SETI INSTITUTE

Appendixes

Required Materials List

Every effort has been made to keep the materials as inexpensive and as easily obtainable as possible. The major single expense in this guide is for mission 8, "Building a Radio Receiver." Each radio receiver will cost less than $10 to build. The overall cost of this mission can be reduced by having students work in large groups. The germanium diodes, and crystal radio earpieces can be ordered from Scott's Electronic parts, http://www.angelfire.com/electronic2/index1/. Micro-tools, http://www.micro-tools.com/store/ or 707.446.1120 sells the germanium diode. Wire is available from several online retailers. Radio "kits" are not recommended because they are too-much preassembled–students lose some of the thrill of building a radio when assembling a kit. MidnightScience.com does offer basic crystal radio kits, one even requires paper and an oatmeal box.

Materials that may need to be ordered or located weeks in advance of use are printed in **boldface** on the supply lists. Some items may be borrowed from local high schools or colleges with advance notice. The quantities listed are for one class of 30 students for all missions.

Many optional, enrichment items, such as additional slides and posters, can be obtained free or at very low cost from the NASA Educator Resource Center in your area. To locate your center go to http://www.nasa.gov/offices/education/programs/national/ercn/home/index.html. Posters depicting the Milky Way Galaxy and the electromagnetic spectrum will be quite helpful to have on hand during the missions in this unit.

In particular, for mission 2, "A Message from Earth," try to locate a copy of the book *Murmurs of Earth* (ISBN 0-345-28396-1) and/or its CD-ROM version if possible. The original version of the book is out of print, but many local libraries have a copy or can obtain one for you. Warner New Media sold the CD- ROM version including the music in the early 90's. If you cannot locate either the book or the CD, do not panic! We have provided a set of 10 images that can be used to teach the basic mission. However, the CD and/or the book will enhance this mission.

Music On Voyager Record

- Bach, Brandenburg Concerto No. 2 in F. First Movement, Munich Bach Orchestra, Karl Richter, conductor. 4:40
- Java, court gamelan, "Kinds of Flowers," recorded by Robert Brown. 4:43
- Senegal, percussion, recorded by Charles Duvelle. 2:08
- Zaire, Pygmy girls' initiation song, recorded by Colin Turnbull. 0:56
- Australia, Aborigine songs, "Morning Star" and "Devil Bird," recorded by Sandra LeBrun Holmes. 1:26
- Mexico, "El Cascabel," performed by Lorenzo Barcelata and the Mariachi México. 3:14
- "Johnny B. Goode," written and performed by Chuck Berry. 2:38
- New Guinea, men's house song, recorded by Robert MacLennan. 1:20

- Japan, shakuhachi, "Tsuru No Sugomori" ("Crane's Nest,") performed by Goro Yamaguchi. 4:51
- Bach, "Gavotte en rondeaux" from the Partita No. 3 in E major for Violin, performed by Arthur Grumiaux. 2:55
- Mozart, The Magic Flute, Queen of the Night aria, no. 14. Edda Moser, soprano. Bavarian State Opera, Munich, Wolfgang Sawallisch, conductor. 2:55
- Georgian S.S.R., chorus, "Tchakrulo," collected by Radio Moscow. 2:18
- Peru, panpipes and drum, collected by Casa de la Cultura, Lima. 0:52
- "Melancholy Blues," performed by Louis Armstrong and his Hot Seven. 3:05
- Azerbaijan S.S.R., bagpipes, recorded by Radio Moscow. 2:30
- Stravinsky, Rite of Spring, Sacrificial Dance, Columbia Symphony Orchestra, Igor Stravinsky, conductor. 4:35
- Bach, The Well-Tempered Clavier, Book 2, Prelude and Fugue in C, No.1. Glenn Gould, piano. 4:48
- Beethoven, Fifth Symphony, First Movement, the Philharmonia Orchestra, Otto Klemperer, conductor. 7:20
- Bulgaria, "Izlel je Delyo Hagdutin," sung by Valya Balkanska. 4:59
- Navajo Indians, Night Chant, recorded by Willard Rhodes. 0:57
- Holborne, Paueans, Galliards, Almains and Other Short Aeirs, "The Fairie Round," performed by David Munrow and the Early Music Consort of London. 1:17
- Solomon Islands, panpipes, collected by the Solomon Islands Broadcasting Service. 1:12
- Peru, wedding song, recorded by John Cohen. 0:38
- China, ch'in, "Flowing Streams," performed by Kuan P'ing-hu. 7:37
- India, raga, "Jaat Kahan Ho," sung by Surshri Kesar Bai Kerkar. 3:30
- "Dark Was the Night," written and performed by Blind Willie Johnson. 3:15
- Beethoven, String Quartet No. 13 in B flat, Opus 130, Cavatina, performed by Budapest String Quartet. 6:37

Office, Art, and General Supplies

Table A.1.

Material	Substitutions or Alternatives. Optional Items Are Indicated.	Quantity per Pair, Team or Center	Quantity for Each Class of 32	Reusable in Each Class	Used in Activity
Butcher paper	Whiteboard, computer screens	1 piece, 2-ft long		No	1, 2, 3, 5, 6
Markers (assorted)			Varies	Yes	1
Black paper with stars pasted on it	Other background, or none		1	Yes	1
Magazines, asst'd	Computer clip art				2
Scissors		1 or 2		Yes	2, 3, 4, 5, 6, 8, 11
Glue or paste		1 or 2		Yes	2, 3, 4, 5
Tape (masking or transparent)			Several rolls	No	2, 3, 4, 6, 8, 11
Notebook paper		Varies			2, 12
Pens or pencils			32	Yes	2, 3, 5
Pieces of plain white 8-1/2" x 11" paper			32	No	3, 8
Measuring tape, 100-250 feet			1	Yes	3
Marked meter sticks			32	Yes	3, 5, 6, 7, 8
String	Fishing line	10 meters			3
Straws		2		No	3
Cardboard					3, 8
Pins or thumbtacks			32 (1 in Mission 6)	Yes	3, 6
Protractors (360^{o})	Optional in 3		32		3, 5
Calculators	Optional				3, 11
Construction paper	Optional				3
Graph paper	Make graph paper		32	No	5, 11
Thin sheets of plastic	Plastic lids, Frisbees	1		No	5
Cotton balls	Other cotton, or fluffy material	1		No	5
Drawing compasses			32	Yes	5
White paint			1		5
Brushes		1			5
Poster-size sheet of thin tagboard			1	No	6
Cardboard tubes	Toilet paper tubes	1		No	6
"Rainbow" sets of markers	Pens, crayons, or pencils	1		Yes	6
Roll of heavy duty aluminum foil			1	No	6, 8
Single-hole punch			1	Yes	6
Single-edge razor blades	X-Acto knives*		Several	Yes	6
Orange marble	Optional		1	Yes	7
Highlighter pens (wide tip)				Yes	8
Envelopes			16		9
Rulers		1		Yes	9
File folders			16	Yes	10
Box to store folders				Yes	10

*Review with students all necessary precautions when handling sharp knives

Laboratory Equipment

Table A.2.

Material	Substitutions or Alternatives, Optional Items Are Indicated	Quantity per Pair, Team or Center	Quantity for Each Class of 32	Reusable in Each Class	Used in Activity
Spectrum tube power supply	Borrow from high school or use video		1	Yes	6
Spectrum tubes of various gases	**(H, He, Ne, N, O, Na)**		1 each	Yes	6
Prisms of assorted sizes		1		Yes	6
Light boxes	Bright light source or sunlight	1		Yes	6
Standard screw-type electric socket	Lamp		1	Yes	6
25-watt bulb			1	Yes	6
Variety of light sources	Fluorescent, incandescent, colored bulbs, candles			Yes	6
Thermometers			2	Yes	6
Ultraviolet light source			1		6
Diffraction grating. Cut into tiny pieces			1		6
Fluorescent paints, fluorescent minerals	Optional		Varies	Yes	6
Commercial spectroscopes	Optional		Varies	Yes	6
Electric buzzer with 9-volt battery	Digikey.com 9 volt DC buzzer		1	Yes	7
Alligator clips on connecting wires			1	Yes	7
100-watt light bulb	Optional				7
Electric motor or other device	Optional				11

Audiovisual Equipment

Table A.3.

Material	**Substitutions or Alternatives, Optional Items Are Indicated**	**Quantity per Pair, Team or Center**	**Quantity for Each Class of 32**	**Reusable in Each Class**	**Used in Activity**
Data projector			1	Yes	2
CD-Rom about *Voyager* and/or the book *Murmurs of Earth*	Optional		1	Yes	2
Computer with CD-Rom drive			1	Yes	2, 3, 5, 6, 7, 9, 10
Smart phones as recorders					2
Overhead projector or data projector	Copied illustrations as handouts or PowerPoint slides				3, 4, 6, 9, 10
Transparency marking pens	If using overhead proj				5, 6, 9, 10
Poster of the Milky Way Galaxy	Optional		1	Yes	5
Radio(s)	Optional in Mission 6		1 in Mis. 6, 2 in Mis. 9	Yes	6, 9
Poster with the emission lines of the electromagnetic spectrum	Optional		1	Yes	6
Pictures taken by infrared-sensitive cameras (webcams)			Varies	Yes	6

Electronic Equipment for Building a Radio in Mission 8

Table A.4.

Material	**Substitutions or Alternatives, Optional Items Are Indicated**	**Quantity per Pair, Team or Center**	**Quantity for Each Class of 32**	**Reusable in Each Class**	**Used in Activity**
Wire strippers			2 or 3	Yes	8
Long wire for antenna			1	Yes	8
Cardboard for radio base (25 cm by 12 cm)		1		No	8
3-inch-diameter cardboard cylinders (15 cm length, 7.5 cm length)		1 each size		No	8
24-guage solid copper wire (coated)		16 meters		No	8
24-gauge stranded wire		3.5 meters		No	8
Germanium diode (type 1N34A)	Scott's Electronic Parts or Micro-tools			No	8
Crystal radio earphones	Scott's Electronic Parts	1		No	8
Piece of extra-fine sandpaper (cut into small squares)				Yes	8
Single-edge razor blade	X-Acto knives*				
Grocery bag	Any bag or box	1			

*Review with students all necessary precautions when handling sharp knives

Ordering Information

Materials that may need to be ordered or located weeks in advance of use are printed in **boldface**. Some items may be borrowed from local high schools or colleges with advance notice. The quantities listed are for one class of 30 students for all missions.

For spectrometers and holographic diffraction grating:

Science First www.Sciencefirst.com
STARLAB Planetarium Systems
86475 Gene Lasserre Blvd.
Yulee, FL 32907
Phone: (800) 875-3214

Spectrum tubes and power supply, diffraction grating, spectrometers, light boxes, UV lamps, radio kits, posters, etc.

Science Kit & Boreal Laboratories
PO Box 5003
Tonawanda, NY 14151-5003
Phone: (800) 828-777

www.sciencekit.com

Edmund Scientific's
60 Pierce Avenue
tonawanda, NY 14150
Phone: (800) 728-6999
www.scientificsonline.com
Educational Discount

Other providers of science kits and supplies.

NASCO
PO Box 901
Fort Atkinson, WI 53538-0901
Phone: (800) 558-9595

www.enasco.com

Overhead Transparency or PowerPoint Slide List

Table A.5.

Transparency Name	Used in Mission
Triangulation	Mission 3
Parallax as Viewed from Earth	Mission 3
Celestial Mapping	Mission 5
Spectrum Observation	Mission 6
Center of Mass	Mission 7
Doppler Effect	Mission 7
Spectrum Analysis Array #1 and 32	Mission 9
Signal and Background Noise #1 and 32	Mission 9
Radio Signal Search Data	Mission 10

PowerPoint Image List

Table A.6.

The Message Sent By Voyager" (Part 1)		Mission 2
2.1	Voyager Spacecraft	
2.2	Voyager Record Cover	
2.33	School of Fish with Human Diver	
The Message Sent by Voyager" (Part 2)		Mission 2
2.4	Solar Spectrum	
2.5	The Planet Earth	
2.6	Closer to the Surface of Earth	
2.7	Human Anatomy	
2.8	Nursing Mother	
2.9	A Family with Two Generations Present	
2.10	Group of Children	
2.11	Southwestern United States	
2.12	Forest Scene	
2.13	Fallen Leaves	
2.14	A Tree in Winter	
2.15	Flowering Plants	
2.16	Human Diver and School of Fish	
2.17	Human and Chimpanzee	
2.18	House Interior	
2.19	A City at Night	
2.20	A Factory Interior	
.2121	Astronaut in Space	
2.22	Sunset	
"Wonders of the Milky Way Galaxy"		Mission 5
5.23	The Beehive (Praesepe) Open Cluster	(M44)
5.24	The Pleiades Open Cluster	(M45)
5.25	Globular Cluster in Hercules	(M13)
5.26	The Trifid Nebula	(M20)
5.27	The Great Nebula in Orion	(M42, M43)
5.28	The Horsehead Nebula	(B33)
5.29	The Ring Nebula	(M57)
5.30	The Crab Nebula –Supernova Remnant	(M1)
5.31	The Veil Nebula –Supernova Remnant	(NGC 6960, 6992)
"Galaxies: Billions Upon Billions of Stars"		Mission 5
5.32	Spiral Galaxy in Virgo	
5.33	Andromeda Galaxy	(M31)
5.34	The Virgo Cluster of Galaxies	(M84, M86)
5.35	Edge-on Spiral Galaxy in Leo	(NGC 3628)
5.36	Large Magellanic Cloud, an Irregular Local Galaxy	
5.37	The Milky Way: Horizon Shot with Trees	
5.38	The Milky Way Within Sagittarius in Visible Light	
5.39	Galactic Center of the Milky way in Infrared Light	
5.40	Artist's Conception of the Milky Way Galaxy	
"Star Light, Star Bright"		Mission 6
6.41	White Light, Rainbow Spectrum	
6.42	Continuous Spectrum	
6.43	Wavelength and Frequency: Violet Waves and Red Waves	
6.44	The Spectrum of Sodium	
6.45	The Spectra of Stars	
6.46	Neon and Sodium	Mission 12
6.47	Helium and Hydrogen	
6.48	Nitrogen and Oxygen	
6.49	Unknown Stars	

Teacher Background Information

Black Holes

Black holes are among nature's most bizarre objects, and they appeal to the inquisitive minds of students. Black holes exist where a dense concentration of matter has produced an enormous gravitational field. The gravity of a black hole is so strong that nothing can escape it, not even light.

Consequently, a black hole cannot be seen directly. Nonetheless, most astronomers believe that black holes are scattered throughout the universe. Astronomers have predicted that large stars, those more than several times the mass of our Sun, will inevitably end their lives as black holes. Gargantuan black holes, containing the mass of millions or even billions of stars, are believed to be lurking in the centers of galaxies. Physicist Stephen Hawking has proposed an intriguing hypothesis–that “mini” black holes, created during the Big Bang and containing as much mass as small mountains, might be roaming the universe.

There are certain prerequisites to the formation of a black hole. A lot of matter must be squeezed into a small volume. Nature does this whenever a star dies–as a dying star runs out of its nuclear fuel, it ultimately cools and collapses under its own weight. Many billions of years from now, when our Sun enters its old age, gravity will shrink it down to a white-hot ball less than one percent of its present radius–an ironic fate, but not a black hole. However, for dying stars whose remnant mass amounts to more than three times that of our Sun, *nothing* can stop the inward collapse. Such stellar behemoths are destined to become smaller than a basketball, smaller than a pinhead, smaller than an atom–indeed, *infinitely* small.

Although the mass that constitutes a black hole shrinks indefinitely, the black hole itself does not. Researchers describe a black hole as a “ball” whose size is given by its Schwarzschild Radius, named after the German astronomer Karl Schwarzschild. This ball marks an invisible, one-way barrier surrounding the collapsing mass, which becomes smaller than an atom. Anything that crosses the barrier defined by the Schwarzschild Radius is doomed to fall into the center of the black hole. And, according to Einstein's laws of relativity, nothing within the Schwarzschild Radius can ever get out, not even light. If one could aim a searchlight beam at a black hole, nothing would be seen–there could be no reflected light because the incoming light would be forever trapped by the black hole's fierce gravity. A black hole is, indeed, black.

The Big Bang

Most astronomers believe that the universe began between 10 and 20 billion years ago in a massive explosion known as the Big Bang. Why do they think this? The most straightforward evidence is the fact that the universe is expanding.

About half a century ago, astronomer Edwin Hubble measured the distances and motions of several dozen nearby galaxies. He was surprised to find that nearly all galaxies are moving away from our Milky Way Galaxy, and also that the farther away from us the galaxy, the faster its motion away from us. This is very reminiscent of the explosion of a hand grenade–a moment later the fastest-moving pieces of shrapnel are the ones farthest from the point of detonation. In principle, by measuring the speed and position of the shrapnel, one could reverse the “movie” of the explosion, and determine exactly when the hand grenade was detonated.

Astronomers can do the same thing with the “movie” of the expanding universe, and this is how they have determined that the explosion must have occurred between 10 and 20 billion years ago. But there are some differences between the Big Bang and the detonation of a hand grenade. When presented with the fact that all galaxies appear to be receding from Earth, many students will naturally assume that we must be near the center of the explosion. This is not true; in fact, there is no center. A possibly helpful analogy for students is to have them imagine a large balloon being slowly inflated, with spots painted on it to represent galaxies. From the point of view of any particular spot, all the other spots seem to be moving away (indeed, the farther ones are moving away fastest!), but no spot is the center of the expansion.

Frequently asked questions about the Big Bang include: “What was here before it went off?” *(The concept of a “universe” defines things like* space, distance, *and* time. *These things didn't exist before the Big Bang,* so *this question, in fact, makes no sense! There was no “before” prior to the Big Bang because there was no time.)* and “What's outside the universe? Is there a wall somewhere?” *(Again, contrary to intuition, though the universe may be finite–that is, the total number of galaxies and stars can be counted up–there are no boundaries. Imagine an ant on an expanding balloon. The ant could go from one “galaxy” to another (and even count them up), but he would never find an “end” to the balloon. Indeed, by walking in what he thinks is a straight line, he would come back to where he started. This might be the case with our universe as well–a straight line, defined by a flashlight beam, for instance, might in principle go all the way around the universe and return to shine on the back of your head!)*

Mission 6: The Chemical Elements in Stars

Prisms

There is no requirement for this mission that you use prisms of different shapes, sizes, or materials. However, if they are different, this can help students to conclude that color is a property of light, not of a specific type of prism. But whatever the shape, size, or material, your prisms should all be clear. The use of colored prisms should be avoided as they would yield different spectra of light, which could lead to erroneous conclusions about the properties of light.

Use of Thermometers

When demonstrating with infrared light, be aware that there are a number of potential problems. Any increase in temperature will depend upon two things: 1) the amount of energy present at the wavelength (color) of interest, and 2) the ability of the thermometer to absorb that wavelength of radiation. For the demonstration in this mission, it is necessary to use a continuum source of light, such as an incandescent lamp or direct sunlight, not just any light that looks white. The use of a bright fluorescent light will lead to big problems. At the same spectral position, different thermometers may give different readings. Taping a small piece of black paper around the bulb of the thermometer will remove this complication–black paper will absorb light efficiently. The temperature reading of the thermometer will also depend upon the total energy available for absorption (*i.e.*, the temperature will depend upon the flux of photons times the energy per photon). Because most continuum lamps do not put out equal numbers of photons at different wavelengths, the total energy available in each color will change. Thus, for a lamp that puts out considerably more photons in the red wavelengths than in the blue, students would most likely record a higher temperature reading in the red wavelengths than in the blue, even though blue photons carry significantly more energy per photon. Thus, you should not focus on the *absolute* temperature measured at any wavelength–students might form an entirely incorrect impression of the relative power of the photons of different colors. Simply use the thermometer to measure the presence of photons. Students may wonder why the thermometer shows no change in the ultraviolet end of the spectrum. This is because glass prisms completely absorb any UV that enters them. For most lamps, students will incorrectly infer that blue photons are relatively "wimpy."

Emission Lines and Absorption Lines

Throughout the discussion of this mission it is assumed that the spectral lines of atoms are detected as *emission* lines. This is a useful simplification for beginning students. However, spectral lines are also often detected as *absorption* lines against a continuum background. Whether the lines are present in emission or absorption depends upon the thermal structure of the star. In fact, under many conditions, the emission and self-absorption lines can cancel each other, in which case no lines would be present, even though the element in question is present. Though a detailed discussion of these effects would probably only lead to unnecessary confusion for students, it might be important to introduce students to the concept of absorption lines–how they can be used to deduce the elemental composition of things. The following are suggested ways of introducing the concept:

1. Discuss absorption when students read the temperatures measured by the thermometer placed at different parts of the spectrum. Explain to students how thermometers are heated by the absorption of the photons; a proper explanation can help alleviate any confusion associated with the differences in absolute temperatures read at different spectral positions. For example, explain why apples and oranges have different colors even through they are illuminated by the same light.

2. Have students measure the different temperatures that are recorded at the same spectral positions when different colors of paper are wrapped around the bulb of a thermometer. Let students "discover" this effect on their own.

3. Have students use their spectroscopes to carefully look at the spectrum of sunlight reflected off a piece of white paper–they should see a continuum spectrum on which both emission and absorption lines are superimposed. The absorption lines are called Fraunhofer lines, which are just as characteristic of individual atomic species as are emission lines. For further information, consult a beginning level astronomy textbook.

Enrichment Lesson
3·D Models of Constellations: The Big Dipper and Orion, the Hunter

Overview

Students build three-dimensional models of two constellations, the Big Dipper and Orion, the Hunter, to hang in the classroom or at home. These models show students that the familiar constellations are made up of stars that are of varying distances from Earth and that they have their familiar appearance for us only from our vantage point, not from anywhere else in the Milky Way Galaxy. Constellations are not flat, as they appear in the sky and in illustrations in books. They would be unrecognizable if viewed from locations in space other than from Earth.

How to Build a 3·D Constellation Model

Name: ________________________________ Date: ______________________

You can build three-dimensional models of two constellations, the Big Dipper and Orion, the Hunter, to hang in your classroom or at home. These models will show you that constellations are made up of stars that are of varying distances from Earth and that they have their familiar appearance for us only from our vantage point, not from anywhere else in the Milky Way Galaxy. Constellations are not flat, as they appear in the sky and in illustrations in books. They would be unrecognizable if viewed from locations in space other than from Earth.

Obtain from your teacher the following items:

- 2 pieces of card-stock paper or cardboard, about 8 by 11 inches
- 15 beads, buttons or small balls of clay ("stars")
- Black thread
- Scissors
- Meter stick
- Templates (guides) for each constellation

1. Use pages 259-261 as templates.

2. Paste each template sheet onto a piece of card-stock paper or cardboard.

3. At each dot, punch a hole with the point of your scissors that is large enough to pass the thread through.

4. Pass a thread through the hole and knot or tape it on the side of the template.

5. Attach a bead, button, or small ball of clay (a "star") to the end of the thread on the other side of the cardboard. The proper length of the thread is indicated next to each dot. Note that black thread and light objects ("stars") work best.

When you are finished, attach the top face of the sheet to the ceiling or a door frame with the threads hanging down. Discover where to look from to recognize the constellation. You may have to stand on a chair before you recognize it! Can you tell which model is which?

Your assembled constellation model should look something like the picture below.

Figure A.1.

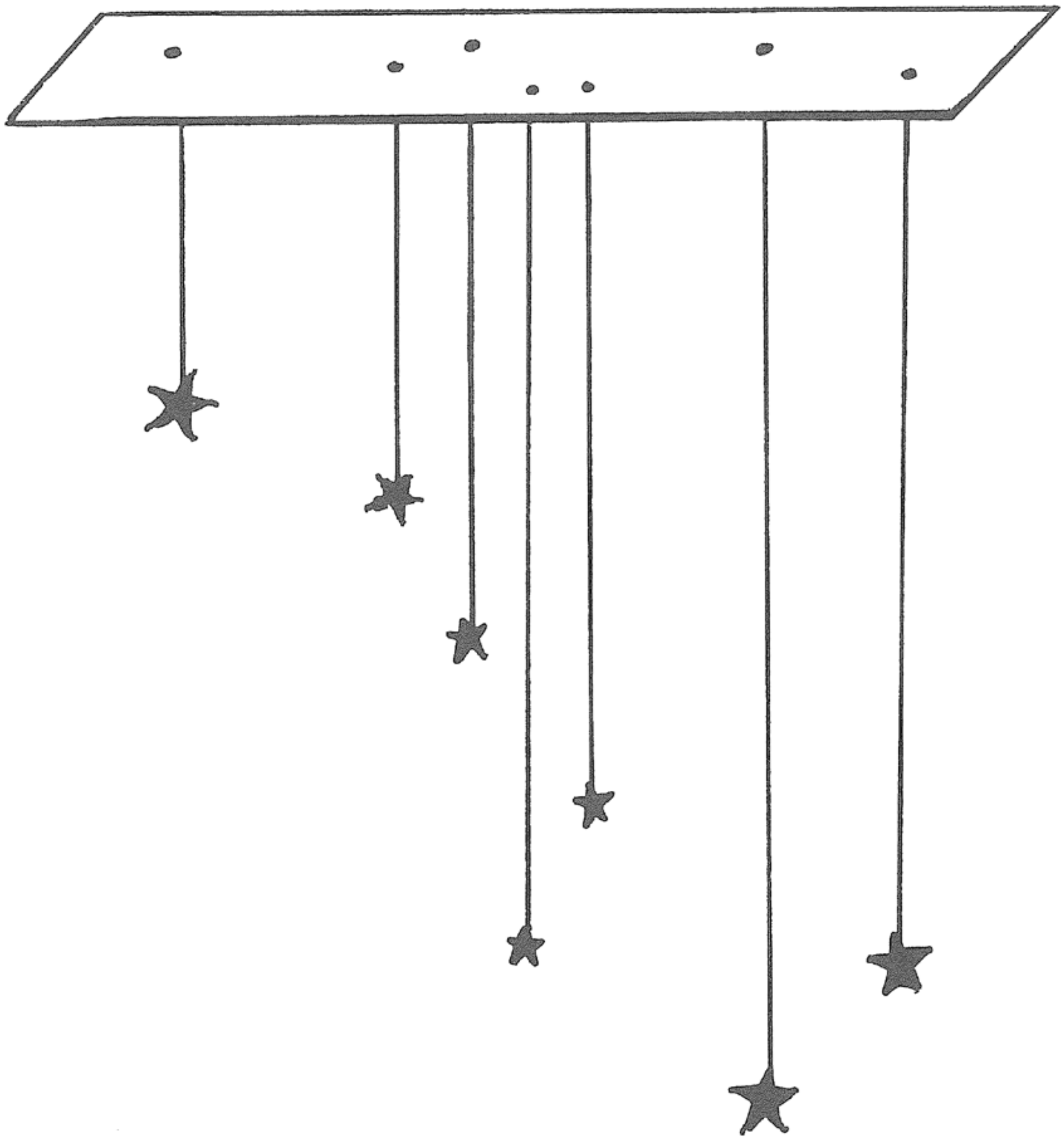
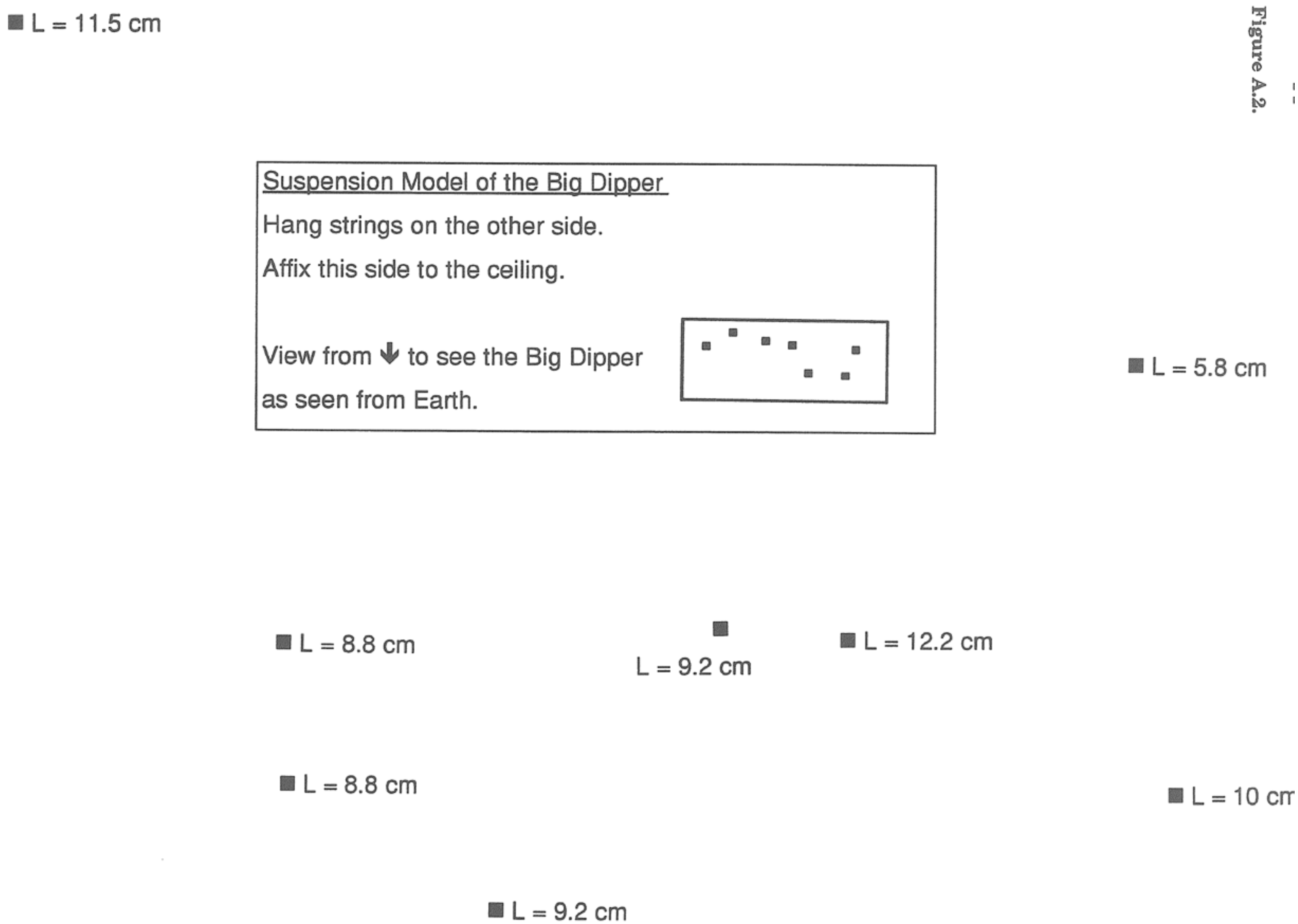
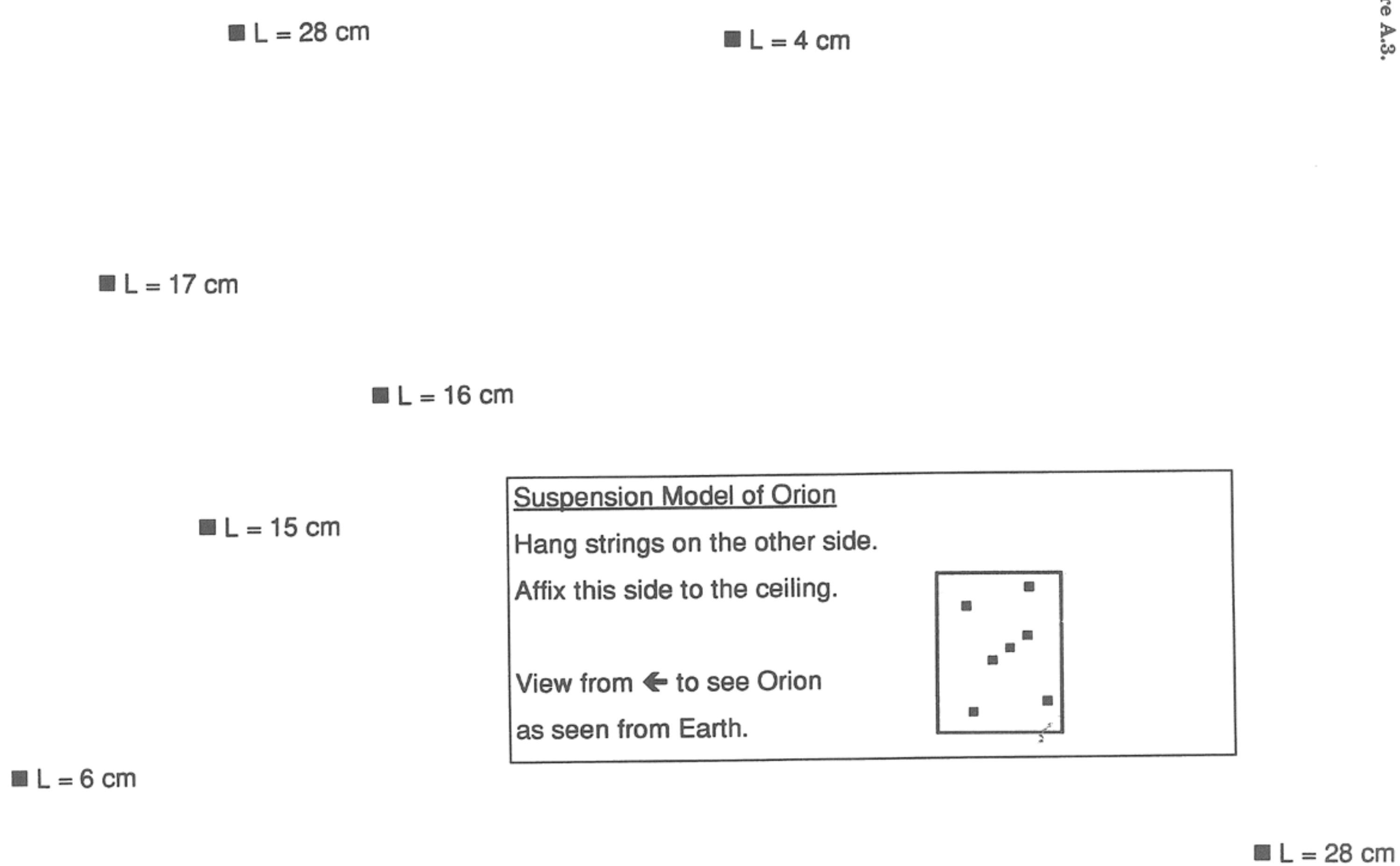


Figure A.2.



L = 11.5 cm
Suspension Model of the Big Dipper
Hang strings on the other side.
Affix this side to the ceiling.
View from ➔ to see the Big Dipper
as seen from Earth.
L = 5.8 cm
L = 8.8 cm
L = 9.2 cm
L = 12.2 cm
L = 8.8 cm
L = 10 cm
L = 9.2 cm

Figure A.3.



L = 28 cm
L = 4 cm
L = 17 cm
L = 16 cm
L = 15 cm
Suspension Model of Orion
Hang strings on the other side.
Affix this side to the ceiling.
View from ← to see Orion
as seen from Earth.
L = 6 cm
L = 28 cm