximately 95 to 100 degrees Fahrenheit. At these temperatures, the resin hardened a little faster than it otherwise would have.

Mixing the Plastic Resins

When all of your preparations have been made, the final step is to mix and pour the plastic. Each lens requires approximately 2 ounces of resin. Preprogram a countdown timer for the maximum working time of your resin. As soon as the catalyst comes in contact with the resin, start the timer. One factor that will determine the casting time is the temperature. Lower temperatures will give you a longer working time with the resin. Of course, lower temperatures will also slow down the casting process.

1. Mix the resin and catalyst in the correct proportions and stir the ingredients well. Make sure to scrape the sides of your container with the flat edge of a stirring stick to ensure that all the material is mixed well.

2. Pour the plastic into your molds carefully. Fill the plastic resin to premarked lines on each mold. Try not to spill any plastic outside the molds as it will eventually harden and make life difficult.

3. Position your LED array as soon as possible in the resin.

Positioning the LEDs

Once you have placed your LED array in the resin, you should fine tune the position of each LED in the plastic. You want to position the LED so that it is both centered in the plastic mold and its depth is as optimal as possible. Getting the LED at the correct depth greatly improves the distribution of light from the pod.

While wearing latex gloves, gently move the LEDs so that they are both centered in the paperweight mold and so that they are at the appropriate depth. You want to gently dip the LED in the plastic so that the base of the LED’s plastic coating is covered in liquid resin. However, you do not want the LED to stay at this position. Instead, you want to position the light-emitting portion of the LED even with the top of the plastic.

Do not spend too much time adjusting the position of any one LED. You have to work quickly since the plastic will be hardening while you make your adjustments.

Waiting for the Plastic to Harden

If you are using an external heat source to speed the hardening process, apply it to the plastic and go away for a while. Even with the proper amounts of resin and catalyst, the plastic will take a certain amount of time to harden. Some things to keep in mind while the plastic is hardening:

- Be careful not to disturb the resin while it is hardening or deformed in any way.
- Do not let any resin spill out of the mold.
- When checking to see if the resin has hardened, wear a latex glove.
- If the edges of the lenses are a little sticky, try stirring the resin in the next batch a little more. You can also try increasing the temperature of the next batch while it hardens.

Cleaning Up the Lenses

Once the lenses have hardened, you can remove them from the plastic paperweight molds. Pop them free of the mold and proceed with the cleanup process. Wipe the lenses down with a damp cloth. You should also do your best to clean up the paperweight molds. Peel away any lingering mold release material and wash the molds as best you can.

Checking the Lens Quality

If the lenses look foggy or rough in texture, it is possible that the paperweight mold is to blame. Even with the mold release, the paperweight molds from Tap Plastics have a limited life span. Once you discover any problems, get rid of the mold and use a fresh one. If you are using more industrial strength molds, make sure to follow the cleanup instructions that came with them.

If the edges of the lenses are not smooth, you can grind them down with an electric grinder. Do this before attaching any LED wires and be very careful not to break the LED leads. Make sure to wear a heavy-duty dust mask or respirator during this procedure or you will find yourself inhaling a large amount of plastic, which your lungs will not like.

IMPORTANT! If the back side of the lenses are too hard, you may have used too much catalyst. When they finish casting, the lenses should have a slightly tacky or sticky feel to them. The plastic should be solid but just slightly pliable.

Cleaning the Paperweight Molds

Another important aspect of the cleanup operation is to remove as much residue as possible from the paperweight molds. Left to build up, this residue will inhibit future use. All of the molds will require replacement eventually, but cleaning the molds with some soap and water will help prolong their life.

Wiring the LEDs

Once the LEDs are cast into a lens, you can begin the process of connecting up the lead wires to the LED. Most of the work in this segment involves cutting, crimping, and heat-shrinking the wire. After that, you have to solder the wires to the LED and apply more heat-shrink tubing to protect the connections.

Prepping the Wire

Prepping the pod wires involves cutting a lot of 1 foot lengths of wire, crimping them, stripping the ends, and adding heat-shrink tubing. We used blue (and later purple) wire to indicate the wires that would be connected to the cathode (ground) of the LED. We used white wires for the anode (+5V) of the LED.

The wire we used was 22 gauge stranded wire. This wire will be handling low voltages and low currents so it does not need to be super heavy-duty. However, make sure that the wire you are using fits the Molex pins you have.

Molex pins are simple male/female connectors that can be crimped directly to a piece of wire using a special tool. Molex pins were used to connect the pods and harnesses for two reasons. First, they allow the pods and harnesses to be stored separately and more efficiently. Second, they provide a measure of safety for the whole system. The molex pins allow a pod to disconnect itself from the harness when a passerby trips or kicks the pod. This prevents damage to all the wires in the system. However, they also introduce an electrical failure point.

A lot of L2K pod failures occurred because of poor connections between Molex pins and wire. There is somewhat of an art to crimping Molex pins onto wire. You have to make sure that the pin is firmly clamped around the wire. If it's too loose, either the pin will fall off the wire or you won't get a clean connection. Both cases will result in more repair work later. One solution to loose Molex pins is to crimp them and then solder them to the wire. This guarantees a strong physical and electrical connection. The disadvantage to this technique is that it takes significantly more time to do (unless you have a machine that can do it automatically).

Below are the steps for prepping the wires. Each of these steps can be time-consuming if you are building large quantities of pods, but most of the work requires little or no skills and can be delegated easily.

Prepping LED wires

1. Cut the wire to 1 foot lengths. If you're making a lot of pods, you'll want to put one or two people on wire cutting duty and have them cut as much wire as you'll need for all your pods. You'll need 2 wires for each LED and its best to use contrasting colors to distinguish the wires.

   Cutting wire does not require any special skills and can be delegated easily.

2. For each piece of wire, strip about 1/2 inch of insulation from one end of the wire using a good quality wire stripper. Make sure that the wire stripper does not remove too many strands of the wire, since you'll need these strands for crimping.

   Stripping wire does not require any special skills and can be delegated easily once the person has been shown how to do it.

3. Crimp the Molex pins to the stripped end of the wire. Apply male pins to blue wires and female pins to white wires.

   This task can be delegated to unskilled workers, but you should definitely do some quality checks on crimps to make sure it is being done properly. Crimping requires some technique and is better suited for more conscientious or meticulous workers. Don't give this job to flaky people or you'll wind up doing it twice.

4. Cut some 1/8 inch heat-shrink tubing into 1 inch lengths. Place a piece of heat shrink tubing over the Molex pin. For female pins, slide the heat shrink tubing all the way up to the end of the pin. For male pins, stop before you reach the plug portion of the pin.

   Note, it's easiest to slide the heat shrink tubing over the uncrimped end of the wire and then push it over the Molex pin. You may need to fold any protruding portions of the molex pin down to get the heat shrink over it.

5. Apply a heat gun to the heat-shrink tubing to secure it to the Molex pin and wire.

6. Once all of the wires have Molex pins and heat-shrink tubing on one end, strip about 1/2 inch of insulation from the other end of the wire.

7. Once all the wires are crimped and stripped, match up the pairs of wires by plugging one white wire into one blue wire. What you want to end up with is matching pairs of wires connected via their Molex pins. This will simplify things later when you get to the lenses.

8. That's it. Now you have a bunch of wire pairs ready to solder to lenses.

Once you have prepped the wire pairs, you can begin connecting them to the already cast lenses.

Soldering wire pairs to a Lens

1. Before you do any soldering, clean each lens with a wet cloth to remove any leftover mold release material from the lens surface.

2. Trim the LED leads down to a reasonable length (roughly 7mm and 5mm respectively). In this step, you must make sure to maintain the relative length relationship between the two leads. This helps you identify the anode and cathode later.

   One way to perform this step is to cut both LED leads at the same time, holding the clippers at an angle to the wires.

3. Tin the stripped ends of the 1-foot long wire pairs. For this process, it's best to use a solder pot and a can of flux to apply the solder. You can tin each wire individually using a soldering iron, but this is much more time consuming.

4. Select a wire pair and a lens and solder them together. This is a pretty tedious and time-consuming step so you'll want to set up several people to do this in parallel.

   The L2K Podmeisters each had their own station set up with a soldering gun, solder, and a glass or mug which was used to hold the lens. The lens was placed roundside down in the glass with the leads sticking straight up. They would then use the following process to solder the wires to the leads:

   a. Tin each of the LED leads separately.

   b. Solder the blue wire to the short lead (cathode) by holding the wire parallel to the LED lead and applying the solder gun. Adjust the wire or add extra solder as needed to get a good connection between the wire and the lead.

   c. Solder the white wire to the long lead (anode) in the same manner as the previous step.

5. After the wires have been soldered to the LED leads, apply a dab of hot glue to the area around the solder joints. The hot glue serves two purposes: it isolates the LED leads electrically and it adds physical stability to the leads.

6. After the hot glue dries, test the lens to make sure it lights up. Using a 220 ohm resistor in series with the LED anode, apply 6V to make sure everything works. LED's have polarity so if the lens does not light up, make sure you have applied the voltage correctly. If the LED still doesn't work, check the molex pins and solder connections for weaknesses.

7. If the lens lights up, it is ready for final assembly.

Assembling Pods

Once you have the cement bases and fully-wired lenses, you can start assembling the two pieces together into final pods. Pod assembly involves using a silicone sealant to glue the base and lens together. Make sure to wear gloves (disposable latex or rubber gloves are preferable) when doing this kind of work.

Assembling a Pod

1. Select a lens and cement base. If the lens wires are slightly offset from the center, try to find a base where the center hole is offset by a similar amount.

2. Thread the wires through the hole in the cement base but not all the way. Leave the lens hanging off to one side.

3. Using a caulking gun, apply an even amount of good quality silicone sealant around the center hole of the base.

   You'll have to experiment with how much sealant to apply. If you apply too much, it'll squirt out from between the lens and base. If you apply too little, you won't know it until the lens detaches later. Figure 5 shows Podmeister Bob applying an ANSI standard dollop during the final pod assembly.

Figure 5 Applying silicone sealant to a pod

4. Press the lens onto the base, pulling the lead wires through from the bottom. Position the glue ball on the bottom of the lens in the center of the hole on the base.

5. Gently twist and push the lens until the sealant spreads out evenly under the lens. According to one Podmeister, "it's kind of like twisting open an Oreo, but in reverse."

6. When the lens is in place, remove any excess sealant from the edges with your finger. You can use this excess sealant for the next step.

7. Turn the pod over and fill the hole in the bottom of the cement base with a dab of sealant. This provides strain relief on the wires coming out of the bottom and helps prevent playa and moisture from getting inside the pod.

8. Set the pod out to dry. One way to do this is to set up drying racks made from pieces of 2x4 lumber spaced 2-3 inches apart on the ground. Place the pods on these racks with the lens up and the center hole and wires suspended between the lumber.

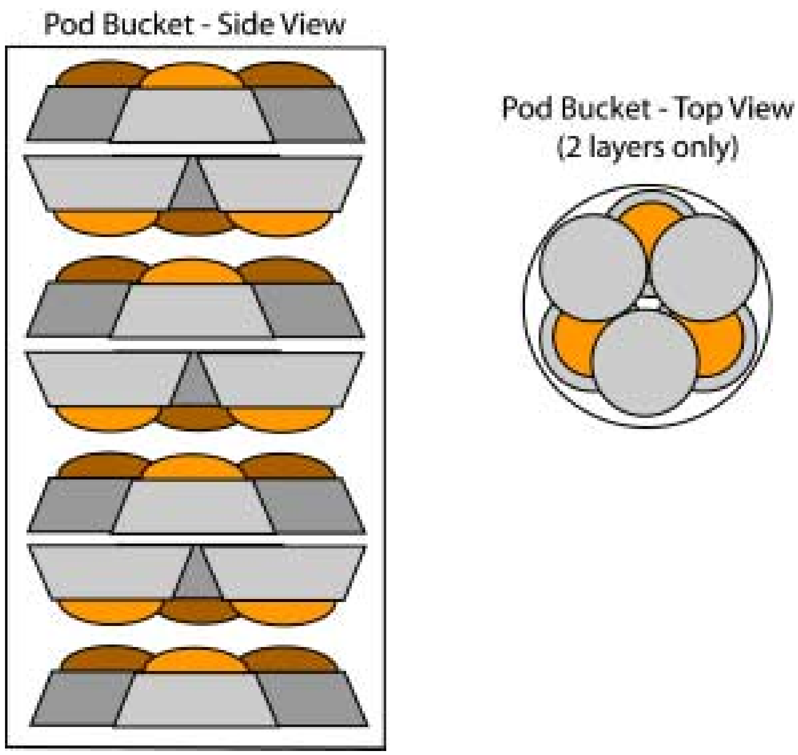
Production capacity for pods is limited by the size of your drying rack so make sure you have enough space available.

Pod Storage and Handling

Despite their rugged appearance, it is still pretty easy to damage pods. You should always be careful when packing, unpacking, or transporting them. The most likely thing to get damaged are the wires coming out from each pod. Little dangly bits of wire get caught easily on just about anything so don't just grab pods out of a transport bucket. Remove them carefully to make sure the wires aren't caught on anything.

If you're using 5 gallon buckets to transport pods, you can fit 21 pods in the bucket if you stack them carefully. Start with three pods in the bottom of the bucket with the lenses up. Then add three more pods in an inverted position so that their lenses face down. You'll have to offset the pods in this layer from the ones immediately below. Add another layer of face-up pods on top of the face-down ones, and so on, alternating face-up and face-down pods. Using this technique, you should have enough room for 7 layers of pods. Figure illustrates the orientation of pods, showing both the side and top views of a pod bucket.

Figure 6 Orientation of pods in a pod bucket



Working With Harnesses

The backbone of the L2K system is the wiring harness. The wiring harness provides power to the entire system and provides the ring circuitry for lighting up individual pods. Most on-site problems occur due to problems with the wiring harnesses, so testing the harnesses prior to installation will make for a faster install time.

This section covers the details of wiring harness construction. This chapter also covers the ring circuit boards used in the harnesses and troubleshooting information for testing and installing the harnesses.

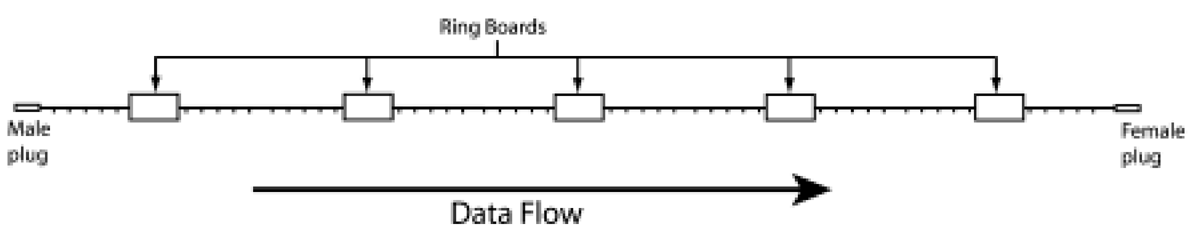
Anatomy of a Harness

A wiring harness is a 50 foot long strand of wires used to control 50 pods. Spaced along the wiring harness are five circuit boards—called ring boards—each of which controls ten pods. At the leading edge of the harness is a male 3-prong high-voltage, locking plug. At the trailing edge is a matching female plug.

When working with harnesses, it is important to remember that harnesses do have a polarity. In this sense, polarity has nothing to do with voltage or current though; it has to do with data flow. Data must always flow in one direction along the harness. You cannot run data backwards through the harness. The connectors on each end of the harness ensure that you plug harnesses together in only one way.

Figure 1 shows the basic anatomy of a harness. Each circuit board is surrounded by 10 pairs of wires, five on each side. Each pair of wires controls a single pod. Data flows from board to board in the direction indicated.

Figure 1 Anatomy of a harness



Using the male and female plugs means that you can never plug in two harnesses wrong. It also provides a visual cue as to which way the harness should face. The male plug always marks the beginning of the harness.

Harness Basics

A harness is a mass of wires that work together to deliver controlled power to each pod. At the heart of this system are heavy duty power lines that provide power to every circuit board. The circuit boards, in turn, turn pod lights on and off in response to data signals received from the previous board.

This section describes all of the components that make up the harness wires. This information is provided to provide perspective on why each component was chosen. It should also provide useful understanding of a harness and where problems can occur.

Power Lines

The backbone of every wiring harness consists of a pair of heavy-duty power lines. The red power line supplies 6 volts from the batteries to the circuit boards, while the black line provides a common ground for the entire system.

These wires are made from 12 gauge solid copper wire because of the amperage loads they must be able to carry. With all lights on, each circuit board draws about 252 milliamps worth of current. At this usage, a single harness draws over 1 Amp. However, the system contains 40 harnesses, all of them connected to the same two power lines. With all of the lights on, the total current in the system is equivalent to over 60 Amps. However, the distributed nature of the power system keeps the maximum total current at any given point at a more reasonable 8 Amps. However, that’s still a lot of current to be pushing around and requires some heavy duty cabling.

When we connected each board to the power lines, we did not cut the power lines themselves. Instead, we soldered shorter wires to the circuit board and then soldered those wires to the surface of the power lines. If you think of the power lines as the freeway, then the shorter wires are an offramp, providing only the power needed by the circuit board. This keeps the boards from getting fried by the peak amperages on the power lines.

Data Wires

Another common sight along each wiring harness is a set of either yellow / black or green / white twisted pair wire. This wire is the data wire that connects each circuit board to its immediate neighbors. Unlike the power lines, there is no common data line that touches every circuit board simultaneously. Each board is connected directly to the boards immediately preceding and immediately following it. Thus, the longest unbroken data wire is at most 10 feet long.

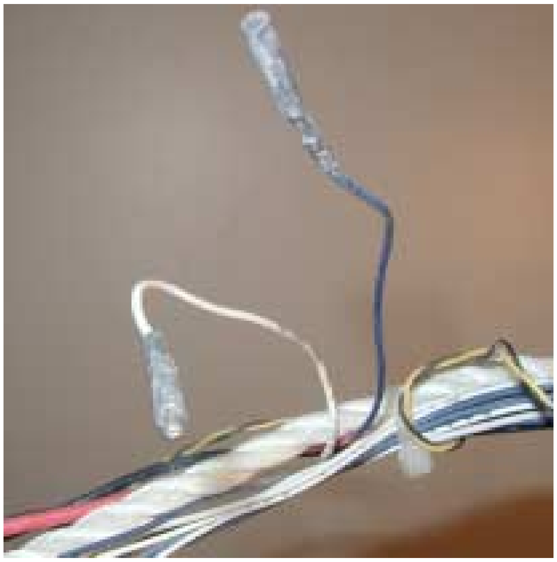
In each twisted data pair, only the yellow or white wire conveys data. The other wire is soldered to the ground connection of the circuit board. The ground wire is not strictly necessary but does provide extra strength to the data wire.

Pod Wires

Spreading out from each board are 10 pairs of wires, five pairs each on either side of the circuit board. These wires connect to the pods at 1-foot intervals along the harness. The pod wires for all the harnesses were precut to the appropriate lengths: 1 foot, 2 foot, 3 foot, 4 foot, and 5 foot. The wires were then soldered to the circuit board, being careful to place the correct length of wire at the correct position on the board.

Pod wire pairs on the harnesses are either blue / white or purple / white. Blue and purple wires represent the ground connection and use female Molex pins. White wires carry +3 volts and use male molex pins. Both types of pins are crimped and covered in heat-shrink tubing to protect the pins and crimps. Figure 2 shows a typical harness wire pair.

Figure 2 Harness wire pair



Rope

In addition to the wires, another feature we added to each harness was a 50 foot-long piece of rope. The rope is there to keep wires from getting pulled loose during uninstallation. We designed the system to be uninstalled by just grabbing one end and pulling it out of the ground. Although this is never a good thing to do with wires, the rope mostly alleviates the problem by absorbing much of the tugging force.

Although the rope is present in each harness, don't assume that it will keep wires from getting damaged. Wires can still get caught as the harness is pulled out. During uninstallation, you should always be very gentle when pulling the wires out of the ground. If you encounter any resistance when removing the wires, dig up the affected section by hand.

IMPORTANT! Rain can cause the playa to pack down tight around the harness. Even if the ground looks dry, the underlying ground could still be hard-packed. Yanking the harness out of this type of ground can damage the wiring, so be very careful.

Circuit Boards

Spaced along each harness are 5 circuit boards. Each circuit board controls 10 pods and is responsible for passing data down the line to the next board. The circuit boards essentially sit on top of the power lines and rope that make up the length of the harness. The circuit boards are then wrapped in a protective coating of Saran Wrap and duct tape to seal them up. The power lines and rope are wrapped with the circuit board to provide added strength to the harness, and they are strapped to the circuit board using tie wraps (see Figure 4 on page 42).

The Saran Wrap is used to seal in the board and prevent playa dust from getting in close contact with the circuit board. A liberal dose of duct tape ensures that the whole thing will not unravel out on the playa, and it adds extra protection and sealing capabilities. Figure 3 shows a mummified circuit board.

Figure 3 Wrapped up circuit board

Figure 4 shows a circuit board without its protective coating of Saran Wrap and duct tape. In this figure, notice the tie wrap around the board. This tie wrap goes around the entire board and also encompasses the power lines and rope of the harness. This helps prevents damaged wires by keeping the circuit board secured to the harness.

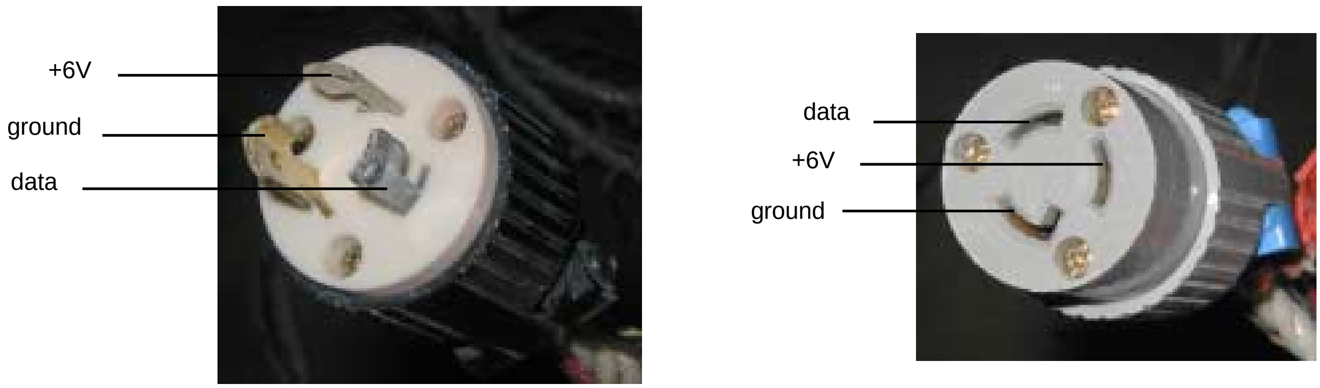
Figure 4 Circuit board strapped to a harness

Harness Connectors

The harness connectors are 3-prong high-voltage, locking connectors. Simply plug the harnesses in male-to-female and you’re set. The male connector marks the beginning of the harness and the female connector marks the end of a harness.

Figure 5 shows the plugs and the electrical connections for each pin of the plug. The angled prong always represents the ground. The silver prong always represents data. The straight prong always represents power.

Figure 5 Plug connections



Battery boxes also use the 3-prong connectors to supply power to the harnesses. Each battery box has both a male and female plug so that it can be inserted between any two harnesses. The power and ground lines of these plugs are connected to the battery to provide additional power at that point in the circuit. However, the data line is not connected to the battery setup in any way; the data line is wired straight through from the male to the female plug.

Working With Ring Boards

The ring boards are the heart of the system. They turn the LEDs on and off and they process data sent along the ring. The following section introduces you the basics of how the boards work. This section does not go into the requirements for building a new circuit board. For information on building ring boards, see *Building New Ring Boards* on page 46.

Board Layout

Ring boards are laid out relatively symmetrically. At the center of the board is a PIC microcontroller, which processes data and decides which LEDs to turn on and off. On either side of the PIC are electronics for controlling the amount of current flowing to the LEDs.

Figure 6 shows the top side of a ring board, which contains all of the board's electronic components. The only elements connected to the bottom of the board are the wires connecting the board to the harness and pods.

Figure 6 Ring board in a harness

In the preceding figure, you can see a row of 5 can-type capacitors along each side of the board. These capacitors provide power storage for individual LEDs to make sure that they are displayed at full power, even when the mainline power is running low. The resistor groups near each capacitor limit the voltage and current applied to the LED. The transistors act as switches, responding to signals from the PIC to turn each LED on or off.

The large capacitor along the middle of the board is a general power storage capacitor. This capacitor provides the board with several seconds worth of energy in the event that the power lines cannot provide enough power at any given moment. This capacitor keeps the PIC from resetting during heavy loads.

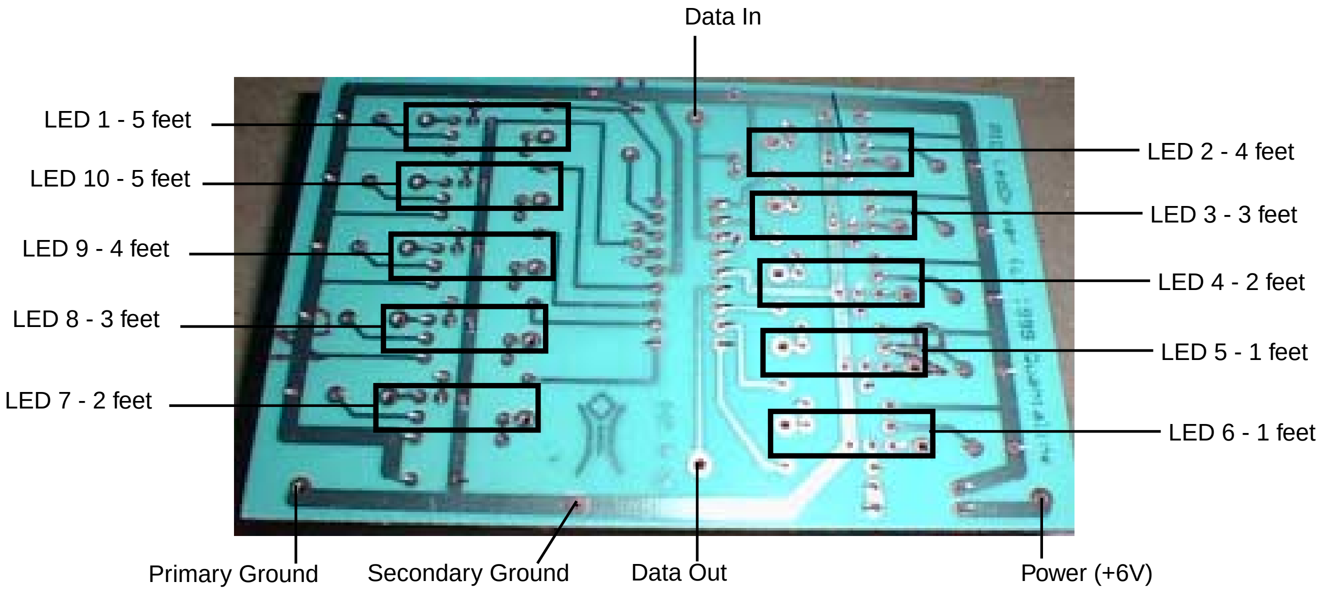
At the top right of the circuit board in Figure 6, you can see a diode and resistor right next to each other. The diode is connected directly to the incoming power line and prevents a negative current. The 1 ohm resistor immediately below it acts as a fuse. If too much current enters the board all at once, this resistor will burn up and break the electrical connection.

Wiring Connections

The bottom of each ring board is where the harness and pod wire connections are made. Soldering wires to the back of the board was done to simplify the final assembly and debugging of the harnesses.

Figure 7 shows the back of a ring circuit board. It is from this side that most harness wiring connections are made. In particular, this diagram shows the connection positions for the LED wires, power, ground, and data connections.

Figure 7 Ring circuit board pod wire lengths (back)



The ground and power connections at the edge of the board are where harness power lines are connected to the circuit board. The additional ground connection close to the Data Out connection is actually the place where the large 10000uF capacitor's negative lead goes. During assembly, the negative lead of the capacitor was used as an anchor for the data line ground wires.

Building New Harnesses

Harnesses require a great amount of labor and skill to complete. Harness tasks can be broken down into wire work and circuit board assembly. These tasks involve different skills and can be assigned to different groups of workers.

Prepping the Harness Wires

The process for prepping the harness wires is similar to the process for prepping the pod wires (see *Prepping the Wire* on page 33). Harness wires differ from pod wires in that harnesses use wires with 1 foot, 2 foot, 3 foot, 4 foot, and 5 foot lengths. Each circuit board on the harness uses two pairs of wire for each length. Thus, the harness has 2 pairs of 1-foot wires, 2 pairs of 2-foot wires, and so on.

Molex pins on the harness wires must mate with those on the pod wires. For harness wires, the blue (or purple) wires must have female Molex pins, while the white wires must have male pins. As long as you solder the wires into the correct location on the circuit board, the circuit board will put out a voltage whose polarity matches that of the LED.

Below are the steps for prepping the harness wires. Each of these steps can be time-consuming if you are building a lot of new harnesses, but most of the work requires little or no skills and can be delegated easily.

Prepping the harness wires

1. Cut the wire to length. For each circuit board, you will need 2 blue wires and 2 white wires for each of the following lengths: 1ft, 2ft, 3ft, 4ft, 5ft. It's OK to make wires a little longer than the desired length. It's not as good to make them shorter.

   Try to get all wires as close as possible to the actual length. The best way to do this is to lay out a piece of tape on a table and place marks at 1 foot increments. You can then measure wire to the tape marks. This technique is much more accurate than trying to measure one wire to an already cut wire.

2. For each piece of wire, strip about 1/2 inch of insulation from one end of the wire using a good quality wire stripper. Make sure that the wire stripper does not remove too many strands of the wire, since you'll need these strands for crimping.

3. Crimp the Molex pins to the stripped end of the wire. Apply female pins to blue wires (ground) and male pins to white wires (+5V).

   As with pod wires, this task can be delegated to unskilled workers, but you should do some quality checks on crimps to make sure it is being done properly. Crimping requires some technique and is better suited for more conscientious or meticulous workers. Don't give this job to flaky people or you'll wind up doing it twice.

4. Cut some 1/8 inch heat-shrink tubing into 1 inch lengths. Place a piece of heat shrink tubing over the Molex pin. For female pins, slide the heat shrink tubing all the way up to the end of the pin. For male pins, stop before you reach the plug portion of the pin.

   Note, it's easiest to slide the heat shrink tubing over the uncrimped end of the wire and then push it over the Molex pin. You may need to fold any protruding portions of the molex pin down to get the heat shrink over it.

5. Apply a heat gun to the tubing to secure it to the Molex pin and wire.

6. Once all of the wires have Molex pins and heat-shrink tubing on one end, strip about 1/2 inch of insulation from the other end of the wire.

7. Once all the wires are crimped and stripped, match up the pairs of wires by plugging one white wire into one blue wire. What you want to end up with is matching pairs of wires connected via their Molex pins. This will simplify things later when you get to the circuit boards.

8. That's it. Now you have a bunch of wire pairs ready to solder to the circuit boards.

Building New Ring Boards

Construction teams can work on building ring boards in parallel with the wire work required for the harnesses. Assembly of a single ring board can take anywhere from 45 minutes to 1.5 hours depending on the setup and speed of the individual.

Parts List

Table 1 contains the list of parts for a single ring board. This list

Table 1 Ring board parts list

Part Name	Quantity per Board	Notes
Circuit Board	1	
18 pin IC socket	1	
PIC16C622A	1	The PIC must be programmed before adding it to the board. Add this component after final harness assembly soldering is complete.
4 MHz Resonator	1	This component fits next to the IC socket and does not have a polarity.
Power diode	1	The voltage drop across the diode brings the actual circuit board voltage down to the correct level. Without this diode, the voltage would ve over 6V, which would be beyond the chip max.
Transistors	10	Transistors have polarity. Make sure to orient them correctly in the circuit.
220uF Capacitor 16V (electrolytic can-type)	10	Electrolytic capacitors have polarity. Make sure to orient them correctly.
0.1uF Capacitor (ceramic)	2	
10,000uF Capacitor 16V (electrolytic capacitor)	1	Do not add this component to the board until the point when you are performing the final harness assembly.
910 ohm resistor (1/4 watt)	10	(white, brown, brown, gold)
47 ohm resistor (1/4 watt)	10	(yellow, violet, black, gold)
200 ohm resistor (1/4 watt)	10	(red, black, brown, gold)
12-22 ohm resistor (1/4 watt)[a]	1	12ohm(brown, red, black, gold)
1.2K ohm resistor (1/4 watt)	1	(brown, red, red, gold)
10K ohm resistor (1/4 watt)	1	(brown, black, orange, gold)

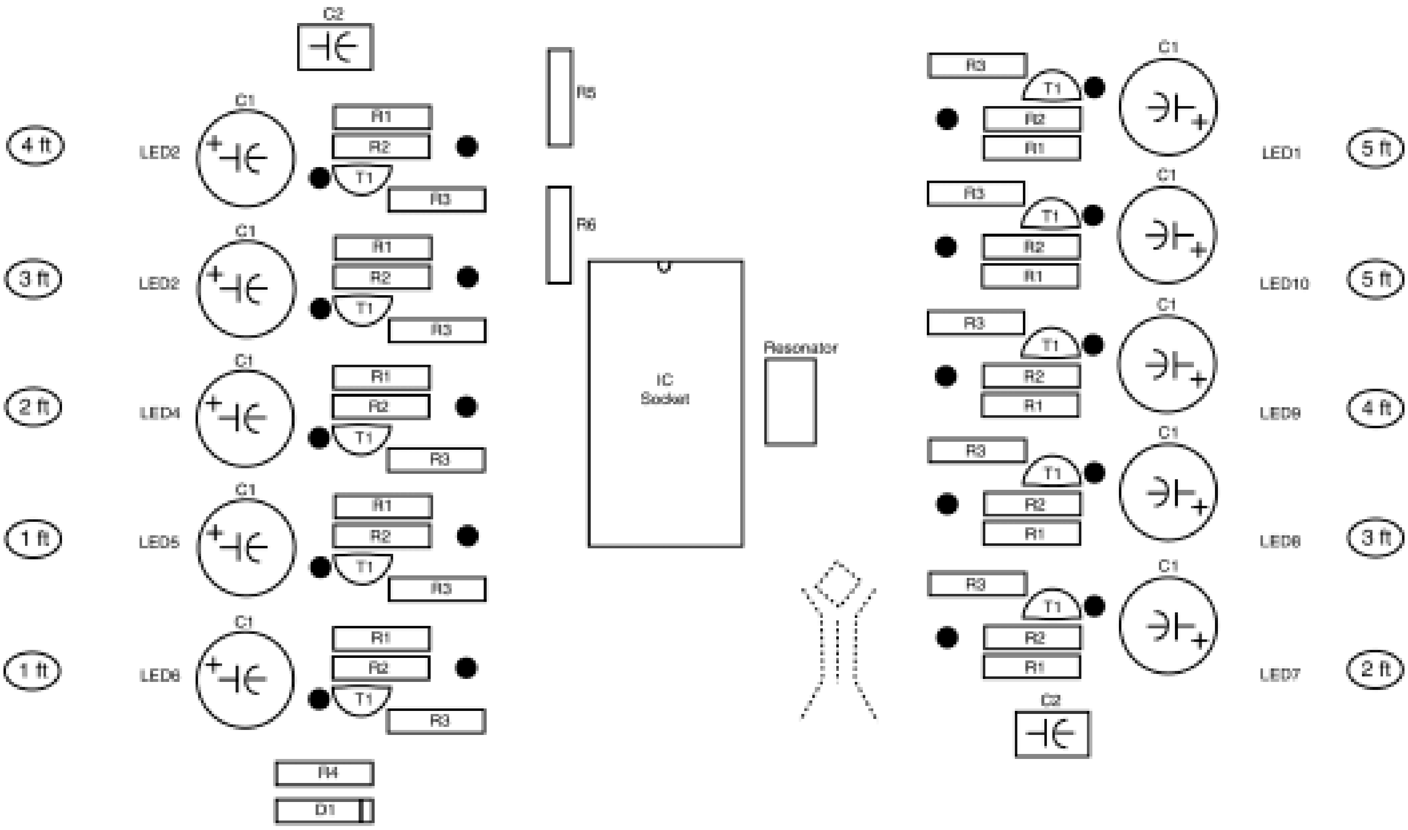
a. The value of this resistor is 12 ohms optimally but can vary in the given range.

Adding Components to the Circuit Board

When building new circuit boards, it is best to fit all of the components in the board first and then solder them all at once. To do this requires a certain amount of skill since you must learn how to fold and clip the component leads so that the component does not fall out. This also allows for an efficient division of labor. People without soldering skills can spend time stuffing the board with components while people with soldering skills can do just that.

Figure 8 shows a diagram of the ring board components, their placement, and orientation. This diagram shows the top side of the board where the components are placed. The Burning Man logo from the backside of the board is superimposed to provide an orientation reference.

Figure 8 Ring board component placement (viewed from top)



R1 = 200 ohm 1/4W
R2 = 47 ohm 1/4W
R3 = 910 ohm 1/4W
R4 = 1 ohm 1/4W
R5 = 1.2K ohm 1/4W
R6 = 10K ohm 1/4W
C1 = 220 uF electrolytic can
C2 = 0.1 uF ceramic cap
D1 = power diode (band indicates anode)
T1 = transistor

Figure 9 shows a picture of a ring board with all of the components inserted. Again, the Burning Man logo is superimposed from the backside to provide an orientation reference.

Figure 9 Ring circuit board (top)

In order to stuff all the components onto a circuit board without soldering, you need to do so in groups. Start with one of the resistor values and stuff all of those components. As you stuff the component into the board, fold the leads down flat to the board to hold the component in place. This requires a little bit of finger strength to do well, but with practice becomes easier. Once all of the resistors are in place, clip the leads as close to the solder pad as you can and move on to the next component.

Here is the recommended order for stuffing board components:

1. diode
2. 1 ohm, 1.2K ohm, and 10K ohm individual resistors
3. 200 ohm resistors
4. 47 ohm resistors
5. 910 ohm resistors
6. transistors
7. resonator
8. IC socket (just fold one pin at each corner for simplicity and do not clip the leads). Make sure the notch points away from the Burning Man.
9. 220 uF electrolytic capacitors
10. 0.1 uF ceramic capacitors

IMPORTANT! DO NOT stuff the 10000 uF electrolytic capacitor onto the board. Wait until the final harness assembly before adding that component.

Once all the components have been stuffed onto the board and the leads have been clipped, solder all of the leads. Make sure not to miss any leads as you do your soldering pass. Soldering the components in a consistent order makes it harder to miss one.

Use a low power soldering iron if you have one. A fine tipped 25 Watt iron works extremely well on the circuit boards. Try to use a light touch if possible too. Most of the components are solid state and can take a little extra heat, but it's best to make quick, clean solder joints.

Once the board is completely soldered, go back and clip any leads that still seem excessively sharp or pointed. In particular, you should go back and clip the leads of the IC socket, which would not have been clipped during board stuffing. Check the board for any leads that are touching other traces and make sure to clip those leads back as well. The cleaner the board is prepared and soldered, the fewer problems you will have to debug during final harness assembly.

NOTE: Board stuffing and particularly soldering is well suited for anal-retentive types, as the author can well attest. You cannot be too neat with clipping the leads and soldering the joints together, as these will mean one less thing to troubleshoot during final harness assembly.

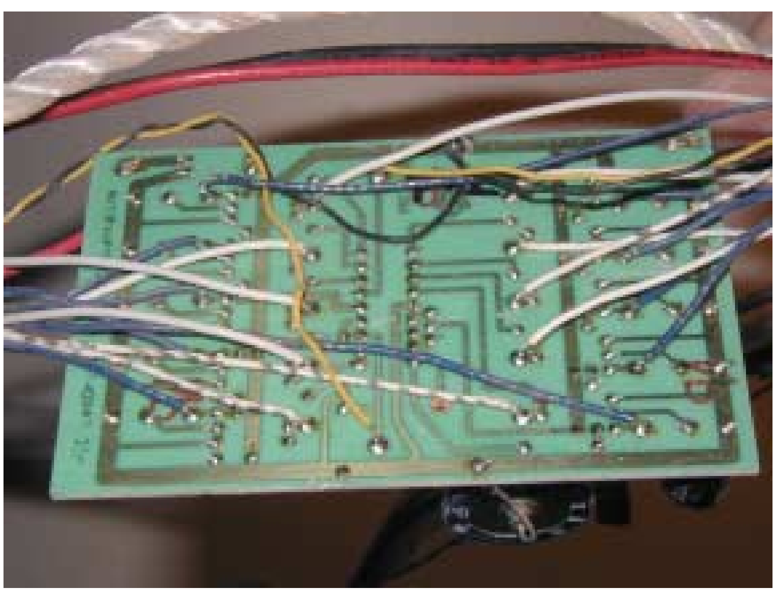
Adding the Wires to the Circuit Board

After you have a quantity of circuit boards completed, add the harness wires to them. This step was originally performed during the final harness assembly but was moved up in the process because it was something that could be done be delegated to multiple people easily. For the LED harness wires, it is easier to solder the wires from the bottom side of the board.

It may seem odd at first working from the bottom side of the circuit board, but it is actually easier than trying to insert the wires from the top, hold them in place, and solder them. From the bottom of the board, you can insert the wire, pin it to the pad with the soldering iron, grab your solder and apply it to the wire, and voila.

Figure 7 on page 45 shows the placement of the different lengths of wire. This diagram also shows which LED is associated with which pair of wires. Figure 10 shows the bottom of a fully-wired ring board. The blue wires represent the ground connection and the white wires represent the +5V connection. In this diagram, notice that the blue wires are always closer to the outside edge of the board.

Figure 10 Ring board back with wires installed



Another set of wires you can add to the board are the power and ground wires. These wires need to be 14 gauge stranded wires approximately 6 inches in length. Strip one end of the wire and place it in the appropriate corner of the board (red for +6V, black for ground). Make sure to place the ground wire in the hole meant for the primary ground (see Figure 7 on page 45), as the secondary ground is meant for the 10000 uF capacitor.

Final Harness Assembly

This section assumes that you have prebuilt 5 circuit boards with harness wires attached. This section also assumes you have the following additional components ready to go.

- 50+ feet of 12 gauge solid copper wire (black insulation)
- 50+ feet of 12 gauge solid copper wire (red insulation)
- 50+ feet of rope
- 50+ feet of twisted pair 22-gauge stranded wire.
- Five 10000 uF capacitors (one for each board)
- The harness assembly jig provided by L2K

Setting Up the Harness Jig

The harness jig provided by the L2K group consists of five 10-foot long boards with nails and holes drilled at appropriate intervals. The nails at the center of each board mark the placement of the ring boards. The nails at 1 foot intervals along the front edge hold the LED harness wires in place. The nails running along the top of the board are used to hold the power wire, ground wire, data wires, and rope in place.

Figure 11 shows 80% of the harness jig setup at the Wizard's house. The circuit board in the foreground is at position 4 along the jig. The data and power lines run along the back edge of the board in a channel of nails.

Figure 11 Harness assembly jig

Prepping the harness jig for final assembly

1. Run a 50 foot length of rope down the channel along the back edge of the jig.
2. Run a 50 foot ground line (black wire) down the channel along the back edge of the jig. Leave extra room at the end for the plugs and for good measure.

3. Run a 50 foot power line (red wire) down the channel along the back edge of the jig. Leave extra room at the end for the plugs and for good measure.

4. Run a 50+ foot length of twisted pair wire down the channel. This wire becomes the data wire. At each circuit board location, wrap the wires around the nails there so that there is extra slack in the data wire for each board.

   Because of its fragility, you want to make sure there is plenty of slack in the data wire. This prevents it from being pulled out of place during uninstallation or general handling.

5. Place a circuit board at each of the 5 locations in the jig. Orient the circuit board so that the bottom side (circuit-side) is facing up and the Burning Man's feet are pointed towards the back edge of the board. (This also means that the power and ground lines will be closer to the back edge of the board.)

6. For each circuit board, position the harness wires at the appropriate location on the jig. With the boards in position, the wire for LED 1 is in the lower-right corner. Subsequent LED positions are obtained by going around the board in a clockwise direction. Thus, the lower left corner is LED 2, the wires above that are for LED 3, and so on.

   Remember that this orientation is based on the orientation of the board when it is in the jig, so the Burning Man logo will be upside down as you face it.

7. Place a 10000 uF capacitor next to each circuit board. You will connect the capacitor to the board during the data wire splicing phase.

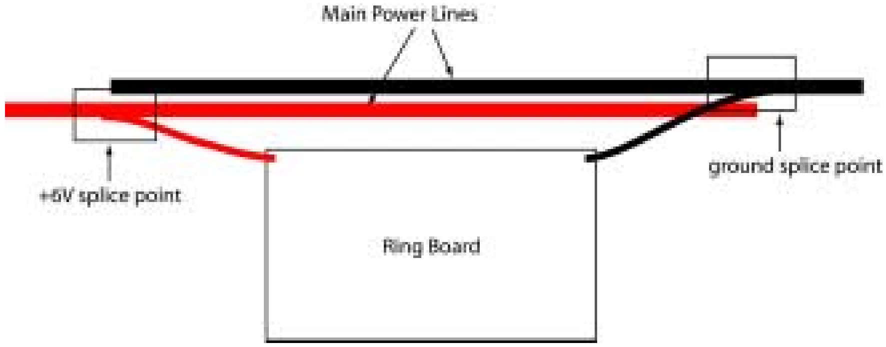
Splicing the Power Connections

For each ring board, one of the first things you need to do is splice its power wires into the main power lines. You must perform this operation without cutting the main power lines of the pending harness. The following steps describe this process:

1. Leaving the ring board in its position on the jig, find the red power wire in the upper left corner of the board. Strip about 1/2" to 3/4" of insulation from the end of this wire if it is not stripped already.

2. Extend the red power wire to the left of the circuit board, running it parallel to the main power lines. You want to find a point on the power lines into which to splice the wires. Figure 12 shows a diagram of how the power splices will look when you are done.

Figure 12 Splicing the ring board power wires into the main power lines



3. Once you have found the splice point, move 1-2 inches closer to the circuit board to allow for some slack and carefully remove about 1/2” of insulation from the wire.

   You have to remove the insulation carefully, without cutting or nicking the main power line. One way to do this is to use a set of regular wire strippers as if you were going to strip the wire normally. Instead of stripping the wire though, just score it at two points to mark the boundaries of the 1/2” of insulation you will remove.

   Once you have scored the insulation, use a pair of wire cutters to nibble away at the top of the wire between the two marks. Again, try not to cut or nick the power line during this operation. Small nicks are OK but large gouges could inhibit the flow of current at high loads.

4. Once the insulation is removed, wrap the power wire from the ring board around the exposed area.

5. Perform the same operation for the ground wire, but going in the opposite direction. (See Figure 12).

6. Once both wires have been prepared, go ahead and solder them using a high power soldering iron. Do not skimp too much on the solder for this joint; you want to make sure you have a solid solder joint to the power lines.

   Due to the size of the power wires, you will need to use at least a 60 Watt soldering iron for the power connections. Butane soldering irons work well and provide plenty of heat. Even with powerful soldering irons like these, it can take some time to heat up the power wires before they will accept the flow of solder.

7. After soldering the wires, wrap the solder joints with plenty of electrical tape to insulate and protect them.

There are two reasons for spreading the power wires in opposite directions from the ring board. First, it prevents possible short circuits between the main power lines by separating exposed wires by a large distance. Second, it stabilizes the position of the ring board in relation to the harness. This second point prevents any undue strain from being applied to the LED wires or data wires.

Splicing the Data Connections

It is best to splice the data wires after you have spliced the power wires due to the stabilizing effect of the power wires. The process for the data wire is much simpler and can be done with low power (25 Watt) soldering irons. Here is the process for splicing these wires onto the ring board:

1. Pick up a ring board and flip it over to the component side.

2. Situate the 10000 uF capacitor on the component side of circuit board. (You thought I’d forgotten about that capacitor didn’t you?) Do not clip or fold the leads.

   This capacitor fits in the two holes along the top and bottom edges of the circuit board. The hole below the Man’s feet (on the trace side) represents the ground connection. The other hole represents the positive connection. The arrow on the capacitor points to the negative (ground) terminal.

CAUTION! The 10000 uF capacitor can store a lot of energy so make sure it is oriented correctly on the circuit board. Failure to do so could cause the capacitor to explode when power is applied!

3. Flip the board back to the trace side and return it to its position on the jig.
4. Solder the capacitor into place. Again, do not clip or fold the leads.
5. Find the data wire wrapped around a couple of pegs above the ring board. Cut the data wire pair in the middle so that there is equal amounts of slack in both directions.
6. Strip all four data wires.

   The wire coming from the left represents the Data In wire. The wire going to the right is the Data Out wire and should be heading towards the next board.
7. From the Data In pair, find the light colored wire (yellow or white) and solder it to the Data In hole on the circuit board. See Figure 7 on page 45 for the position of this hole.
8. From the Data Out pair, find the light colored wire (yellow or white) and solder it to the Data Out hole on the circuit board. See Figure 7 on page 45 for the position of this hole.
9. Collect both of the dark colored wires (black or green) from the Data In and Data Out pairs and solder them to the ground lead of the 10000 uF capacitor. This is the lead near the Man's feet on the circuit board.
10. Clip the capacitor leads.

Once you have connected the power and data wires to the ring board, you are done with that circuit board. Repeat the process for each ring board on the harness.

Testing the Harness

Once all 5 boards have been connected up to the harness, you can begin testing the harness. You should always test harnesses and fix any accompanying problems before doing the final mummification. For your tests, make sure each of the LEDs lights up and make sure that you can run data across all of the boards.

Running Data Across the Harness

Before you can run any data across the harness, you must first connect some test lenses to the harness. The top edge of the jig has holes drilled in it to allow the insertion of the lens wires. Connect these wires to the harness wires at the corresponding positions.

Before you connect the L2K computer to the input end of the harness, you must install the PIC chips onto the ring boards. The Wizard should have already provided chips for you to use at this stage. Make sure to align the notch on the chip with the notch on the socket. The pins on brand new chips are a little wider than the socket so you will have to gently fold the pins inward a little to get the chip in the socket.

Another piece of equipment you should have is a 3-prong female plug with some short wires connected to it. This plug has black and red wires for the ground and power connections, respectively. This plug also has an RCA-type audio jack that you can plug into the computer's Data Out port.

Once you provide power to the ring boards, they should go into self test mode. Self-test mode does not always guarantee that a particular board will come up right away. Due to various factors, most boards will run the self-test pattern at slightly different speeds and at their own intervals. This is normal.

Plug the data connection into the computer and turn the computer on. In autonomous mode, the computer will send out several initialization statements, followed by a preset group of patterns. Use these preset patterns to make sure data is reaching all of the boards. You should also use these patterns to make sure all of the lights on the harness are lighting up. If a particular light does not illuminate, check the Molex pin crimps and the wire connections. Do not proceed to wrap up the harness until every single light illuminates and every board receives data and processes it correctly.

Wrapping it Up

Once a harness has been thoroughly tested and verified to be in working order, you need to seal it up to protect it from the elements. There are two steps to this process. The first involves wrapping the harness wires with a plastic coil to keep the wires in place and mark the spacing for the LED leads. The second step involves encasing the circuit board in a protective plastic box. For detailed instructions on how to encase a new harness, see the instructions in the section *Repackaging the Harnesses* on page 59.

Adding Plugs

The final step for any new harness is the addition of plugs to both ends. The plugs we used are 3-prong, high-voltage, twist-locking plugs. These plugs provide several important benefits. First, they are capable of handling large currents. Second, the locking feature of the plugs lets us pull harnesses out of the ground without worrying about the harnesses coming unplugged.

Figure 5 on page 43 shows the electrical connections to use for the plugs. Because the data line contains an extra ground wire, you need to solder this wire to the main ground wire before feeding it into the plug. When you solder this wire, do so high enough on the ground wire so as to still be able to insert the main ground wire into the plug terminal. Also make sure you feed all of the wires through the base of the plug before inserting them into the plug terminals. Trim any wires as needed to make the ends match up.

When you close up the plug casing, you need to clamp the wires down at the back of the plug casing. Make sure the rope gets clamped together with the other wires. Do not let any of the wires get pinched to the point where their insulation is compromised.

Troubleshooting

This section contains debugging information for the wiring harnesses. This information is based on problems we found during the testing and installation cycles.

Debugging Problems Before Install

Before taking L2K out to the playa, it's always good to test the gear to make sure it's in good condition. The most important pieces to test are the harnesses themselves. The harnesses are the most critical element of the system and they are also the most complex, and therefore likely to have problems.

There are several things to test on the harnesses.

Testing data integrity

Making sure data is flowing from one end of the harness to the other is very important. Any break in the data transfer disables the system past the break.

If you have easy access to the ring boards, visually inspect them for broken or bare wires. Bare wires can lead to short circuits very easily. Wrap the wires with electrical tape or apply a dab of hot glue around them. Resolder any broken wires.

If you do not have easy access to the ring boards (because they're mummified), try running some data across the harness and see what happens. Plug in 3-4 pods at the end of the harness and connect the L2K computer to the beginning. If the pods remain in self-test mode when the computer is turned on, you probably have a data problem. If the pods display the pattern then the harness is probably OK.

NOTE: Note that performing this test does not guarantee data integrity for the harness. Even if the pods at the end of the harness light up, the last board may not be transmitting successfully to the next harness. To guarantee harness data integrity, you must connect two harness together and make sure data reaches the second harness.

If you discover data transmission problems as a result of your tests, you need to take the following steps to fix the problems:

1. Perform a quick check using the auto-testing rig to verify the problem is with the harness. See *Doing a Fast Data-Integrity Test* on page 59 for more information.

2. Check to make sure you are supplying enough power to the harness. A single harness can pull 1 Amp of current. If you are using old batteries to test the harness, they may not be able to provide enough instantaneous power. When this happens, downstream ring boards will experience a voltage drop caused by the increased load. This voltage drop is enough to reset the ring boards and put them into self-test mode. Use a solid-state DC power supply or get fresh batteries.

3. If the harness still does not pass data, determine where the data stops. Find the last board displaying data and the first board not displaying data. You may need to connect additional pods to the harness to determine this.

4. Once you know where the problem is, you can set about examining both circuit boards to find out which one is the culprit. Remove the protective casing from either board and examine it for broken or bare wires. Examine the data wires and make sure they are not impaled on any of the soldered leads on the bottom of the board. Even if a data line does not appear to be impaled, check the wire insulation for any cuts or breaks, since those might indicate a previous problem.

5. If the first board looks OK, check the other board for the same problems. Also check the voltage being supplied to the second circuit board. If the board's voltage is under 5 volts and you are certain your power supply is not at fault, check the solder joints connecting the board to the power lines. Make sure the solder joints are clean and connected. Check the voltage both before and after the diode and 1 ohm resistor to make sure these components have not failed.

   The 1 ohm resistor acts like a fuse by blowing out during a short circuit. However, we have found that these resistors sometimes fail without blowing out. You can tell if the resistor is bad by trying to measure its resistance. It should read near to 1 ohm. If it's value is off the scale or excessively high, replace the resistor.

6. Check both boards for any bad solder joints. Make sure the solder joints cleanly contact both the circuit board pad and the component lead. Resolder any bad joints.
7. If both boards look OK, check the 10-foot length of data wire for any breaks.
8. If everything still looks OK, hook up an oscilloscope to the data out pin of the upstream board's PIC. The oscilloscope should show a series of pulses when the computer is turned on. If no pulses appear, the chip itself could be at fault.
9. If everything still looks OK, hook the oscilloscope to the data in pin of the downstream board to make sure pulses are arriving at the board. If they are not arriving, the problem has something to do with the data wire. Replace it or resolder it to both circuit boards.
10. If data is reaching the input pin of the chip, the chip may be at fault.
11. If none of the preceding suggestions fixes the problem, then give the harness to someone else to confirm your results independently. If both of you reach the same conclusions, then you have discovered a truly puzzling new bug. Have fun tearing the harness down and recycling the known working boards because I'm stumped.

Testing harness wires

Another test you perform from time to time is to make sure the pod wires on the harness are good. This is a simple but time consuming test. All you need to do is plug pods into every position on the harness and make sure they light up. You can use the computer to verify they are lighting up or just leave the harness in self-test mode.

When you perform this test, make sure you do so using known good pods. If you are using the computer to test the lights, make sure you have debugged any data transmission problems with the harness first.

If you find a pod that does not light up, check for the following problems:

1. Check the crimps on the harness wires. Give the Molex pin a light tug. If it comes off, touch the bare wire to the pod to make sure it really was a crimping problem. If the pod now lights up, recrimp the wire and test it again.
2. If the crimps look OK, go ahead and pull the Molex pins off anyway and try to light the pod using only bare wires. If the pod now lights up, recrimp the wire and test it again.
3. If the crimps are not the problem, then you need to check the circuit board. Remove any protective materials from the circuit board and check for any wires that have been torn from the board. Check also for any short circuits caused by bare wires or wires impaled on a soldered lead. Fix these problems and check the pod again.

Debugging Problems on Site

When we first built L2K, we had no idea what sort of problems we would run into once we had it installed. The playa is an unforgiving place and it has a tendency to find every minor defect in a design. Although we have attempted to fix many of the deficiencies in the design, the following section includes a list of the known problems and what was required to fix them. This information should be used by future maintenance crews to fix problems that arise.

A single pod is not lighting up

When data is flowing through the ring, you should be able to identify any pods that are not lighting up. There are several causes for pods not lighting up. Some of them are simple to fix while others are not. Here is an ordered list of things to check:

1. Check to see if the pod is plugged in. People often trip over pods, kick them, or knock them loose by riding over them in a bicycle. When this happens, the pod usually gets knocked out of position and it gets disconnected from the harness. Dig up the pod wires to see if they are plugged in.

2. If the pod is plugged in and still not lighting, the pod itself could be bad. Try plugging in a known good pod (like one that is already lighting up on that harness). If the replacement pod lights up, you have a bad pod. Replace it.

3. If the known good pod does not light up, there is a problem with the wiring or the circuit board. It's possible that the Molex pin on the harness wire was crimped poorly. Try pulling the Molex pins off and touching the bare wires to the known good pod. If the pod lights up, you had a bad crimp. Recrimp the harness wires.

4. Lastly, if nothing else worked, the problem is probably at the circuit board. Most likely, the harness wire became disconnected from the circuit board at some point. You can dig up the board and reattach the wire or just leave it. After all, one bad pod is not very noticeable.

Data flows correctly for some boards, but after a certain point, the boards are all in self-test mode.

If some boards are handling data correctly and others are not, there are two possible problems:

- The first board in self test was not initialized correctly.
- There is a short circuit in the data line.

Initialization problems are becoming less frequent as the wizard debugs the software. The current system sends several initialization messages on restart to make sure that all of the boards initialize themselves. However, glitches still happen from time to time. The most recent version of the software initializes the system every three minutes or so, so you should not have long to wait for a restart.

If a restart fails to bring the boards out of self-test, the data line probably has a short circuit. The short circuit will be either at the last board still receiving data or the next board along. Once you find the pod where the pattern stops, count backward 5 pods. The last known good board is 5 pods back from the end of the pattern. The first known board not receiving the data is 5 pods into the self-test zone.

Dig up the suspect boards one at a time. If you cannot find any problems with the first board, try the other one. Short circuits in the data line are usually caused by the data wire being impaled on a protruding solder joint from the circuit board. Check the data wire for punctures or cuts along the circuit-board side.

If the boards look OK, there is actually one last possibility. If the two suspect boards mark the end of one harness and the beginning of the next, the problem could be a bad connection in the 3-prong harness plugs. Dig up the plugs that connect the two harnesses (right where the pattern stops). Make sure there is no dirt in the plugs. You might also have to open up the plug casings to make sure the wires are still connected inside the plugs.

If the problem still does not go away after all of these possibilities, replace the harness.

CAUTION! If you dig up any boards, make sure you seal them back up before reburying them. Burying an exposed board will seriously damage the board.

Doing a Fast Data-Integrity Test

For 2001, the Wizard has created a new set of devices for testing harness data integrity quickly. The first device is a small box with a power switch, a reset button, and a female plug attached to it. The second device is a clear plastic tube with a small circuit board inside. The circuit board has 10 LEDs and is basically a variant on the ring-board design. This second device is attached to a male plug and is referred to as “the testing dildo”.

To use the pair of devices, connect the box to the leading end of the harness and connect the testing dildo to the other end. Turn on the power switch for the box and then push the reset button to make sure the system resets properly. After a short while, you should see data patterns running inside the testing dildo. If you do not see patterns, or if the dildo runs the self-test pattern, you will need to do a more complete test on the harness to see where data is stopping. The following sections describe how to do that testing.

Repackaging the Harnesses

As part of the 2001 overhaul of L2K, a new encasement process was devised for the harnesses. This process uses a coiled plastic cover to hold the wires in place and plastic project boxes to protect the circuit boards. The following sections describe the process for modifying an existing harness to use this new protection.

Prepping the Harness

The first step in prepping the old harnesses is to remove the existing duct tape and plastic wrap from the circuit boards. This material was used to protect the circuit board from corrosion caused by playa dust. Now that the circuit boards will be protected by project boxes, the existing layers of tape and plastic wrap are unnecessary.

Removing the duct tape and plastic is a fairly straightforward job. Most of the work can be done by hand and in fact is safer to do by hand. Using knives or other sharp instruments is not recommended due to the close proximity of wires underneath. Multiple people can work on the same harness or different harnesses. As you work on wires, make sure to remove all traces of the material.

Once the tape and plastic wrap is removed, it is a good idea to check the boards for damage or inordinate amounts of playa dust. You should look for wires pulled out of the circuit board and wires embedded onto the back side of the board. All wires should be firmly secured to the board but clear of any sharp edges that might cut the wire’s insulation. You should also briefly examine the traces on the board to make sure there are no obvious bits of metal shorting out two points.

Wrapping the Wires

The most time-consuming task of the harness rework is wrapping the wires. This work requires some concentration and care in positioning the wires correctly. It is also work that lends itself to parallelism as long as you have the space.

Wrapping the wires requires a workspace to place the wires. You will be working on five foot lengths of wire so you will need a table slightly longer than that. The table should have markings to identify the appropriate spacing of the LED wires. Tape works well to identify the LED positions.

Mark the spacing of the LEDs on the table

1. Place one end of a harness on the table.
2. Place a mark on the table undernetath the center of the board.
3. Using a tape measure, place another mark six inches out from the center of the board. This marks the position of the first set of LED wires.
4. Place another mark one foot out from the position of the first LED wires.
5. Continue placing marks one foot apart for the third, fourth, and fifth LED wires.
6. Place a final mark six inches from the position of the fifth LED wires. This marks the position of the circuit board for moving in the other direction.

In addition to placing marks on the table, you will need to have some way of pinning the harness to the table. The harnesses tend to move around on the table while they are being worked on. The marks you placed on the table tell the volunteer where to place the LED wires. If the circuit board is not positioned correctly, the LED wires will be incorrectly spaced. One way to pin the circuit board in place is to place a reasonably large (10 pound) weight on the harness wires on the other side of the board.

Apply the coil wrap

1. Cut the coil wrap into roughly 5 foot lengths. Each harness requires ten such lengths of coil wrap.
2. Lay the harness out on your marked table. Place the center of the circuit board on one of your end marks. The mark for the first set of LED wires should be only 6 inches away. If it is one foot, the circuit board is on the wrong mark.
3. Carefully clip and remove the 5 cable tie wraps holding the LED wires for the segment you are going to wrap. If the circuit board has a cable tie wrap, clip and remove that one as well.

   DO NOT cut any other tie wraps yet. It is best to work on the harness 5 feet at a time.
4. Untangle the LED wires. After they're untangled, you can set these wires aside but do not forget them momentarily. Do not forget them though, since you'll need them shortly..
5. Find the mid point between the circuit board you're working on and the next circuit board along the line. This is the starting point for wrapping.

NOTE: Wire wrapping always moves towards the circuit board whose wires you are wrapping. You should never start wrapping wires beginning at a circuit board.

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6. Starting at the midpoint, remove any kinks from the power lines. The goal is to straighten them out so that any slack in the wire will be around the circuit board. Do not remove any slack from the rope. In fact, make sure the rope is taut as you move from circuit board to circuit board.

7. Once the wires are straight, take the coil wrap and start wrapping from the midpoint between circuit boards back towards the circuit board.

   As you wrap the wires, make sure to maintain a rough 1/4 inch spacing between individual coils. A 5 foot length of coil wrap will expand naturally when it is applied to the harness. If you do not include some spacing, you will run out of coil wrap before you reach the circuit board.

8. As you apply the coil wrap, keep an eye out for the marks on the table. When you reach one of the marks, grab the next set of LED wires so that you can wrap them into the coil wrap. Try to put the wires as close to the 1 foot mark as possible.

   For LED wires, leave approximately 3 to 4 inches of wire protruding from the coil wrap. Do not pull the wires tight from the circuit board. In fact, make sure there is a little slack between between the circuit board and where the LED wires are integrated into the coil wrap. This slack will help prevent damage to the LED wires later.

NOTE: Since you are working backwards towards the circuit board, you will always be grabbing the longest set of wires and integrating them into the coil wrap. Thus, you will always start with the 5 foot wires, followed by the 4 foot wires, and so on.

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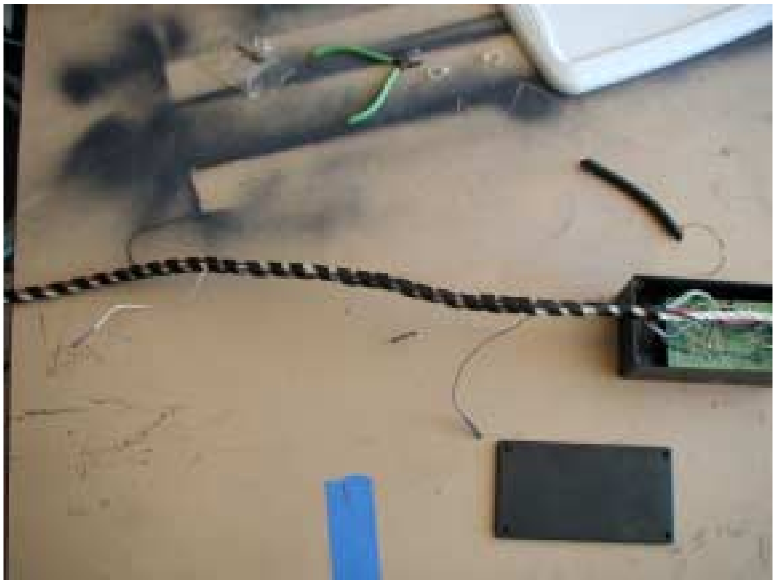
9. Continue integrating LED wires until you reach the circuit board. If you have left enough spacing between the coils, you should have somewhere between 3 and 6 inches of coil wrap left. Having more coil wrap is alright and does not need to be redone. However for future segments, reduce the amount of space between coils to try to hit the 3 to 6 inch target.

Figure 13 shows a harness after the coil wrap had been applied. The spacing on the coil wrap should be approximately one quarter inch. You can play with this spacing to try to leave about 3 to 6 inches of coil wrap left when you reach the circuit board.

Figure 13 Wrapping the wires with coil wrap



If you work on multiple segments of a harness, you will be wrapping in different directions depending on which side of the circuit board you are on. In all cases, you should always be working towards a circuit board.

Encasing the Circuit Boards

After you have applied the coil wrap to the harness, you can proceed to seal up the circuit boards themselves. The circuit boards will be encased in plastic project boxes. This enclosure provides better protection than did the original plastic wrap and duct tape because it does not hold the wires close to the circuit board. In 2000, several data transmission problems were caused by a data wire impaled on the back of the circuit board. The new project enclosures will remove the pressure from the wires and prevent them from being impaled.

The first step in encasing the circuit boards is to prepare the project box itself. Each project box must have channels on either side to accomodate the harness wires. The channels should be approximately 1/2 inch in diameter and positioned next to the lid of the box.

Before you place the circuit board in the box itself, Make sure the power lines and rope are positioned along the back side of the circuit board. With the wires in this position, the component side of the circuit board can go face down into the project box. The wires themselves will also have more slack when they are positioned on the back of the board.

Wrap the board with about 18 inches of plastic wrap just prior to sealing it in the project box. The plastic wrap adds a little extra protection from playa dust seaping in through the cracks of the box.

Use rubber tape to wrap the wires where the enter and leave the box. Rubber tape provides extra sealing power for the box.

Figure 14 shows a circuit board after it has been wrapped lightly in plastic and placed in the project box. The channels on either side of the box provide a space for the harness wires to enter and leave the box. Notice that the rope is relatively taut but that the power lines have plenty of slack.

Figure 14 Encasing the circuit board

With the circuit board in the box and the wires in the channels, put the lid on the box. Make sure all four screws are in tight so that there is no significant seam between the lid and the project box. The rubber tape should make the wires sit snugly in the channels. Once the box is sealed up, you’re done with this board.

Controlling L2K

This chapter covers both the original and updated design of the L2K power systems and pattern generators. The original designs are provided as background to L2K's operation during the first two year.s. The newer designs are intended to keep L2K going for years to come.

NOTE: Most of the information in this chapter is either incomplete or subject to change. Once more information is known about the new battery and controller towers, this document will be updated.

New Devices for L2K

Beginning with Burning Man 2001, the L2K ring will have improved power management and pattern generation capabilities. These new capabilities will also be packaged in a new way to provide better interactivity for users and better protection for L2K.

The Towers of L2K

The new packaging system for the batteries will consist of some 4 foot tall obelisks. There will be 8 of these obelisk-shaped towers altogether. Four of the towers will contain batteries controller circuitry, while the remaining four will be empty. All of the towers will be decorated for the playa and completely self contained.

Placement of the towers will be organized around the points of the compass. At each of the four main cardinal points (12, 3, 6, and 9 o'clock relative to the man) there will be two towers that mark an entrance into the center of the ring. One of the two towers at these entrances will always be a controller tower, while the other one will be a dummy tower.

Midway along the arcs that span between the gateways, Midway between the gateways will be durable plastic boxes containing the other four batteries needed to power the ring. See Figure 2 on page 16 to see the placement of the towers and battery boxes relative to the man.

Controller Towers

Each controller towers contains a lead-acid golf cart battery and controller circuitry. Each battery contains enough energy to run the ring for several days by itself. The combined energy of all eight batteries in the ring is enough to run the ring with 25% of the lights lit for 2 weeks.

Each controller tower will contain a pattern-generating computer and an interactive device. The four controller towers arbitrate with each other for control of the ring. Each towers has four LEDs in the pyramid top to signal when it is in control of the ring. During this time, it generates patterns from one of several different pattern generators. If a user is interacting with the tower, the input device for the tower will provide data instead.

Dummy Towers

The four dummy towers do not contain any electronics or circuitry. They are distinguished from the controller towers by the fact that they have no controls on their pyramid top. The dummy towers are used to mark the opposite edge of the gateway from the corresponding controller tower.

Battery Boxes

In addition to the towers, there will be four battery boxes. One battery box will be placed roughly halfway between each pair of gateways. These batteries provide distributed power to the ring and are basically the same system used in previous L2K installations. The power cables from the battery box tap into the junction between two harenesses.

Enabling the Controller Towers

Installation of the controller towers involves opening up the tower and running the power cables out the bottom of the tower. Inside the bottom portion of the tower is the power circuitry. This circuitry consists of a physical switch for disconnecting battery power, a fuse, and the solar sensor pack for disabling the battery during the daytime. Inside the pyramid cap is the controller circuitry used to generate the patterns.

To set up a tower, you must use a power drill with Phillips head bit to remove the deck screws on the corners of the tower just underneath the pyramid top. With these screws removed, you can remove the pyramid cap and access the interior of the tower. Do not remove the plywood panelling of the tower.

To enable the tower, do the following:

1. Remove the pyramid cap.
2. Plug in the solar sensor RCA plug to the solar sensor box.
3. Plug the molex-pin connectors together.
4. Turn on the power switch.

Once you turn on the power, the pyramid will try to take control of the ring. If it is not receiving any data, it will succeed and start generating patterns.

Closing the Ring

For 2001, a new feature has been added to L2K. This year, we will be closing the ring, allowing patterns from any controller tower all the way around and back to that same controller tower. This is different from previous years where patterns were generated at one point only and travelled back to that point but no further.

Closing the ring is a potentially dangerous thing to do out on the playa for one main reason. A large closed ring acts like a one-turn transformer. Large magnetic fields (such as those caused by a lightning strike) can induce a high current in this ring, with potentially disasterous effects for the L2K circuitry. Given the potential of the Burning Man to act like a lightning rod, this danger is amplified.

To prevent a lightning strike from destroying the ring, a special piece of equipment is being introduced to provide an electrical break in the ring but still allow data to pass through. A special opto-isolator box has been created and fitted with male and female plugs. When plugged between two harnesses, it provides electrical isolation between the two harnesses, while permitting data signals to pass through the gap.

CAUTION! It is critical that the opto-isolator be installed any time you close the ring. Failure to do so could cause potential damage to the ring if it is brought into contact with large magnetic fields.

Tower Maintenance

The following sections cover maintenance instructions for Burning Man crew holding the battery and controller towers out at the Burning Man storage site in Nevada. These instructions

Maintaining the Batteries

Because of the sealed environment of the towers, it was necessary to outfit each battery with hydrocaps to prevent the outgassing of hydrogen from the battery. Using a special catalyst, hydrocaps recycle hydrogen as it is expended from the battery and combine it with oxygen to make water, which is then returned to the battery.

Although the hydrocaps do a wonderful job of preventing the outgassing of hydrogen, there are limits to how long the hydrocaps last and how much load they can handle. It is never a good idea to put a heavy load on the battery for a long period of time, as this will tax the hydrocap's ability to process the hydrogen and could result in outgassing of excess hydrogen. Hydrocaps also require replacement after several years as the catalyst is depleted.

Battery Maintenance Checklist

Table 1 includes the maintenance checklist for the L2K battery towers. Burning Man staff should perform the following tasks at the given intervals in order to maintain the life of the L2K battery towers. Failure to follow these instructions could result in damage to the batteries or towers.

Table 1 Maintenance checklist for battery towers

Time	Maintenance
September - October	After Burning Man, it is important to recharge the batteries before putting them into storage. The best solution is to keep the batteries accessible so that you can apply a float charge to them every month or so.
January-February	Check the charge on the batteries again. Reapply a float charge to them to top them off.

Table 1 Maintenance checklist for battery towers

Time	Maintenance
May-June	Check the condition of the batteries and top off the charge. Plan to replace any damaged batteries about now. Check the hydrocaps and replace them as needed.
August	Do a final recharge of the batteries shortly before Burning Man.

Appendix A

The Wizard's Corner

The following section contains notes from an interview with Tim Black (aka the Wizard) about how L2K came into being. Thanks to Rebecca Firestone and Tim Black for supplying this text.

How It All Started

I enjoyed the art and performance of the Nebulous Entity last year (Burningman 98). I was basking in the glow of last year's success and expecting to just go and enjoy other people's art, take it a little easy after the overcommitment of '98. Then Larry called me up and asked, "What are you going to do for the Wheel of Time?"

Being a somewhat literal-minded engineer, I though: Wheel... Circle... 2000... OK, what about 2,000 lights in a circle... individually addressable... at a speed of 2,000 times a second... a Ring, artwork consisting of patterns and light!

The more I thought about it, the more it appeared I was not going to rest this year after all. Team building started in February. Because of the great work being provided by the members of this project crew, this huge project is getting done well. All these cool people have to have a place to hang, thus, the High Energy Magick Camp

The High Energy Magick Camp

The name for the High Energy Magick Camp came from Terry Pratchett's Discworld series. Among the wizards at the Unseen University are a group of geeky younger wizards who spend all their time in the High Energy Magic lab looking for the basic particles of magic.

There are parallels between the L2K project and magical rites and rituals. Many magic rites take place inside a ritually defined boundary or circle. The Ring is a circle describing a great boundary around the fire ceremony that is Burningman. A small circle (the Pattern Buffer Lounge) is logically connected to the larger circle to concentrate the energy raised by the larger circle. There's so much personal energy involved that I had to call it High Energy Magick.

Interactions with the Ring through the Pattern Buffer Lounge are magical, in that you're performing actions that influence things you don't see, or that aren't obviously connected. It's a celebration of the small controlling the large, which is to me the essence of magic.

Individual's Sense of Scale

This project plays with levels of perception and sense of scale. On the one hand, the Pattern Buffer Lounge offers a small, intimate setting. You can play with the buttons, walk across it easily, and see the whole thing all at once. Just the opposite is true for the big ring out on the Playa. But at the same time, when you're in the PB lounge, feeling like you're in this private space, you're affecting the big circle.

There's a gradual realization of this. The two contrasting spaces are connected. There's some kind of metaphor in this. The macrocosm of the Playa being affected from the microcosm of the PB Lounge, the "as above, so below" concept, and the small influencing the large.

Pattern Matching

Human vision is an incredible pattern matching device. It has an almost unbelievable ability to look at almost anything and find what it's expecting to see; for example, seeing animals in clouds. We don't like randomness. We want patterns to emerge.

The fact that the pods are in the ground means that they define our sense of place and space. At one of the beach burns, a couple came up to the pods and started walking up and down on opposite sides, as if it were a boundary that they were exploring. Another person went and stood by one particular pod, and jumped up and down every time it flashed. This behavior is an expression of people wanting to be in harmony or in synch with their environment. I'm looking forward to watching the way people will interact with the lights on the Playa.

About the Pods

The pods, like everything else, are the result of experimentation. Originally, we tried encasing them in foam, or casting them in cups, before finally settling on the current rugged design. The pod base is a 1.5-lb base of mortar mix or thin concrete, cast in a plastic breakfast bowl that has a straw stuck in the middle. Thus we have a tapered flattish cylindrical base with a hole running through the middle for the pod wires.

The LED lights, which we researched as explained elsewhere, are cast inside a plastic hemispherical lens shaped roughly like paperweight. Each LED has a pair of 1-foot wires with disconnects on the other end, so you can unplug the pods from the main harness for shipping and moving them around. The lenses, with the LEDs are then glued to the pod bases with silicon caulking, and the LED wires go down through the hole in the base.

This is a very sturdy and rugged design. We bury the pods so that only the lens is showing. Once they're buried, the pods can be stepped on, driven over, etc. without taking any serious damage. We have tested them at several beach burns and they seem to withstand the sand very well. Any abrasions can be polished off. Even with abrasions and cracks, as long as the LED point source is still visible, they remain effective.

LED Color

The particular orange we are using is a bright and flame-like color, very much in the spirit of Burningman. It catches the attention, induces excitement. The exact light frequency is 620 nanometers. We experimented with different colors at the beach, and this particular orange was the most compelling.

It's visible at 600-1,000 feet. Some of the other colors were either too expensive or didn't carry as well. For example the white was brilliant but cost $5-6 per light, and the blue looked great but didn't carry.

Flash Pulse Control

There's a pulse drive that controls how the lights flash on and off. After experimentation, we found that varying the intensity of the light during the flash was far more effective than a simple on / off.

There's a peak of brightness, followed by a plateau, which then tapers off. The combination of brightness and duration is dazzling, and affects vision profoundly. It peaks at 20-25 Hz, which puts the effect in mid-Beta, a highly active brain state. The lights appear to be much brighter, and the after-image is unusually intense.

All this occurs in a fraction of a second, too quick for the eye to discern. Our beach experiments showed that even in peripheral vision, this flash creates a strong impression of physical movement. It actually feels like something went by you.

Psychological Effects

Modern science currently classifies the following brain wave states, which are measured in cycles per second, or Hertz (Hz):

- Delta (0.5-4 Hz) - unconsciousness and sleep
- Theta (4-7.5 Hz) - deep relaxation; border between sleep and waking
- Alpha (7.5-14 Hz) - light relaxation
- Beta (14-35 Hz) - waking state or “normal” consciousness

There is also Gamma state which is a hyperexcited, manic state, characterized by very large bursts of energy. It’s not clear if this is ever desirable, or if it's possible to use this state for anything.

Different light patterns produce different psychological effects. Certain frequencies of flashing lights draw the brain into different modes of operation. As we know from the Pokemon 1 episode, they can also induce epileptic seizures, but these are merely a side effect of the brainwave shifts. The Dream Machine at Burning Man 98 was an example.

Flashing lights can bring you to states such as lucid dreaming, meditation, or out-of-body sensations. The theory is that these brain states are associated with different resonant frequencies. By providing an external stimulus at those frequencies, you can induce these same states within the brain.

This doesn't work the same for everyone. For some, it only produces very mild effects. Also, you might not necessarily be able to bring someone from Theta to Beta, for example (deep relaxation to waking state), merely by flashing lights in a pattern.

The brainwave machines so popular among certain consciousness crusaders are a very personal sort of gadget. My challenge was, could I produce these frequency shifts in a large-scale presentation? The ring can go from 1 cycle / second up to 2,000 cycles / sec. It should therefore be able to reproduce any brainwave frequency of which the human brain is capable.

Because running the Ring at a high frequency allows analog looking brightness modulations (pulse width modulation). Plus, I needed 2000 cps to use all the lights in a sweep second hand.

Engineering Philosophy: Optimization

Since around 1976 I've been designing embedded systems with microcontrollers. Microcontrollers are tiny computers embedded in other systems. There are in things like cars, VCRs, microwaves, answering machines, phones with "features", telephone switches, Internet routers, and aircraft - especially the "fly by wire" aircraft, where the pilot doesn't directly control the plane. The thing about these embedded systems is they're invisible. You only notice them when they're not working. In this type of application, it's considered elegant engineering to design devices in such a way that they simply vanish. In the L2K project, however, it's all visible. It's just for fun, and has no commercial value.

The fun and the challenge of this project for me has been optimization: to design the components as cheaply as possible, and the code to be as efficient as possible.

The first computer I owned was a 2Mhz Altar 8080 with 256 bytes of memory. I programmed it by flipping toggle switches on the front of the machine to load binary machine code instructions one at a time.

Even as desktop computers became more powerful, a lot of the work I was doing stayed minimal. In embedded systems there is always a requirement for compact and efficient code. Programming like this is fast becoming a lost art - (did you know that Microsoft Office 2000 needs almost 700MB for a full installation?)

"Put everything into everything" is the current trend. To me, however, design elegance is doing one thing really well, so that it is perfectly balanced to the task at hand.

About the Microcontrollers

They are called PICs. Each one has 1,024 words (each word is 14 bits in this case) of program memory, and 128 bytes of data memory. These chips are extremely cheap at $1.70 each, which is important when you're buying 400 of them.

Programs Running in the Ring

Currently the program is right around 800 bytes. It consists of the following parts:

- Communications system
- Event list manager
- Code to read and de-bounce the push buttons [clean up signal when someone pushes them]
- Code to display the patterns

The Data communication around the ring is in 24-bit packets transmitted synchronously at 2,000 times a second. Each microcontroller simultaneously transmits and receives a packet of data using 50% of its available capacity. The other 50% of the CPU is used for decoding instructions, processing events, and displaying patterns.

Turning Live Data Sources into Patterns

Since packets are transmitted synchronously in real time, patterns from live sources can be transmitted and displayed immediately. We have a box with an audio spectrum analyzer that outputs 10 bands representing various audio frequency ranges. You can select different frequency bands to feed into the ring.

Pattern Overlay

There are three different ways to get a pattern onto the Ring, and each one can be functioning simultaneously with all the others for complex overlays.

- The first way is to program the Ring with an event list of up to 30 different patterns, on each of the 200 driver boards. By staggering event points around the boards, you can have the appearance of a single large pattern. This means that each of the 200 boards has its own set of 30 patterns, or 30 x 200 = 6,000 total available pattern events. For example, you can use this to program the sweep of a second hand clockwise around the Ring.
- The second way is direct display. every light can be changed individually up to 10 times a second by directly writing to that light. Or, any particular light can change 2,000 times a second.
- The third way is a shift command that takes a single bit, moves it 1 step clockwise, and adds a bit. Shift patterns can run at any rate, separate from other functions.

Playing Patterns Interactively

This is a very simple system, using only a few basic components. We start with a line, which is a set of points. This line is bent to form a circle. From there all other combinations are formed. We are playing within a boundary of great simplicity. This approach is the opposite of that taken by modern computer graphics programs, with their perfect shading and super-realistic rendering. In the L2K project, there isn't a lot of preconceived structure. Any meaning is in the mind of the observer.

The Pattern Buffer can be played interactively in a number of ways. Each LED in the PB Lounge has its own button, which turns the LED on or off when pushed. A preset pattern can also set or reset the LED.

More complex patterns can be created by our PB "Lounge Lizard" patrons as follows:

- The Loop sits quiet. People push buttons. At some point the pattern is "stored" and then repeated, probably every 5-10 seconds. What people are currently playing is overlaid against what they were playing a few seconds ago. Meantime their new actions are stored again for playback in the next loop.
- Play pre-existing patterns (like the clock sweep) and let people try to catch it and "erase" it. They have to hit the LED push button at the exact moment that the pattern sweeps through, otherwise they'll add a new bit to the pattern instead of erasing the existing one. Whatever they did would go racing around the Ring.
- You could even have group games for "erase the pattern" with preprogrammed starting points. For example, a group in the North would try to make the Ring all light, whereas a group in the South would try to make it all dark (erase North).

The computer controlling the Pattern Buffer Lounge is a Z80 with 512K of battery-protected memory and 128K of flash memory. It also has a higher-level event list with programmable date, time, and event triggers. So you can program a particular pattern to start at midnight, for example.

Magic, Technology, and Engineering

Arthur C. Clarke once remarked that any form of technology is indistinguishable from magic (to a civilization that isn't advanced enough to comprehend it yet). I'd turn that on its head and say that any sufficiently advanced magic is indistinguishable from technology.

We’re focusing our own will towards the effectiveness of small influences at critical points. That’s what technology is, it’s getting the most out of any action by applying that action in the right place, at the right time, for maximum results. It’s a “Give me a lever long enough, I can move the world” kind of thing.

This ties back to my remarks about the importance of elegance in engineering, because every component in this project is designed for optimum fitness for the task. It’s remarkable that I’m getting this level of functionality out of such tiny computers. But that’s essence of it - engineering done right has a kind of magical feeling to it.

Tinkering with Reality

Physicists and magicians both do similar things, which is they tinker with the nature of reality. So too do the software engineers who were the creators of the Information Age redefine our notions of reality with respect to things like business and money.

If you go down far enough in hard science you come up in metaphysics. Particles pop in and out of existence, and people like Stephen Hawking, citing developments in modern physics, concluding that anything at all can happen.

Like these physicists, software engineers are doing magic all the time. They’re redefining the world in tiny places, doing interesting things that end up having a massive influence on the world. They’re totally focused on the task at hand, in their intimate space. It surprises them when their work is so far-reaching.

The Information Age and Reality

The nuclear scientists didn’t all know right away that their work would lead to such mass destruction. After the bomb, Oppenheimer said that he had become the destroyer of worlds. I wonder why he never thought of that while he was doing it...

Information Technology is now as influential as the Industrial and Nuclear Ages. Information Technology changes the fabric of reality by redefining our notions of money and value. It removes boundaries between the group and the individual. We don’t know yet what the end result will be. It could become a world of big brother watching everything you do. Maybe not, I'm hoping that tolerance, freedom, and self-expression become "normal" as people come to have ubiquitous access to other points of view.

Impact of Information Age on Society

The Information Age is leading towards a society with an increased emphasis on the individual, with power in the hands of connected communities that are no longer separated by geography. Maybe it will be possible to have technology with lower energy consumption by a return to community living. (Walk around your village, commute around the net)

I could enjoy that...

Final Thoughts

“Why am I doing this? Why turn my life upside down to create acres of art in the desert?

It's not a logical thing, My head says I must be completely nuts, but it just feels like I should do this. It's somehow a heart thing. There are a lot of invisible people working on this, people who do science and technology in cubes and other hidden places. People who are extremely creative, but normally their work is not directly seen. I'm one of them, and this project is about that somehow. About how the hard core tools of engineering, circuit boards and software debuggers, are valid tools for art. That technology can be a medium, used like paint or marble, and formed into things delightful and unexpected.

It just matters in ways that I can't begin to explain, and I deeply thank everyone who is helping make this happen."

- The Wizard

Appendix B

Podmaking: An Oral history

Podmaking is an ancient tradition dating back years. It's origins are masked in the mists of time to all but the illustrious Podmeisters of L2K. This learned group of masters form a mysterious cult whose purpose is to bring podmaking to the unenlightened masses. It was through their devotion and cooperation that the information in this chapter was prepared.

It was also through the Podmeister teachings that the history of pods came to light. That history is presented in the following sections. As with other theological treatises, this information is presented as a transcribed oral history. It is hoped that the reader may be able to glean insights into this ancient tradition, or at least gain a deeper appreciation of the science, nay art, of podmaking.

The Legend of L2K

"Legend has it that after the very first burn, not all of the Man's flames died out. In the fading glow, a handful of men ventured forth and captured the remaining living bits of the Man, trapping them in small, transparent cages.

These brave souls, known today as the Pod People, were saddened, however, for as they trapped each piece of fire, the Man-bit would fade out and glow no more.

So the Pod People approached the Wizard with their dilemma. And the Wizard found that the Man-bits had not died, as the Pod People feared, but lay merely dormant.

Over time, the Wizard learned to coax these bits of fire to follow his wishes--to light up when desired, to lie dormant otherwise. He instructed the Ringmaster in his methods, and together they were able to control the lights, playing them in complex rhythms, as one might play a musical instrument.

Each year we gather 2000 of these glowing Man-bits and place them in a never-ending circle to pay tribute to the Man and his never-ending spirit."

- The Podmeisters

The Book of Gayle and Mike

This dynamic duo were father and mother to every cement base of every pod. Their story reflects the origin of the species known as Podus Illuminatis. It is a tale of Gods and Goddesses, of Earth and Water, of Poetry and poets, of Harmonies and Harms. Heed their words of the Creation as it is told here.

The Parables of Safety

"latex gloves must be worn at all times, as contact with human elements during construction changes the mystic nature of the unit. white are okay. purple are better."

Prepare Thine Ark With the Following Materials

- Costco virgin styrofoam soup bowls
- Costco virgin non-flex straws, preferably those from bulgaria
- bags of Portland cement. do not use those from Seattle. inferior product and will anger the godz.
- bags of 30 mesh washed sand. does not need too be sterile, must be washed. no dry cleaned products, please.
- 1 bag of lime. not green fruits. mineral
- 1 bag Stealth Fiber. who says we aren't part of the jet set.(available at concrete supply yards)

Genesis

having donned virgin latex gloves, respirators, and holy bandanas, mix the following in L2K approved five gallon buckets. do not deviate from this standard or beware the consequences:

use one pound coffee can for optimal results. South American coffee preferred. adds to ambience and also creates link to Macchu Pichu and Pasadena. this has significant impact on mystical quality of final product.

- 1 part Portland, again, we emphasize PORTLAND cement
- 3 parts washed sand.
- 1/4 part lime
- 1 healthy pinch of Stealth Fiber. consult your local pyro for further information and training on this additive. must be handled with utmost care.

combine the above-listed dry components. using industrial-strength 1/2' drill or other L2K approved mixing device outfitted with detachable metal mixing paddle. metal mixing paddle must be blessed by the Wizard annually by special appointment. this is critical to the success of the finished product. DO NOT DEVIATE. OR BEWARE.

add water until consistency is similar to well blended cake batter. this will vary with atmospheric conditions and astrological line ups. for best success, it is recommended that manufacturers obtain the certification offered by Mr. Mike's Mystical Masonry Society. (also known as the MMMMS). Seminars costs are tax and Burning Man deductible.

having achieved appropriate slump to mixture, fill virgin Costco soup bowl completely with the masonry mixture. USE FOUR CUP MEASURING DEVICE AS APPROVED BY L2K. This is critical to the mystical ambience of the finished product, which is the base, altar and stability of the pod.

each bowl must be burped to eliminate undesirable terra firma gas molecules and level the field.

after thirty minutes or when the proper harmonic hydration level is achieved, insert virgin Costco straw in exact center of each bowl. symmetry is essential. straw must contact bottom of virgin Costco soup dish as L2K mantra is chanted. do not deviate from this procedure. contact L2K for mantra seminar locations. participants must meet stringent qualifications.

every 1/2 hour, rotate the virgin Costco straw with a wobbly motion as the mantra is repeated. the exterior portion of the aperture is to be larger than the side in contact with the virgin Costco soup bowl. do not deviate from this practice or the product will become unstable.

when Portland cement becomes stable and removal of the straw can be positively achieved without affecting the structural integrity of the unit, remove straw. again, recitation of mantra is required. this process generally occurs 3-4 hours after pour. refer to seminar handbook for specifics.

allow product to cure for 24 hours.

release pods from mold. use of final and most illuminating base mantra chant is required. do not use kazoos during any of the above procedures or be prepared for the direst consequences.

straw hole can then be drilled completely thru for uniformity using L2K approved and Wizard blessed masonry bits. a bit of this and a bit of that will not do.

Thus ends this vain and glorious chapter on the Mysteries of the Pods

The Book of Melissa

Lens Mother Melissa was responsible for giving the light unto the pods. She crafted each lens from the raw elements, enabling it with the phosphorescent properties needed for a nighttime display. Her story is presented as an open letter to the editor:

Through the Looking Glass

Hello Podmeisters,

Remembering back to the beginning of time (December 1998), when The Wizard was sitting in his study pondering life past present and future, I listened as he thought out loud. He began to talk about the great number 2000 and how such a number was hard to imagine. He began to speak about a ring the size of which could enclose two football fields. It sounded impressive, but I did not yet comprehend the scope of the project. The opportunity to work closely with my father to create a prototype pod was irresistible. After nearly 3 months of testing and researching plastics, molds, base structures and LED's we finally had the pod of today.

For weeks I spent my free time stripping (wire that is) and crimping (no, not the 80's hair style) with the growing number of fellow Podmeisters in-between beginning full time production on the first batches of sacred lenses. Following is the wisdom I acquired when I spent my summer days inhaling the fumes of liquid plastic baking in the sun:

1. Even in the great outdoors the fumes from the plastic resin used to make the lenses is strong. Gas masks make a big difference. I used one during the last few weeks of casting and had wished I'd done it sooner.

2. As long as the dome molds are kept in good condition there should be no need to file the edges of the lenses to create the flat surface.

3. It's a good idea to special order the dome molds from Tap Plastics. When we made L2K the first time we bought out the dome molds from all the Tap Plastics in the area. Problem was, we still needed more.

4. It is Very Important to stir the plastic completely and remember to scrape the edges of the bowl with the flat edge of the stir stick.

5. The time it takes for the plastic to harden depends allot on what the temperature is when it is setting. It's a good idea to monitor the temp to find the ideal setting time. This may vary depending on the heat source.

6. The trick with the LED's in the plastic is to put the LED into the plastic until all of the plastic tip is coated and just the beginning of the LED's have been touched. Then pull it back out to just the point in which the bottom of the metal thingy inside the plastic ball part of the LED is level with the top of the plastic. (hmm, I hope you understand what I'm saying) This is an important part of the process because this positioning is what creates the best amplification of the light.

7. It is also important that once the lenses are put aside to harden great care is taken when checking hardness so the plastic is not spilled. And I don't advise checking with your bare fingertip. That plastic is hard to get off. Use latex gloves when stirring and handling not-yet-hardened plastic.

8. If lenses seem foggy or not smooth it is likely that the mold used is worn out. We have tried many methods of extending the life of the molds and what we found is that some may help for a run or two but then you just have to replace the mold.

9. If the edges of the lens are a little sticky try stirring the plastic in the next batch more, or try increasing the temp of the hardening area a little.

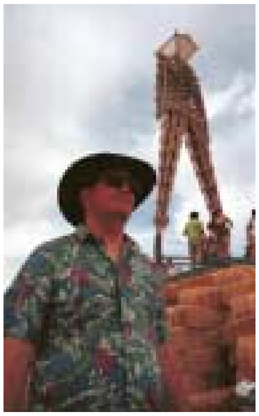
10. If the edges of the lens aren't smooth the best bet is to grind them down, but be very careful not to cut the LED leads. It is also a good idea to do this before putting the wires on. It is important to use a dust mask when grinding them down.

I leave the descriptions of other portions of the project to those individuals who specialized in those areas. There are many people who contributed to the production and instillation the first and second years L2K was in the desert.

It's a big project but it feels really good to be part of it.

Lens Mother

The Book of Bob



Podmeister Bob is the Father of modern podmaking. He protected the infant pod children from their birth right through to their eventual demise. The writings of Bob have been the subject of some debate, engaging scholars around the world to help in the deciphering of his text. The most famous of his teachings are presented here in summarized form:

On the preparation of wire

"Shall we begin, as we began, with the connecting wires? Cutting, stripping and crimping. For me, the most important point was to buy a StripAx Professional wire stripper, which in addition to being quite good at baring wire, allows one to refer to one's previous occupation as a Professional Stripper."

On the application of heat-shrink tubing

"Then there was crimping on of the male and female connectors and somehow getting the heat shrink around them. I did that hundreds of times and never did figure out how to do it. Little differences in the different reels of heat shrink made a big difference in how hard it was to slip that stuff on, but I don't think anybody had a method. Now, the last, easy step of actually shrinking the heat shrink, now there we had some methods or styles at least. I liked to rotate the ends individually in the heat gun air like cooking a hot dog on an open fire. Other people, "sane" people, just held groups of four or five ends in the hot air and got theirs done four or five times faster."

On preparing the bases

"The other thing about the bases is to put straws in the middle to leave a space for the wires. Now, we did end up drilling through each base, but you want to have the straw hole as a starter, I'm sure. But the uniformity of the holes after drilling did make a difference in how quickly the wires to the bulbs could be threaded through the bases. A bit of a taper at the top of the hole helped when the LEDs were hanging low in the lenses."

On soldering wires to the lenses

"Then there were the Soldering Parties, where we learned that after enough beer, you will stop burning your fingers...as far as you know or care. Seriously, the two big innovations there were dipping wires by the bunch into Tim's solder pot - much, much faster than tinning the wires individually - and using hot glue instead of heat shrink to insulate/ separate the wire connections at the base of the LEDs.The hot glue apparently also protected the LED connection a bit mechanically, since we had many more failures after transporting lenses that used the heat shrink. It's a Good Thing we had plenty of glue sticks. Yes indeed. Oh, and you want to test the lens connection right after the soldering. Particularly if you've been drinking a bit. You do have to remember that LEDs have polarity, leave one lead longer than the other, and you can clip the leads individually maintaining traditions of Old World Craftsmanship like me or you can be "sane" and cut the two leads with one diagonal cut. Oren's idea. The 20th century in a nutshell. Glad that's over."

On the final assembly

"Have we come to Final Assembly? Remember this: Properly applied, an ISO squeeze of the glue gun will result in an ANSI Dollop. Very precise. Then the smooshing. Well, actually it was clear when too much glue was applied, it squirted out the sides. Too little was less obvious. I remember Melissa ground the bases of the early lenses flat, but we dropped that later on. Is there a trade off in lens adhesion where more glue compensates for a less planar lens base? This is, to my knowledge, an open question in Pod Theory."

The Book of T.J.

T.J. was the Godfather of modern podmaking. Like Bob, he was there at the beginning of each pod's life, seeing it through to its eventual demise. T.J.'s wisdom is presented here.

First Shalt Thou Cast the Concrete Bases

I don't know much about the casting process, but I believe that the use of straws was helpful. After the bases were cast, we reamed out the center holes using a drill with a standard masonry bit. I think that having pre-formed holes made the drilling much quicker and easier.

Second Shalt Thou Cast the Lenses

This is Melissa'a area, but I do remember that using the right mold release and using it consistently made a big difference in lens quality.

Third Shalt thou Prepare the Lenses

We started with wire bundles pretty much ready to go--pairs of blue / white(?) with connectors already crimped at one end and plugged into each other (this made it easier to keep pairs together), and the other ends stripped.

The only other preparation for the wires was to tin the stripped ends. For this, a can of flux and a solder pot greatly sped up the process. We originally tinned each wire individually, which was very tedious.

The lenses had been cast with the LED's already embedded. The first step was to clean the lenses using a wet cloth, since many of them still had mold release on them. The second step was to trim the leads on the LED's down to a reasonable length (roughly 7mm and 5mm). In this step, you must make sure to maintain the relative length relationship between the two leads so that you know which one is cathode and which one is anode. One shortcut we discovered in cutting the leads was to cut both leads at the same time, using the wire cutters at an angle.

The next step was to solder the wires onto the lens. This was probably the most tedious step. Each person soldering had their own station set up with soldering gun, solder, and a glass or mug which was used to hold each lens as it was worked on. The lens was placed roundside down in the glass or mug, with the leads sticking straight up. First, we tinned the leads of each LED individually. Second, we soldered each wire to the proper lead by lining up the wire and the lead parallel to each other and touching them with the soldering gun. Usually the solder on the wire and the lead were enough to join them satisfactorily, but sometimes we had to add solder in the process.

This step was very tedious ("it takes a very steady hand...") and could stand improvement (though I don't have any good ideas offhand).

After both wires had been soldered onto the leads, the area surrounding the solder joints was filled in using a dab of hot glue. The hot glue served two purposes: to isolate the two leads, and to provide mechanical stability (so the leads / wires wouldn't bend, and weak solder joints would have reinforcement).

After the hot glue dried, the final step was to test the whole assembly. A tester was rigged up with a 6V battery and two molex connectors, and every lens was tested. The most common causes of failure were reversed polarity (the wrong wires connected to the wrong leads), and poor solder joints. Overall, though, the failure rate was pretty low (1-2 per 100).

As far as the whole process is concerned, we tended to split it up based on function (one person did one function), and did them in batches. The soldering step had the lowest throughput, so we usually had several people doing that at once, whereas hot gluing or testing was usually a one-person job.

Fourth Shalt Thou Assemble the Pods

To assemble a pod, you need:

- Lens assembly (see previous step)
- Concrete base (with hole drilled through center)
- Silicone sealant (in caulking gun)
- Gloves
- Table for assembly
- Drying rack

Assembling a pod is simple. First, thread the wires of a lens assembly through the center hole in a concrete base, leaving the lens hanging off to one side. With the caulking gun, apply "one ANSI dollop" of silicone sealant evenly on the top of the base, around the center hole. Then put the lens in place, positioning the leads / hotglue ball into the center hole, and gently twist and push the lens until the sealant is spread out evenly under the lens. It's kind of like twisting open an Oreo, but in reverse. When the lens is in place, remove any excess sealant around the edges with your finger. You can use this excess sealant in the next step.

After the lens is in place on the base, turn over the base and fill in the hole in the bottom with a dab of sealant. This provides strain relief on the wires coming out the bottom, and helps prevent playa from getting inside the pod.

Once the bottom is plugged, it's time to set the pod to dry. We set up drying racks made of 2x4's spaced 2-3 inches apart on the ground. We placed the pods on these racks so that the lenses faced up, and the center holes and wires were suspended between the 2x4's.

Production capacity for assembling pods was usually limited by the size of the drying rack.

NOTE: When threading lens assemblies into concrete bases, try to pair up lenses with off-center LED's with bases, which have holes drilled off-center.

The Book of Oren

Oren was the Favorite Uncle of modern podmaking. He devised new techniques to help the infant pods survive the harsh new world they would be facing. His wisdom and advice are heeded without question. The picture here shows him entering the Solomon Copper mines in Israel in search of Biblical pods. What follows is Oren’s own words of the Podmaking traditions:

Pod Making in the 20th Century - The Industrial Revolution

Podmeister Bob strongly holds to traditions of the Ancient Ones. Hand crafting each pod to a perfection, making it an art object to be sold centuries later in auctions around the globe. Having the Podmeister style imprinted into the mold. One can point the podmeister name and his artistic period by just looking at the pod in candle light.

The Good Old Times

The 1st time I have seen a pod it was in Melissa hands. She was sitting on the stairs outside trying in the ways of the ancient ones to fit the lens edge to the base. Slowly grinding the lens to fit the edge.

Oren: "Is that the pod?"

Melissa: "Yes."

Oren: "Can I have a look?"

Melissa: "Go ahead"

Oren: "Are we doing them one by one?"

Melissa: "Yes"

Oren: "How many do we need to make?"

Melissa: "About 2200, 10% over the 2000 for L2K..."

Yeah right. I almost gave up at this point.

Moving into the 21st Century

A change in concept had to be introduced. No longer the Ancient Ways. Welcome to 20th century. What was needed? A model T like PRODUCTION line. We need to deal with materials, suppliers, manufacturing, quality, storage, shipment.

So here are few snippets from our industrial ways of doing pods.

Suppliers:

I know all the TAP plastic shops in the bay. The item we needed the most of the dome shaped molds. These things are not meant for industrial use and needed replacement often.

Few examples from the manufacturing line:

1. I think the box for making (molding) ~20 lenses at once with the LED inside deserve a chapter in a book.

2. We grinded the lens base with electrical grinder covering everything in Tim's garage in thick layer of plastic dust. Moved it outside later. It was done to remove the sharp edge of the lens. Worked great. Best done before wiring.

3. We created small area for assembly which is relatively high. Working on normal desk while standing brake your back. We used ladder and wood to create high desk. It was important to have this area accessible from all directions because 3 of us worked on it in parallel.

   - one was placing bases on the desk.
   - second will place the lens wires inside the straw hall, but not all the way, base top is still exposed.
   - the victorious glue gun owner (it was a constant fight between Bob and TJ, I had my share of real guns) will put the glue on the base top.
   - someone with gloves place the lens in its final location, the middle of the base. And wipe the extra glue and place it in the base bottom in the straw hole the seal the base.
   - Take the pod to the drying area.

4. 4) We used 2x4 to create an area to store the lenses to dry out, we spaced the 2x4 by about an inch and used that space to place the wires to stick out from the pod base. We later found out we can stack lenses to dry out by placing 2nd layer of lenses upside down on to top the 1st layer.

5. 5) We packed it all into the famous buckets.

Miscellaneous comments

The pod is forever. We used cement and plastics to make sure archeologists of the black rock city will find a pod in pristine condition. We used plastics from TAP plastics and many dome shaped molds. The smell of these materials can convince anyone the ozone layer has no chance in the long run. However, with the new president it does not have a chance anyway. The liquid plastic became hard after adding few drops of enzyme which is yet another nasty stuff.

The dome molds had to be cleaned a bit after each use otherwise the next batch of lenses will not be as transparent and will stick to the mold.

Soldering parties

I getting tired, so just the conclusions:

1. Beer is good
2. Soldering irons are HOT
3. Too much beer will burn your fingers. (hence 1 + 2 = 3)
4. You will never get the clipped LED leads out from your rug. never. never
5. Commerica Bank VP's cook very well and can test lenses very quickly.
6. Keith has no clue in soldering, but will die trying.

7. TJ does the best soldering, close to zero defects!
8. Bob has the best soldering iron by far.
9. Soldering parties can make your landlord worried.

Appendix C

Project Statistics

The following table lists some random factoids about the L2K project.

Table 2 L2K project statistics

Ring Construction Statistics	
Button board mass production dates	May 1999 - August 1999
Ring board mass production dates	July 1999 - August 1999
Harness assembly mass production dates	July 1999 - August 1999
Average time to assemble 1 ring board	50 minutes (without soldering LED wires)
Number of boards per harness	5
Number of harnesses	42
Average time to make 1 harness (without soldering LED wires)	2-3 hours
Average time to make 1 harness (with soldering LED wires)	5-6 hours
Amount of wire used in the ring	approximately 25,400 feet (4.8 miles)
Number of crimps	approximately 8,600
Number of stripped wires	10,000+
Number of solder joints for ring boards	approximately 39, 200
Number of solder joints for button boards	approximately 25, 400
Number of pods originally constructed	2211
Electrical Characteristics	
Peak pulse current per LED	70 milliAmps (for 100 milliseconds)
Steady current per LED	25 milliAmps
Max ring current with LEDs in steady state	60.4 Amps
Total battery capacity	1760 Amp Hours This is enough to power the ring with 25% of the LEDs lit for 12 hours a night for 14.6 days.
Impulse energy storage	2,440,000 uF (2.44 Farads!)
Impulse current (all lights on)	140.4 Amps for 40ms

Table 2 L2K project statistics

Ring average current with 25% active LEDs	12 Amps
Ring idle current (displaying idle pattern)	2.4 Amps
Ring sleep current	5.2 mA
Computer Statistics	
Total computing power	800 Mips (million instructions per second)
System transfer rate	>100Kbaud
Data packet size	24 bits
Data packet transfer rate	2000 packets per second
Ring board program size	800 bytes
PIC program memory	1024 bytes
PIC data memory	128 bytes
Miscellaneous	
total construction time	over 5000 person-hours
weight of the entire installation	approximately 3.3 tons
maximum velocity of a light pattern	approximately 1,000 mph
Number of guys named Tim who worked on the project	3
Number of guys named Mike who worked on the project	3
Number of guys named Bob or John who worked on the project	1 each
number of animals harmed during construction	zero

Appendix D

Credits

Thanks go out to everyone who pitched in to make L2K happen. Special thanks go out to the L2K core team for all of the long hours and hard work they put into this project. The L2K project would not have happened were it not for the incredible effort put forth by the following people:

Table 3 The L2K Core team

L2K concept by:	Tim Black Melissa Black
Master Designer, Prototyper, PIC programmer, and L2K brain trust:	Tim Black (The Wizard)
Project CFO	Kassandra Eden
Pod lenses casting crew:	Melissa Black (Pod Mother) Tim Vogt Bob Culley Oren Gershon John Wendt
Pod base casting crew:	Mike Morphy (Mix Master Mike) Gayle Hoover
Pod Assembly crew:	Bob Culley (Podmeister Bob) Tim Vogt (Podmeister T.J.) Oren Gershon (Podmeister Oren) Keith MacDonald (Solder Boy) Melissa Black Dennis O'Connor Rahul Bhatt
Circuit board assembly crew:	John Wendt Colette Wendt Steve Boverie Scott Gasparian (Gaspo) Seth Golub Dennis O'Connor Michael Weldon

Table 3 The L2K Core team

Harness construction crew:	John Wendt (The Ringmaster) Steve Boverie Tim Black Paul Weidler Janet Major
Wire workers:	Melissa Black Bob Culley Kassandra Eden Seth Golub Gayle Hoover Mike Morphy Dennis O'Connor Colette Wendt John Wendt
Recruiters:	Timothy Childs (Sky Squid) Rebecca Firestone
L2K Camp Personnel:	Louis Brill Timothy Childs Dee Dee Kassandra Eden Rick Rowland Paul Sochacki
2001 Retrofit crew	Tim Black Melissa Black Rick Rowland John Wendt and many others whose names I never wrote down. If you were one of the folks, please send me your name so I can include you.
Installation Crew: 1999	Melissa Black Timothy Childs Bob Culley Dennis O'Connor Rick Rowland Tim Vogt John Wendt and countless volunteers
Installation Crew: 2000	Timothy Childs Bob Culley Keith MacDonald Paul Sochacki Tim Vogt Colette Wendt John Wendt and countless volunteers
Installation Crew: 2001	Tim Corvis Bob Culley Keith MacDonald Rick Rowland Melissa Black Sherman Amsel John Wendt and countless volunteers

Figure 1 shows the crew of L2K posing in the remnants of the L2K Pattern Buffer Lounge. This lounge housed the button boards, with which people could send patterns out on to the playa.

Figure 1 L2K crew posing in Woodhenge

- Front Row (L to R): Louis Brill, Paul Sochacki, Timothy Childs, Bob Culley
- Row 2: - On couch back: Melissa Black, Rick Rowland, Yoda, Colette Wendt
- Row 3: Kassandra Eden, Claudia, Oren Gershon, Tim Vogt, John Wendt, Dee Dee, Steve Boverie
- Remaining Rows (front to back): Gayle Hoover, Eric (behind Gayle), Chris Black, Roger, Gaspo (not posing, in the back)
- Back Row: Tim Black, Mike Morphy

Acknowledgements

Thanks also to all of the volunteers who have helped us install this thing out on the playa. Thanks to everyone who helped load the trucks, pack the buckets, carry the gear, make us food, and a whole bunch of other stuff I'm forgetting.

Thanks to Tim Corvis from Reno for taking over as the head honcho on L2K. His dedication is deeply appreciated and L2K couldn't be in better hands.

Thanks to Burning Man for their continued support and enthusiasm.

The Ringmaster would still like to thank Colette for being understanding during the construction of L2K. Thanks to the Wizard for designing such amazingly cool stuff. “It’s always an honor to work with you.” Thanks to Kassandra, Bob, T.J., Melissa, Rick, Oren, Steve, Mike, Gayle, and everyone else for being such wonderful people.