Scale Model Solar System: In this exercise (based on the Colorado Model Solar System on the Campus of the University of Colorado at Boulder), students create their own scale model solar systems from common materials for the purpose of exploring concepts of size and distance in the solar system. The same scale factor is used for both size and distance. On a scale of 1 to 10 billion, the sun is the size of a large grapefruit, the Earth is the size of a candy sprinkle, and Jupiter is the size of a marble. A space of only 80 m, which can easily be accommodated on most school grounds, allows students to make a distance model from the sun to Jupiter and to see the difference in spacing between the inner and outer planets. An updated version of this activity was created following the reclassification of Pluto as a dwarf planet in 2006.

Key concepts include:
- All planets are much smaller than the sun.
- The Earth is a relatively small planet.
- The solar system is mainly empty space.
- The scale of the solar system is immense.
- The small inner planets are much closer to the sun than are the outer planets.

Sizes of Stars: Students model the sizes of main sequence stars with every day objects using the same scale as the Scale Model Solar System activity, and compare the sizes of stars of different classes (on this scale ranging from the size of a cherry to a small car) to the Sun and Earth.

Key concepts include:
- Stars are not all the same. They come in different colors, sizes, and masses.
- The Sun is a medium-sized star.
- The Earth is much smaller than any main sequence star.

Distances of Stars: Using maps, students will plan a scale model to explore the distances between stars, focusing on Alpha Centauri, the system of stars nearest to the sun. This activity will build upon the activity Sizes of Stars, and once again uses a scale factor of 1 to 10 billion.

Key concepts include:
- Distances between stars are immense compared with the sizes of stars.
- The planets are much closer to the Sun than to the next closest star.

On a model with a scale of 1 to 10 billion, the distance between Alpha Centauri and the model sun is roughly equal to the width of the continental United States.

Map courtesy of www.theodora.com/map. Used with permission.

Star Birth: Students learn about the birth of stars in interstellar clouds of gas and dust. This activity differs from the previous lessons in the set in that will not involve scale models. Rather, students will use a hands-on exercise in probability to learn about the relative number of main sequence stars of different classes (masses) that are born in a typical stellar nursery. An Internet extension is also provided in which students

compare and contrast images of different stellar nurseries imaged by the Hubble Space Telescope.

Key concepts include:
- Stars are different ages.
- Stars are born in giant clouds of gas and dust.
- Many more low mass (cool) stars are born than high mass (hot) stars.

Lifetimes of Stars: In this activity, students return to the concept of a scale model to make a scale model of time rather than distance. The lifetimes of different masses of stars are compared to each other and to the geologic timeline for the Earth. Students then make predictions about what classes of main sequence stars might have planets with interesting life forms (as defined by the students), assuming the history of life on Earth is typical.

Key concepts include:
- How long a star shines is very dependent on its mass.
- Low mass stars have less hydrogen to convert to helium than do high mass stars, but live much longer.
- Our sun has lived about half of its life as a main sequence star.
- For most of the history of the Earth (and the sun), bacteria and other microorganisms were the only form of life on our planet.
- The lifetimes of stars are relevant to the search for life on extrasolar planets.

Death of Stars: Each of the previous activities on the topic of stars dealt with stars on the Main Sequence. In Death of Stars, students will once again use a scale factor of 1 to 10 billion. Working individually or in small groups, students will determine the scaled sizes of exotic objects such as red giants and super giants, white dwarfs, and black holes. They will then compare the sizes of dying stars and stellar remnants to the scaled sizes of the sun, Earth, distances in the Scale Model Solar System, and a Main Sequence M class (red) star from the previous activities.

Key concepts include:
- Dying stars can be much bigger than main sequence stars.
- The objects that are left behind when a star dies (a white dwarf, neutron star, or black hole) are the size of the Earth or smaller.
- Our sun will never go supernova.

Planet Hunting: This two-part activity in *Stars and Planets* brings together many of the concepts presented in the other lessons in an investigation of the challenges astronomers face in the ongoing search for extrasolar planets.   In part 1, students begin with a discussion of why Uranus, Neptune, and all of the dwarf planets in our own solar system weren't discovered until after the invention of telescopes. Turning to the search for extrasolar planets, students will draw upon knowledge from the previous lessons, and some new demonstrations, as they discuss the challenges presented by the size, distance, and the brightness of stars. Finally, students learn of the clever techniques astronomers use to find planets without "seeing" them. In part 2, students learn about the discoveries of Jupiter-like planets around other stars and make scale models of several of these planetary systems to compare to our own solar system. The students are also be introduced to current planet hunting efforts, and future projects

such as Kepler and Terrestrial Planet Finder that hold the promise of finding Earth-like planets around main sequence stars.

Key concepts include:
- Planets shine by reflecting light from their parent star.
- Stars are much brighter than planets.
- Planets can be detected without being "seen".
- Earth-like planets are much harder to find than Jupiter-like planets.
- No Earth-like planets orbiting other normal stars have been found so far.

"Trying to see the Earth from Alpha Centauri would be like trying to see a candy sprinkle on a donut in New York when you are standing in San Francisco!" - from Planet Hunting.

A Gaggle of Galaxies: A Gaggle of Galaxies was added to the Stars and Planets sequence to meet the requirements of middle school space science content standards in several states. In A Gaggle of Galaxies students learn about our own Milky Way, the local group of galaxies, and create their own classification scheme for galaxies in the Hubble Ultra Deep Field, an image of galaxies just 400 to 800 million years after the Big Bang. Students will then have an introduction to the concept of red shift and how it relates to the Big Bang Theory for the origin of the Universe .In their exploration of galaxies students will move from the 1 to 10 billion scale model used with stars to one showing the size of the Milky Way in comparison to the spacing between galaxies in the Local Group. Images of our galactic neighbors are provided for the teacher to enrich the introduction to galaxies beyond our own.

Key concepts include:
- Our galaxy, the Milky Way, is a barred spiral containing 200 to 500 billion stars.
- Our own galaxy is one of hundreds of billions of galaxies in the known universe.
- Galaxies are closer together in comparison with their size than are stars.
- Galaxies can take many different forms.
- Galaxies are classified by their morphology.
- The red shift of galaxies in the Hubble Ultra Deep Field is evidence for the Big Bang.

Links to National Standards: Each lesson in the *Stars and Planets* sequence meets several National content standards for science and mathematics. Because of the large number of standards we intend to meet, links to general categories for the 5-8th grade *National Science Education Standards* (NSES) and the 6-8th grade *Principles and Standards for School Mathematics* (PSSM) are given in Tables 1 and 2 respectively. Examples of NSES content standards that will be met by the lessons include:

- From D, Space Sciences: "The earth is the third planet from the sun in a system that includes the moon, the sun, eight other planets and their moons, and smaller objects, such as asteroids and comets. The sun, an average star, is the central and largest body in the solar system.

- From B, Physical Sciences: "The sun is a major source of energy for changes on the earth's surface. The sun loses energy by emitting light. A tiny fraction of that light reaches the earth, transferring energy from the sun to the earth."

- From A, Science as Inquiry: "Mathematics is important in all aspects of scientific inquiry."

Table 1: Matching of Individual Lesson Plans to NSES Content Standards for Grades 5-8

Lesson Plans	Unifying Concepts Processes	Science as Inquiry	Physical Science	Life Science	Earth & Space Science	History & Nature of Science
Scale Model Solar System, Part 1	X	X			X	
Part 2	X	X			X	
Sizes of Stars	X	X	X		X	
Distances of Stars	X	X				
Star Birth	X	X	X			X
Lifetimes of Stars	X	X		X	X	
Death of Stars	X	X	X			
Planet Hunting, Part 1	X	X	X			X
Planet Hunting, Part 2	X	X				X
Gaggle of Galaxies	X	X			X	X

Table 2: Matching of Individual Lesson Plans to PSSM Standards for Grades 6-8

Lesson Plans	Number & Operation	Measurement	Data Analysis & Probability	Problem Solving	Connections	Represent-ation
Scale Model Solar System, Part 1	X	X		X	X	X
Part 2	X	X		X	X	X
Sizes of Stars	X	X	X	X	X	X
Distances of Stars	X	X	X	X	X	X
Star Birth	X		X	X	X	X
Lifetimes of Stars	X	X	X	X	X	X
Death of Stars	X	X	X	X	X	X
Planet Hunting, Part 1	X	X		X	X	X
Part 2	X	X	X	X	X	X
Gaggle of Galaxies	X			X	X	X

In addition to matches to content standards, the *Stars and Planets* lesson plans incorporate many of the appropriate NSES assessment, teaching, and professional development standards as part of its written materials and associated educator workshops.

Special attention has been paid to the Project 2061 *Benchmarks for Science Literacy* during the development of *Stars and Planets*. The abilities and background knowledge of middle school students will be kept in mind at all times. When dealing with conceptually challenging topics such the fate of atoms in the formation of neutron stars, the recommendation of the *Benchmarks* regarding student comprehension will be carefully applied in the creation of both student and teacher background materials.

Relevance of State Standards: State standards differ from the National standards in several respects. In Texas, California, and many other states, middle school rather than high school is where students are expected to learn the majority of Earth and space science topics. Therefore, topics such as the nature of stars that are in the NSES content standards for grades 9-12 are relevant to the 6-8th grade content standards for these states. Specific examples include:

1. *Texas Essential Knowledge and Skills* for 6th and 8th grade science:

    * 6.13 A) identify characteristics of objects in our solar system including the Sun, planets, meteorites, comets, asteroids, and moons;

    * 8.13.A) Students can "describe characteristics of the universe such as stars and galaxies";

    * 8.13.B) Students can "explain the use of light years to describe distances in the universe".

2. *Content Standards for California Public Schools*, 8th grade science:

    * 4b) Students know "the sun is one of many stars in our own Milky Way galaxy. Stars may differ in size, temperature, and color;"

    * 4c.) Students know "how to use astronomical units and light years as measures of distance between the sun, stars, and Earth;"

    * 4d) Students know "stars are the source of light for all bright objects in outer space. The moon and planets shine by reflected sunlight, not by their own light."

The development plan for *Stars and Planets* has been specifically designed with the needs of these states, and other states with similar requirements, in mind. As a result, there is a much stronger match between the *Stars and Planets* lessons and many state Earth and space science content standards for middle school than there is with the National Science Education Earth and Space Science Content Standards for the same grade range.