Interpreting Solar Power Graphs
Demonstration Activity

To the Instructor: SunViewer.net™ allows students to access daily information from locations across the country using web-based data access. To see an example of the data available, go to http://www.sunviewer.net. Students can choose among the data available at SunViewer.net™ to create their own plots and then compare data from different days or seasons at one location, from the same day at different locations and numerous other combinations for comparison. A student worksheet is provided for your use at the end of this demonstration.

Objective: The following activity is designed to allow students: 1) to understand and compare plots of the amount of sunlight falling on a photovoltaic array (solar panels) and the power generated by the array, 2) to compare the plots for different days and hypothesize the reasons for visible differences, and 3) to find and explore local weather data which may help support or refute the hypotheses.

National Science Education Standards: This activity can be used to meet portions of the National Science Education Standards in Science as Inquiry (Content Standard A), Physical Science (Content Standard B), Life Science (Content Standard C), Science and Technology (Content Standard E) and Science in Personal and Social Perspectives (Content Standard F) for Grades 5-8 and 9-12.

Preparation: Understanding of different units of sunlight, power and energy is required. The data presented below is taken from a 2 kilowatt solar photovoltaic array installed at the Boston Nature Center in Boston, MA. Reviewing the features and photographs of the Boston Nature Center solar power array would be useful. Go to http://www.heliotronics.com/cases/cases_main.html

Part I. Compare the following 24 hour plots of sunlight and solar power output. The plots on the left show how much sunlight is falling on the solar panels. The plots on the right show how much power the solar panels are producing.

For each, think about what factors might be affecting solar power production.

Hint: Power output from solar photovoltaic panels is very sensitive to shading. The slightest amount of shading can result in a dramatic reduction of power output. Photovoltaic installations should be unshaded between the hours of 9AM-3PM to maximize power output.

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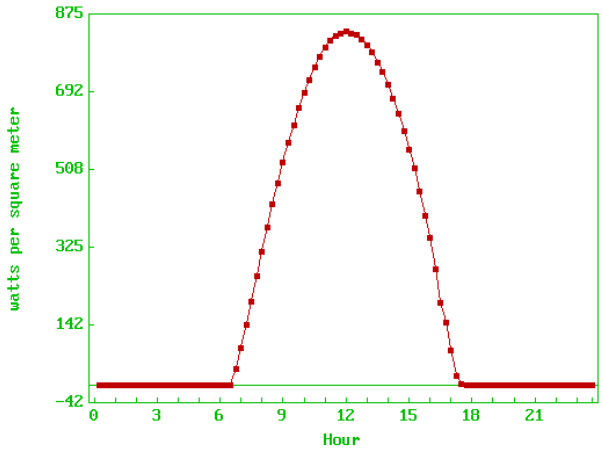
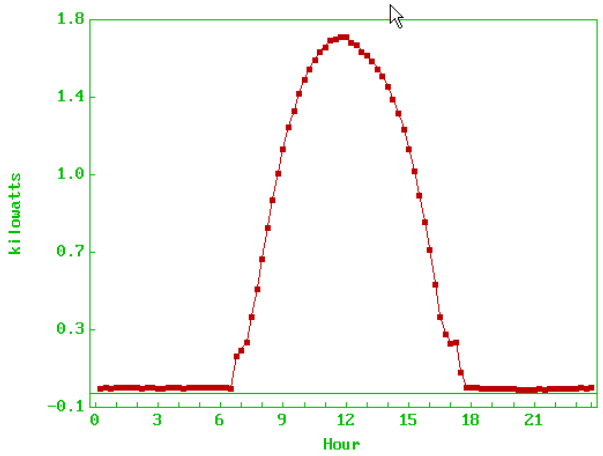
Day 1:

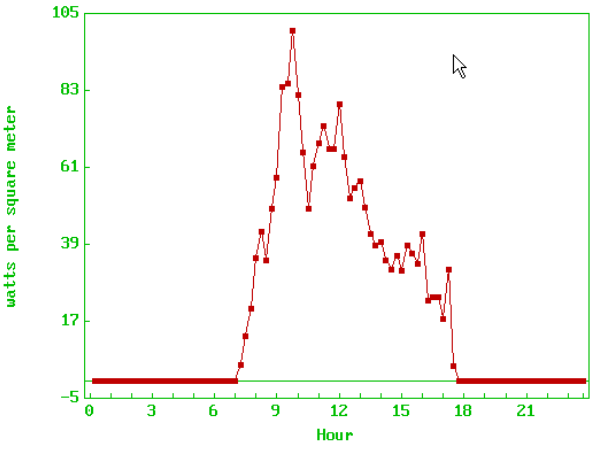


Sunlight

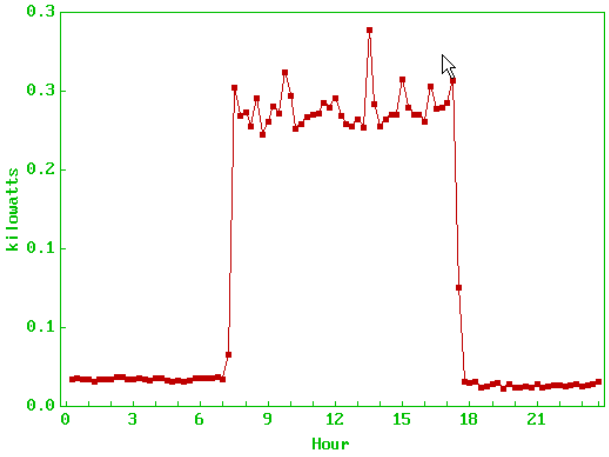


Solar Power

Day 2:

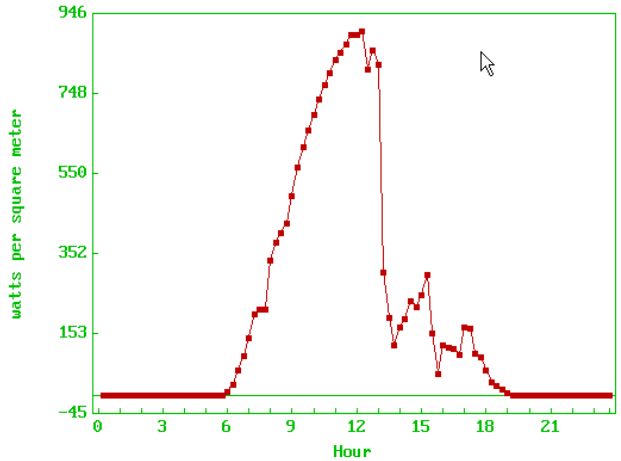


Sunlight

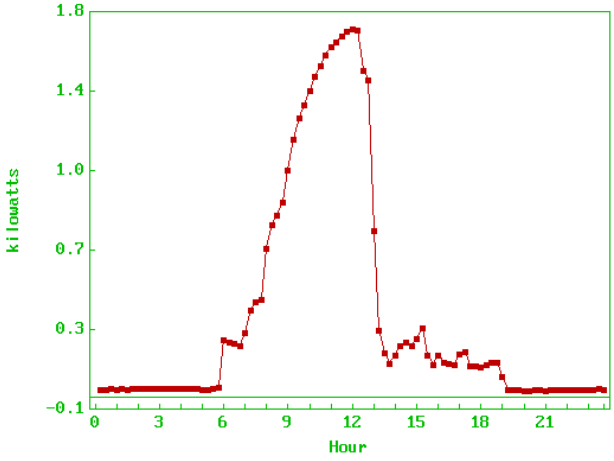


Solar Power

Day 3:



Sunlight



Solar Power

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Questions:

What are the units for “sunlight”?

What are the units for “solar power”?

Why are these units different?

Which day is the sunniest day?

Which day is the cloudiest day?

What happened on Day 3?

Why does Day 2 look so different from the others?
Hint: In low-level sunlight, the solar power inverter is not able to fully power up.

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Part II. Choose from one of the links of live solar data online at http://www.sunviewer.net.

View the live data and create a plot for daily power. Examine the plot and answer the following questions.

Location:

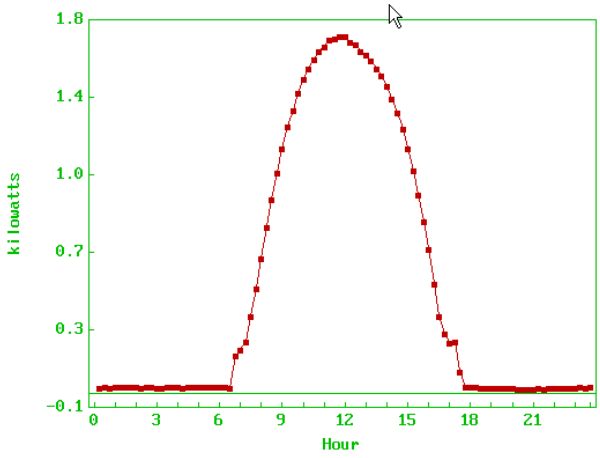
Date:

What was the weather like on this day, based on power output?

Create a daily plot of sunlight, Irradiance. Does this confirm your ideas?

Go on the Internet and confirm the weather conditions for the location and date that you selected. You can use http://www.intellicast.com. Type in the city or zip code of the location you selected. From the current forecast page, you can select "Historic" and "Archived Observations". Type in the date and compare the weather observations with your predictions.

Part III. How many light bulbs would light up?
Go to http://www.sunviewer.net and choose a solar installation site, or you can use the following plot from Feb. 26, 2004 at the Boston Nature Center.



Solar Power

What is the maximum power produced on this day?

At what time of day were the solar panels producing at maximum power?
Hint: Solar panels produce the most power when facing the sun. In the Northern Hemisphere, they are installed facing the southern sky to maximize the amount of sunlight reaching the plane of the solar panels. At 12 noon, the sun is at its highest and the solar panels are receiving the maximum direct sunlight. If the panels were facing West of due South, the power peak would be shifted to later in the day.

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Why was the max at this time?

How many incandescent light bulbs (60 Watt) could be powered at max power?

What about energy efficient compact fluorescent lights (CFLs – a 13 Watt CFL is equal to a 60 Watt incandescent light bulb)?

Part IV. Determine the total amount of energy produced on that day.

Energy = Power x Time
Hint: Units of power are watts or kilowatts and so units of energy are watt-hours or kilowatt-hours (kWh). You may be familiar with kWh from your household electric bill.

Using the graph of power, how can you estimate the amount of energy produced?
Hint: It is the area under the plot.

At SunViewer.net™ you can produce a table of the values used to produce the graph using "Output Format Table" at the bottom of the webpage. This produces a table displaying power values for every 15 minutes. Multiply each power value by time (.25 hrs) and total them to provide a good estimate of Total Energy. Below is the table of values for the solar power plot given above.

15-minute power values for 26-Feb-2004 for Boston Nature Center

Site Id	Time	Value
4	2004-02-26 06:45:00	0.176
4	2004-02-26 07:00:00	0.206
4	2004-02-26 07:15:00	0.246
4	2004-02-26 07:30:00	0.366
4	2004-02-26 07:45:00	0.495
4	2004-02-26 08:00:00	0.641
4	2004-02-26 08:15:00	0.792
4	2004-02-26 08:30:00	0.921
4	2004-02-26 08:45:00	1.049
4	2004-02-26 09:00:00	1.165
4	2004-02-26 09:15:00	1.267
4	2004-02-26 09:30:00	1.348
4	2004-02-26 09:45:00	1.430
4	2004-02-26 10:00:00	1.492
4	2004-02-26 10:15:00	1.543
4	2004-02-26 10:30:00	1.585
4	2004-02-26 10:45:00	1.624
4	2004-02-26 11:00:00	1.650
4	2004-02-26 11:15:00	1.683
4	2004-02-26 11:30:00	1.685
4	2004-02-26 11:45:00	1.695

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4	2004-02-26 12:00:00	1.696
4	2004-02-26 12:15:00	1.670
4	2004-02-26 12:30:00	1.659
4	2004-02-26 12:45:00	1.625
4	2004-02-26 13:00:00	1.611
4	2004-02-26 13:15:00	1.580
4	2004-02-26 13:30:00	1.545
4	2004-02-26 13:45:00	1.510
4	2004-02-26 14:00:00	1.459
4	2004-02-26 14:15:00	1.401
4	2004-02-26 14:30:00	1.333
4	2004-02-26 14:45:00	1.256
4	2004-02-26 15:00:00	1.164
4	2004-02-26 15:15:00	1.061
4	2004-02-26 15:30:00	0.944
4	2004-02-26 15:45:00	0.819
4	2004-02-26 16:00:00	0.683
4	2004-02-26 16:15:00	0.517
4	2004-02-26 16:30:00	0.367
4	2004-02-26 16:45:00	0.285
4	2004-02-26 17:00:00	0.240
4	2004-02-26 17:15:00	0.247
4	2004-02-26 17:30:00	0.104

If your students are familiar with Microsoft Excel, you can also download a raw data file (CSV) from SunViewer.net and import this data into Excel. Once in Excel, the students can quickly calculate the energy value.

Extensions:

How does the energy produced by the solar photovoltaic system compare with the energy used in your home? Have students bring in an electric bill from home or you can provide one, and determine the average daily energy consumption.

How does this energy value compare to the energy in one gallon of gasoline or a bucket of coal? Have students use the Internet to research the energy value of a standard fuel and compare to the power produced by the Boston Nature Center installation during one sunny day.

Lesson developed by Laurie McDonough Assistant Professor of Science at Dean College and Matthew Arner of Heliotronics, Inc. Heliotronics gratefully acknowledges the support of the Leadership Initiatives for Teaching and Technology (LIFT2) program and its parent organization The Technology Initiative, Metro South/West Regional Employment Board.

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Interpreting Solar Power Graphs
Student Worksheet

Name: _____ Date: _____

Have you read or heard about Solar Power in the news? The technology to convert energy from the sun to electricity for human use is not new. Many people have used solar power for years to generate hot water and electricity for their homes. Now, with prices of fuel going higher everyday, there is more interest in using solar energy. This exercise will allow you to examine an actual solar power system and compare sunlight to the energy and power it can produce.

Objective: The following activity is designed to allow you to: 1) to understand and compare plots of the amount of sunlight falling on a photovoltaic array (solar panels) and the power generated by the array, 2) to compare the plots for different days and hypothesize the reasons for visible differences, and 3) to find and explore local weather data which may help support or refute the hypotheses.

The data presented below is taken from a 2 kilowatt solar photovoltaic array installed at the Boston Nature Center in Boston, MA. To read more about the project, go to http://www.heliotronics.com/cases/cases_main.html

Part I. Comparing sunlight and power produced by solar panels.
Compare the following 24 hour plots of sunlight and solar power output. The plots on the left show how much sunlight is falling on the solar panels. The plots on the right show how much power the solar panels are producing.

For each, think about what factors might be affecting solar power production.

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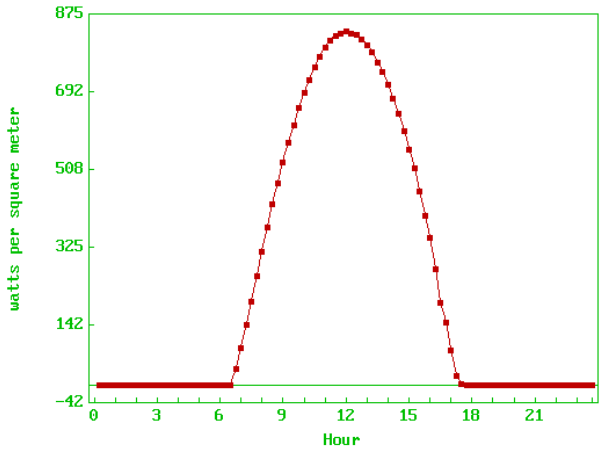
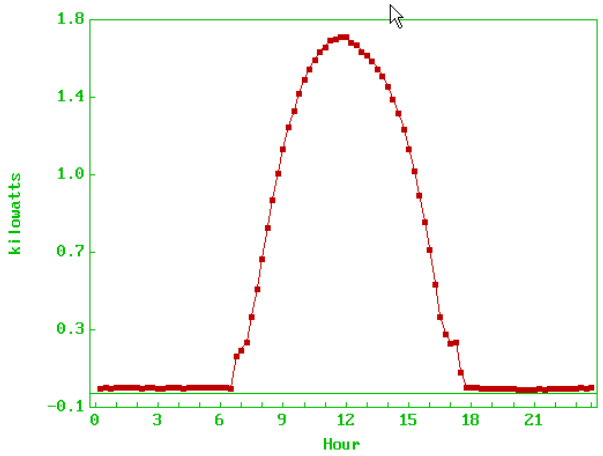
Day 1:

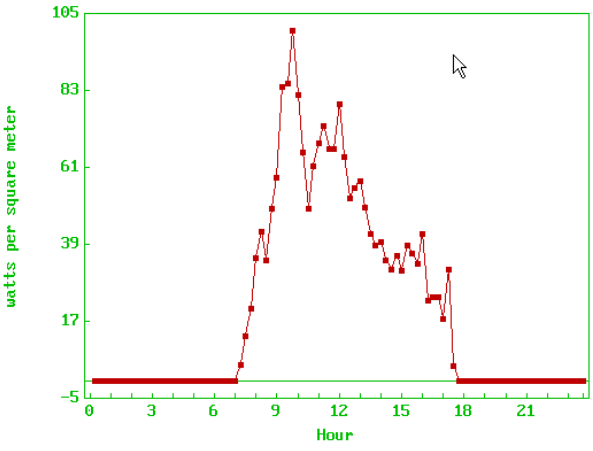


Sunlight

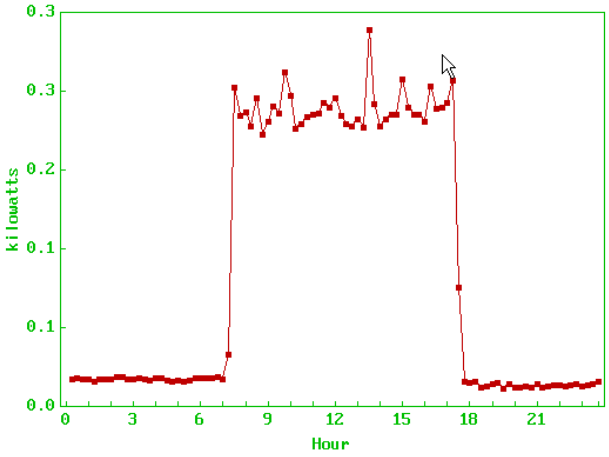


Solar Power

Day 2:

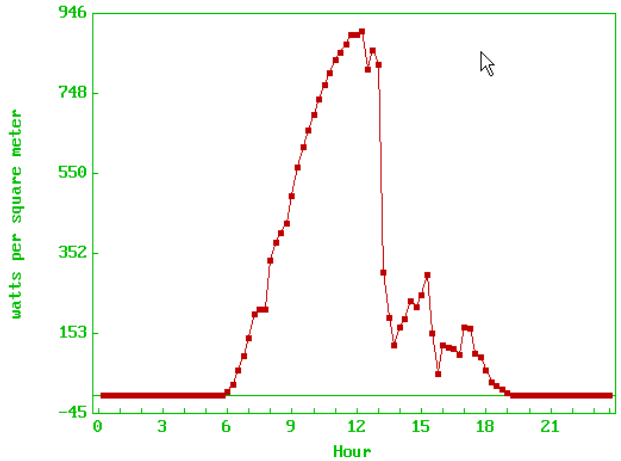


Sunlight

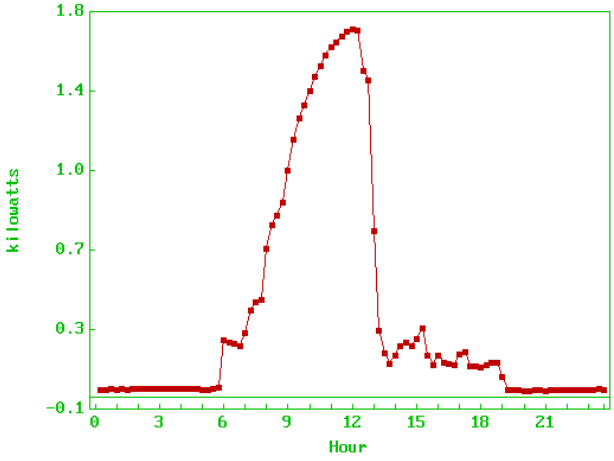


Solar Power

Day 3:



Sunlight



Solar Power

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Questions:

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What are the units for “solar power”?

Why are these units different?

Which day is the sunniest day?

Which day is the cloudiest day?

What happened on Day 3?

Why does Day 2 look so different from the others?

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Part II. Compare solar power production to weather conditions.
Choose from one of the links of live solar data online at http://www.sunviewer.net.

View the live data and create a plot for daily power. Examine the plot and answer the following questions.

Location:

Date:

What was the weather like on this day, based on power output?

Create a daily plot of sunlight, Irradiance. Does this confirm your ideas?

Go on the Internet and confirm the weather conditions for the location and date that you selected. You can use http://www.intellicast.com. Type in the city or zip code of the location you selected. From the current forecast page, you can select "Historic" and "Archived Observations". Type in the date and compare the weather observations with your predictions.

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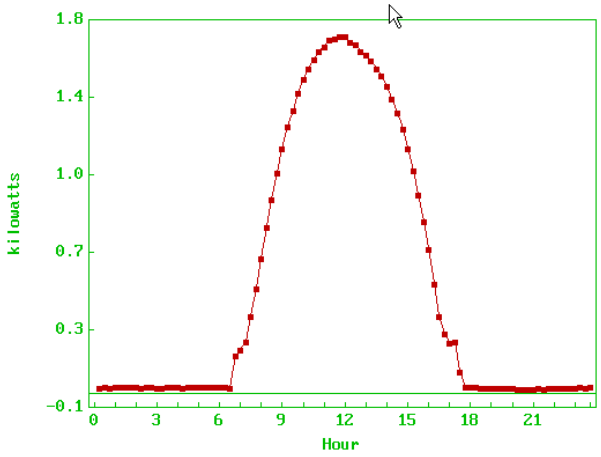

Solar Power

What is the maximum power produced on this day?

At what time of day were the solar panels producing at maximum power?

Why was the maximum at this time?

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How many incandescent light bulbs (60 Watt) could be powered at maximum power?

What about energy efficient compact fluorescent lights (CFLs – a 13 Watt CFL is equal to a 60 Watt incandescent light bulb)?

Part IV. Determine the total amount of energy produced on that day.

Energy = Power x Time
Hint: Units of power are watts or kilowatts and so units of energy are watt-hours or kilowatt-hours (kWh). You may be familiar with kWh from your household electric bill.

Using the graph of power, how can you estimate the amount of energy produced?
At SunViewer.net™ you can produce a table of the values used to produce the graph using "Output Format - Table" at the bottom of the webpage. This produces a table displaying power values for every 15 minutes.

Make sure the date is set at Feb. 26, 2004 and that you have chosen "Daily Data – Power" and "Output Format – Table." Print out the table produced or fill in the data below.

Multiply each power value by time (15 minutes = .25 hrs) and total them to provide a good estimate of Total Energy. You can filter the data (and reduce your work) by discarding power values below 0.2 kW.

Time	Power Value	x 0.25 =
_____	_____	_____
_____	_____	_____
_____	_____	_____
_____	_____	_____
_____	_____	_____
_____	_____	_____
_____	_____	_____
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_____	_____	_____
_____	_____	_____
_____	_____	_____

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GRAND TOTAL POWER = ______________

Lesson developed by Laurie McDonough Assistant Professor of Science at Dean College and Matthew Arner of Heliotronics, Inc. Heliotronics gratefully acknowledges the support of the Leadership Initiatives for Teaching and Technology (LIFT2) program and its parent organization The Technology Initiative, Metro South/West Regional Employment Board.

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