NEWSLETTER of the WESTMINSTER ASTRONOMICAL SOCIETY
December 1984, Vol 1 No 7

December Meeting December's guest speaker is Harrisson Gilmer, retired. The lecture topic is "A Newtonian Satellite Distance Formula: The Titius-Bode Law of Planetary Distances Ammended". Mr. Gilmer has modified the Titius-Bode law using data obtained in the last several years. The original law, published in 1772, produces an uncanny yet simple model of our solar system. It predicted the planet Uranus nine years before its discovery. Titius-Bode also implied that the gap between Mars and Jupiter could not be empty. In 1801 Ceres, the largest asteroid, became the first body in the famous asteroid belt to be discovered, at the distance predicted by the law. Mr. Gilmer has extended the law to include the moons as well as planets. A good summary of the Titius-Bode law is found on pp. 280-1 of the May, 1972 issue of **Sky and Telescope** magazine.

Because of Christmas, the meeting is not being held on the last Wednesday. In addition the college will be closed for the holidays. The December meeting is scheduled for **7:30 p.m., Tuesday December 18,** in the **Carroll County Public Library Westminster Branch,** 50 E. Main St.

Guest Comet at December Star Party The star party for this month will be at Blaine Roelke's observatory, on Saturday December 15, starting around 7:00 p.m. Blaine's address is 6700 Keysville Road, Keymar. To get there take Rt. 140 West from Westminster to Taneytown. Downtown at the stoplight, turn left on Rt. 194 heading southwest. Drive about 1 1/2 miles then turn right on Keysville Road. Blaine is a short distance up the road. Blaine's phone number is 756-2886.

A newly found comet should be visible for those who do not arrive too late. Blaine reports observing a colorful Aurora Borealis from his home two weeks ago. Perhaps another will occur at the star party. If the weather looks questionable, call either Blaine or Curt Roelle (848-6384) before making the long drive.

Manned Space Station Series Continues The third installment of the WAS series on the U.S. space station focuses on the design requirements of the station.

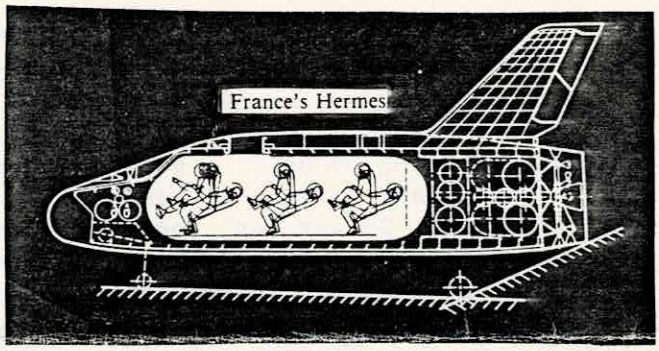
Free Newsletter A free bimonthly newsletter entitled **Tonight's Asteroids** is available free by writing to Dr. J. U. Gunter, 1411 N. Mangum, Durham, NC 27701. All Dr. Gunter requires is that you provide a self-addressed stamped (20 cents) envelope for each newsletter. Blaine Roelke suggests that sending a half-dozen or so envelopes at a time is more convenient than remembering to mail an envelope every other month. The letter contains feature articles and finder charts for selected asteroids. Occaisionally "Comet Specials" are sent when a new bright comet is discovered.

Space Station III: The Human Side Last month the unmanned platforms and orbital maneuvering vehicles were discussed. Although they are part of the space station program, they are external to the station itself. Human activities, except for an occaisional EVA (spacewalk), are confined to the interior of the station.

The space station is designed for growth. Changing requirements and new technological

developments will make hardware modifications inevitable. The major design will be complete by 1987 and must remain valid for 30 years. Recall that only 23 years ago the first American was placed in space.

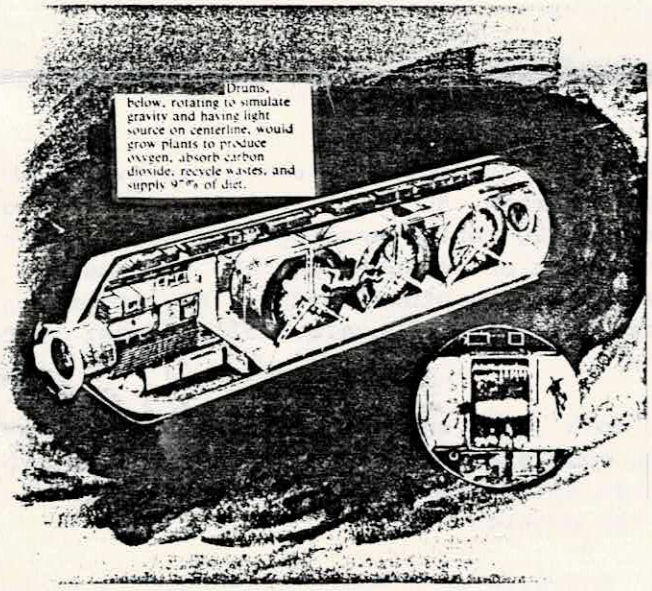
Standardization will allow the station to grow and evolve incrementally by the installation of additional modules. Structures are limited by the cargo capacity of the national Space Transportation System, or space shuttle. Other developments are now under way for new classes of shuttles, some of them unmanned. The European Space Agency (ESA) is also developing the Hermes, an Ariane-launched manned vehicle similar to but smaller than America's shuttle, as its contribution to the international space station development effort.



An astronaut crew of six to eight is expected although at first the number may be smaller. Onboard the station orbiting 250 miles above Earth will be laboratories for conducting experiments in weightlessness, or zero-g. Supplies, new parts, and proplellant will all be delivered by the space shuttle.

Communications will utilize the Tracking and Data Relay Satellite System (TDRSS), managed by SPACECOM of Gaithersburg, MD. This system of geosynchronous communication satellites allows an orbiting spacecraft to maintain contact with the ground longer per orbit than with traditional ground-based tracking systems.

One of the changes that will come with the station is the transition of operation and control from the ground to the station itself. The cost of running a continuous manned control center on the ground makes the space-based choice more attractive. The first major growth change would be onboard control of OTV (Orbital Transfer Vehicle) and OMV (Orbital Maneuvering Vehicle) operations. The future potential of planetary and lunar exploration missions is being studied in the long range space station program plan.



Eventually the station could become nearly self-supporting. On the one hand the biological systems of the space shuttle are "open". Supplies are provided from an initial store and are used up without recycling. Closing the biological system through recycling and recapture could potentially result in reduction of mass. Oxygen and drinking water for instance could be recycled in parallel from cabin air. Oxygen can be produced from the reclaimed water through electrolysis.

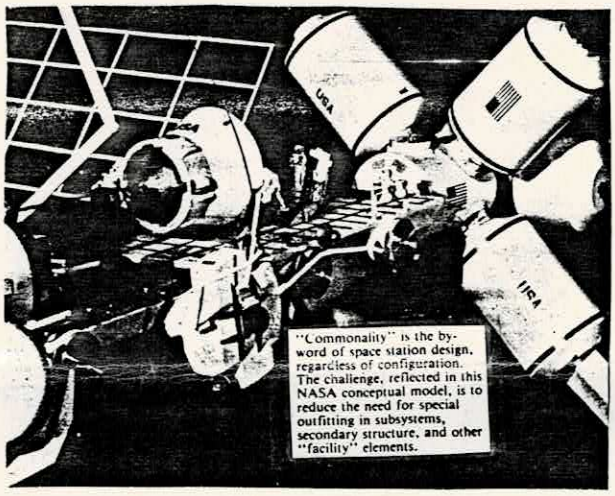
The technology does not exist to create a fully closed ecological system. The closed system will be approached through incremental adaptation of partial closures. Eventually plants may be grown aboard the space station in rotating illuminated drums that simulate gravity for the benefit of the plants, in the same way that science fiction has imagined building large rotating space stations to provide the familiar feel of gravity once thought necessary for man.

How much will the space station cost? NASA has proposed that it will cost $8 billion in 1984 dollars. The House Science and Technology Committee has approved $150 million for space station development in the 1985 budget.

Opponents disagree with the NASA estimate. **Photonics Spectra** reports Prof. Peter Banks of Stanford University as saying the actual price will more likely be $18 or $19 billion. Operational costs, launch facilities, scientific equipment, and general price escalation are not included according to Banks, chairman of NASA's advisory task force on scientific uses for the space station.

According to John D. Hodge, acting deputy director of NASA's Interim Space Station Program Office, once the station is built modifications would become expensive and costs would have to be supported partially by private funds stimulated by industrial and economic potential. Added capabilities could involve berthing of upper stage rockets and/or an OMV compartment, spacecraft assembly facilities, and perhaps even a large hanger with a shirt-sleeve environment for spacecraft servicing.

Next month some of the preliminary designs will be presented.



"Commonality" is the by-word of space station design, regardless of configuration. The challenge, reflected in this NASA conceptual model, is to reduce the need for special outfitting in subsystems, secondary structure, and other "facility" elements.

Updated Constitution Copies of the Club Constitution or bylaws will be available at the December meeting. Originally printed in July, several modifications were requested at earlier club meetings.

The Titius-Bode Law: A Strange Bicentenary

STANLEY L. JAKI, *Seton Hall University*

EARLY in 1772, there was published at Hamburg the second edition of a widely read astronomical book by Johann Elert Bode, who was not yet 25 years old. This book, *Anleitung zur Kenntniss des gestirnten Himmels* (Introduction to the Study of the Starry Sky) had first appeared in 1768. Before Bode died in 1826, it went through nine editions, and long afterward it was still being reissued.

But in 1772 one could hardly guess that young Bode was soon to regenerate astronomical studies in his native Germany as director of Berlin Observatory and as editor of the famous *Astronomisches Jahrbuch* (Astronomical Yearbook). His *Anleitung* was not meant to be a scholarly work, but rather a pleasant and informative popularization.

Bode's interests reached well beyond technical astronomy. The science's broader philosophical perspectives clearly fascinated him; otherwise he would hardly have perused the German translation of a philosophical book by a Swiss naturalist, Charles Bonnet. This version, *Betrachtung über die Natur* (Reflections on Nature), appeared in 1766 in Leipzig two years after the French original, *Contemplation de la Nature*. In this book, Bonnet tried to present natural evidence of the wisdom of the Creator, selecting for his first example the planetary system, but he offered only a few generalities about it.

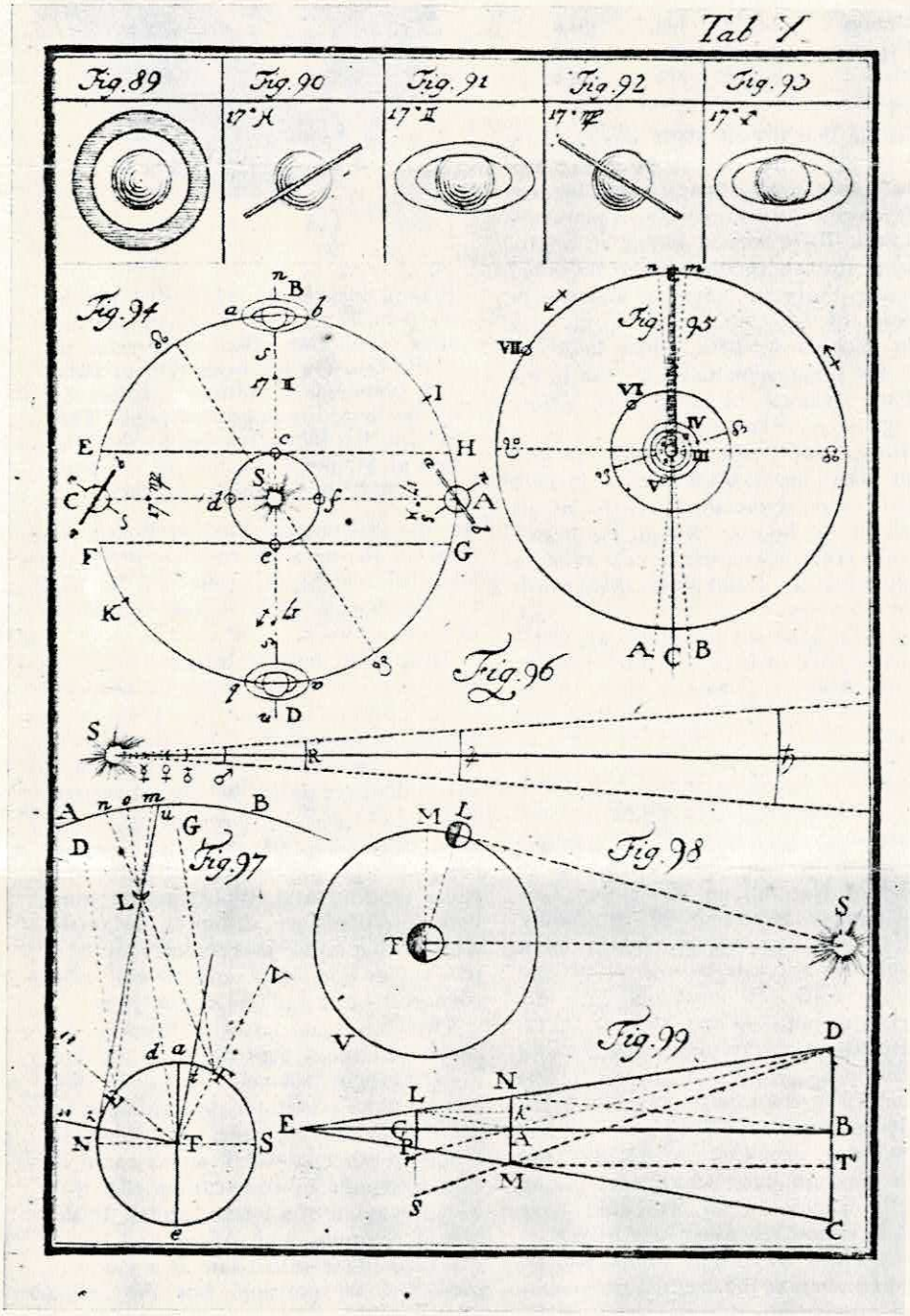
However, when the second edition of the translation appeared in 1772, this part of the text was considerably rearranged. Twenty-two lines on page 7 now appeared as a footnote signed T, clearly indicating that they were not by Bonnet but by the translator. He was Johann Daniel Titius, then 49 and professor of mathematics at Wittenberg. His name also appeared both on the title page and at the end of the dedicatory epistle of the new edition.

The footnote for which Titius claimed credit was this:

> Divide the distance from the Sun to Saturn into 100 parts; then Mercury is separated by 4 such parts from the Sun; Venus by $4+3=7$ such parts; the Earth by $4+6=10$; Mars by $4+12=16$. But notice that from Mars to Jupiter there comes a deviation from this exact progression. After Mars, there follows a distance of $4+24=28$ parts, but so far no planet or satellite has been sighted there. . . . Let us assume that this space without doubt belongs to the still undiscovered satellites of Mars. . . . Next to this for us still unexplored space there rises Jupiter's sphere of influence at $4+48=52$ parts; and that of Saturn at $4+96=100$.*

Almost exactly the same words appeared in the 1772 edition of Bode's *Anleitung* on pages 462-463. Bode felt that there had to be a planet between Mars and Jupiter, and as a proof he offered "the astonishing relation which the six known planets observe in their distances from the sun":

> Let the distances from the Sun to Saturn be taken as 100, then Mercury is separated by 4 such parts from the Sun. Venus is $4+3=7$. The Earth $4+6=10$. Mars $4+12=16$. Now comes a gap in this progression. After



In this plate from J. E. Bode's 1778 manual of astronomy, the part labeled Fig. 96 illustrates the Titius-Bode law of planetary distances. A short arc of the orbit of each planet from Mercury through Saturn is shown, with *R* marking the hypothetical planet between Mars and Jupiter. Elsewhere on this plate, Figs. 89-94 explain the varying appearance of Saturn's rings, while Fig. 98 illustrates Aristarchus' method for determining the sun's distance by measuring the angle *MTL*, when the moon is exactly at first-quarter phase. This reproduction is from the first edition of Bode's *Erläuterung der Sternkunde*, Hamburg, 1778.

*For the full English translation of the statements by Titius, Bode, and Wolff, see my article, "The Original Formulation of the Titius-Bode Law," which is scheduled to appear in the *Journal for the History of Astronomy*, June, 1972. My brochure, *Das Titius-Bodesche Gesetz im Licht der Originaltexte*, soon to be published by the Olbers Gesellschaft in Bremen, will give the complete story of the law from 1766 to 1803, with ample documentation from the original material.

Mars, there follows a distance [from the Sun] of $4 + 24 = 28$ parts, in which no planet has yet been seen. . . . From here we come to the distance of Jupiter at $4 + 48 = 52$ parts and finally to that of Saturn at $4 + 96 = 100$ parts.

Like Titius, Bode could not believe that the Creator of the universe had left empty the space between Mars and Jupiter. The difference between the two versions was that Bode did not assign that empty space to some hypothetical satellites of Mars.

Titius did not compare specifically the round numbers 4, 7, 10, 16, 18, 52, and 100 with the actual mean distances of the planets from the sun. In Bode's *Anleitung* the actual mean distances were given in Earth radii: for Mercury, over 8,000; Venus, almost 16,000; Earth, 22,000; Mars, 33,500; Jupiter, 114,000; and Saturn, 210,000. (He also gave them in German miles.) Bode did not compare these figures with the progression, but had he set the earth-sun distance of 22,000 equal to 10, the series of mean distances would have become: over 3.6, almost 7.3, 10, 15.3, 52, and 95.5.

The general agreement of this series with the progression would have appeared undeniable. Of course, remaining differences would have been serious if the progression were regarded as a strict arithmetic sequence embodying, so to speak, a Pythagorean law of nature. Clearly, the actual planetary distances were not exact multiples of the Mercury-Venus distance. But this point was not explored for the next 15 years.

MEAN DISTANCES OF PLANETS FROM SUN

	Titius-Bode Law	*Actual**
Mercury	$4 + 0 = 4$	3.9
Venus	$4 + 3 = 7$	7.2
Earth	$4 + 6 = 10$	10.0
Mars	$4 + 12 = 16$	15.2
(Ceres)	$4 + 24 = 28$	27.7
Jupiter	$4 + 48 = 52$	52.0
Saturn	$4 + 96 = 100$	95.4
Uranus	$4 + 192 = 196$	191.8
Neptune	$4 + 384 = 388$	300.6
Pluto	$4 + 768 = 772$	394.4

*In units of 10 for Earth-Sun distance

During that period, Bode was the only astronomer to mention in print the progression that about a century later became known as the Titius-Bode law of planetary distances. Bode seemed intent on appropriating the law to himself, for he failed to name Titius in the third and fourth editions of his *Anleitung*. Titius was again slighted in 1778, when Bode set forth the progression as a footnote in his scholarly manual of astronomy, *Erläuterung der Sternkunde*.

Titius himself did not seem to care about Bode's use of his idea when in 1774 he sent to press the third edition of his translation of Bonnet. But in the fourth edition (1783), there was a new twist to the situation, for Titius added these words to the footnote:

The progression and its significance, which Bonnet believed to have been first noted by [Johann Heinrich] Lambert, were already put forward by [Christian] Wolff more than 40 years earlier in his "German Physics."

However, this attribution to Wolff is wrong. The "German Physics" of Wolff was his *Vernünftige Gedancken von der Absichten der natürlichen Dinge* (Reasonable Thoughts on the Phenomena of Things of Nature), an elementary German-language treatment of astronomy, physics, and meteorology, which went through five editions between 1724 and 1752. In each edition, Wolff gave the planetary distances as equal to 4, 7, 10, 15, 52, and 95, when the sun-Saturn distance is taken as 95. For Wolff, these numbers were not a mathematical progression but merely an aid for students to recall the approximate distances. Wolff did not invent these numbers, which were the essentially correct values he could have found in almost any astronomy book.

As to Titius' claim that Bonnet had regarded Lambert as the original proponent of the progression, this was rebutted by Bode. In 1784 Bode published a monograph on the planet Uranus (discovered in 1781), in which he expressed his pleasure that the mean distance of Uranus justified the extension of the progression as $4 + 192 = 196$. Bode also made public a letter written to him by Lambert on February 3, 1772, expressing his surprise at the progression described in Bode's *Anleitung*. In the same context, Bode also admitted for the first time that he took the progression from Titius' translation of Bonnet's work.

Thus the famous planetary-distance relationship that was originally proposed under Bonnet's name in 1766, then claimed by both Bode and Titius in 1772, sets the stage for a strange bicentenary, which deserves notice for several reasons. First, the usual accounts of its origin need correction. Second, a long-overdue recognition should be given to Titius who, while mulling over Wolff's round numbers for planetary distances, originally realized that a nice progression resulted if the values for Mars and Saturn were changed by one and five, respectively.

Titius' insight, bolstered by the discovery of Uranus, contributed to the finding of Ceres in 1801 and Neptune in 1846. But these were questionable triumphs for the Titius-Bode law. Ceres was followed by a host of other asteroids, which could be explained only by conjecturing that they were fragments of a former planet. In the case of Neptune, both Adams and Leverrier used the so-called law as a guide in predicting its position, but the actual distance of Neptune from the sun is only 30.1 astronomical units, not 38.8 as predicted by the progression. The discovery of Pluto in 1930 gave a still worse discrepancy: actual distance 39.4, predicted 77.2.

For all that, the "law" has continued to influence many speculations about the origin of the planetary system.

Betrachtung
über
die Natur
vom
Herrn Karl Bonnet

Mitgliede der römisch-kaiserl. Gesellschaft der Naturforscher, und der Akademien und Gesellschaften der Wissenschaften zu Petersburg, London, Stockholm, Lyon, München und Bologna; wie auch Correspondenten der königl. Akademie der Wissenschaften zu Paris, und der königl. Gesellschaften zu Montpellier und Göttingen.

Mit Kupfern.

Mit gnädigster Freyheit

Leipzig,
bey Johann Friedrich Junius, 1766.

The title page of the book in which the Titius-Bode law was originally announced, published at Leipzig in 1766. It is the German translation by J. D. Titius of Charles Bonnet's *Contemplation de la Nature*. Bonnet (1720-93) was a versatile Swiss amateur scientist. Reproduced from Cornell University Libraries' first edition, courtesy Cornell public information department.

Johann Elert Bode (1747-1826) was in the front rank of the German astronomers of his day. He was director of Berlin Observatory from 1787 to 1825, and prepared 54 annual volumes of the Berlin astronomical yearbook. This portrait has been provided by the History of Science Collection in the University of Oklahoma Library.

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FOR CHRISTMAS

Curtis & Cheryl Rolle
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Merry Christmas