# Occultation Newsletter

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Joan Bixby Dunham, Editor

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## FROM THE PUBLISHER

For subscription purposes, this is the fourth and final issue of 1994. It is the sixth issue of Volume 6. IOTA annual membership dues, including ON and supplements for

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|---|---|
| U.S.A., Canada, and Mexico | $30.00 |
| for all others | 35.00 |

Annual IOTA membership dues may be paid by check drawn on an American bank, money order, cash, or by charge to Visa or MasterCard. If you use Visa or MasterCard, include your account number, the expiration date, and your signature.

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| ON subscription (1 year = 4 issues) | |
| for U.S.A., Canada, and Mexico | 20.00 |
| for all others | 25.00 |

Single issues are 1/4 of the price shown.

Although they are available to IOTA members without charge, nonmembers must pay for these items:

| | |
|---|---|
| Local circumstance (asteroidal appulse) predictions | 1.00 |
| Graze limit and profile predictions (per graze) | 1.50 |
| Papers explaining the use of the predictions | 2.50 |

Asteroidal occultation supplements will be available at extra cost: for South America via Orlando A. Naranjo (Universidad de los Andes; Dept. de Fisica; Merida, Venezuela), for Europe via Roland Boninsegna (Rue de M ariembourg, 33; B-6381 DOURBES; Belgium) or IOTA/ES (see below), for southern Africa via M. D. Overbeek (Box 212; Edenvale 1610; Republic of South Africa), for Australia and New Zealand via Graham Blow (P.O. Box 2241; Wellington, New Zealand), and for Japan via Toshio Hirose (1-13 Shimomaruko 1-chome; Ota-ku, Tokyo 146, Japan). Supplements for all other areas will be available from Jim Stamm (11781 N. Joi Drive; Tucson, AZ 85737; U.S.A.) for $2.50.

Observers from Europe and the British isles should join IOTA/ES, sending DM 40.- to the account IOTA/ES; Bartold-Knaust Strasse 8; D-30459 Hannover, Germany; Postgiro Hannover 555 829 - 303; bank-code-number (Bankleitzahl) 250 100 30.

## IOTA NEWS

David W. Dunham

The main purpose of this issue is to announce IOTA's policy about detailed total occultation predictions for 1995 and give other prediction news not included in the last issue, as well as to publish some articles that could not be included in previous issues. Among the latter are important articles about using the Global Positioning System (GPS). We thank Andrew Seacord for typing in WordPerfect format the articles that were submitted only in hardcopy form. Several reduction profiles of observed grazing occultations have recently been received by Robert Sandy. Some of these are included near the end of this issue, and more will appear in future issues.

ESOP XIII Proceedings: The 13th European Symposium on Occultation Projects was described on pages 108-110 of the last issue. Proceedings of this interesting meeting are available; copies can be requested from Marek Zawilski and Błażej Feret, e-mail blzferet@mitr.p.lodz.pl. After receipt of the Proceedings, a bank check for $15 should be sent to Zawilski at Ul. Julianowska 5/7 M 369; PL-91473 Łódź, Poland.

$\chi$ Virginis Graze: Early reports of the December 26th graze, mentioned on pages 105 and 106 of the last issue, indicated no evidence of duplicity, but this may have been caused by glare associated with the small cusp angle or, more likely, orbital motion of the secondary star since the 1988 graze when the duplicity was first noted. The profile, dominated by perhaps the highest mountain of the lunar profile, produced only one D-R pair for each observer in the expedition at Wallingford, CT.

About 10 hours and 100 miles after the graze, when we slowed down in heavy traffic on the NJ Turnpike, I heard something on the roof of our minivan. We stopped on the road shoulder and retrieved my TimeKube, left from the graze; fortunately, the antenna had wedged in our roof luggage rack.

Next Issue: The main purpose of the next issue will be to document IOTA's 1995 planetary and asteroidal occultation predictions, publish Joseph Carroll's total occultation tallies for 1981-1985, and to include a few other articles and observed grazing occultation profiles that could not be included in this issue. If you have a contribution for the next issue, the editor should receive it as soon as possible. The issue will be produced quickly after data for the 1995 asteroidal appulse predictions are distributed, and it will likely be mailed in late January.

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## PREDICTIONS FOR 1995

David W. Dunham

Between producing the last issue of **ON** and this one, I sent necessary data to the national and regional coordinators, and graze computors, to compute and distribute the lunar total and grazing occultation predictions for IOTA members. New developments are given below:

Evans Total Occultation Predictions: If you are an IOTA member and on the 1994 active prediction mailing list, your "Evans" total lunar occultation predictions for 1995 should have been sent to you by now by your regional coordinator, if you live in North America. European members of IOTA/ES on the active list should similarly have received their "Evans" predictions from their national or regional coordinator. These predictions can now be provided by IOTA as a privilege of IOTA membership (one set of predictions per member). Everyone with a low O-code limit is encouraged to receive their predictions on diskette or by e-mail. Most observers with photoelectric-option predictions will be receiving them from ILOC; in mid December, I sent them diskettes containing those predictions for 1995 for that purpose. Observers outside of North America and outside of Europe probably already have received 1995 predictions from ILOC, but the ILOC predictions do not include many of the features of the Evans predictions; such observers who are IOTA members can obtain these predictions upon request to their regional coordinator. Those who are not photoelectric observers and not members of IOTA can purchase Evans predictions from IOTA for the following prices:

| O-code Limit | USA | Canada &Mexico | other Western Hemisphere | Europe | Others |
|---|---|---|---|---|---|
| 7-9 | $0.50 | $0.60 | $0.80 | $1.00 | $1.20 |
| 5-6 | 0.75 | 0.85 | 1.25 | 1.50 | 1.85 |
| 4 | 1.00 | 1.10 | 1.70 | 2.10 | 2.60 |
| 3 | 1.60 | 1.65 | 2.50 | 3.40 | 4.20 |
| 2 | 2.10 | 2.20 | 2.90 | 4.00 | 5.00 |
| 0 | 3.00 | 3.00 | 3.30 | 4.75 | 6.00 |
| On disk* | 2.00 | 2.10 | 3.50 | 3.50 | 3.50 |

* The disk can include 2 O-code limit 0 predictions and OCCLIST, or 3 O-code limit 0 predictions; see text below. If the files can be compressed (zipped), predictions for more stations can be included. Diskettes are IBM PC-compatible, although Mike Kazmierczak may be able to provide Macintosh-compatible diskettes.

The cost includes first-class postage in the USA and airmail postage for other areas. The costs are for a single set of predictions for one station. Predictions for additional stations, or copies of predictions for the same station, each cost an additional 80% of the listed prices, for IOTA members as well as non-members. Payment should be made in US dollars and sent to either your regional coordinator or to IOTA c/o Craig and Terri McManus; see the masthead and FROM THE PUBLISHER on p. 123. Coordinators in other countries can establish rates in the currency of their country.

The coordinators were asked to provide predictions for at least early January to non-IOTA members to give them time to buy their predictions. If you are not an IOTA member and are on the active occultation list, give your address code and state that you want Evans total occultation predictions when you send your renewal, or upgrade from **ON** subscriber only to IOTA membership, to the McManuses; they will then either ask Richard Wilds to supply your predictions, or notify your coordinator to supply data for the rest of the year. When possible, the latter will usually be done when possible for those outside of North America.

Other possibilities for obtaining predictions include the following:

- A few coordinators (if not, then I) can send your predictions for free by e-mail, provided that you can receive large, uuencoded ("attached") files; the predictions for one station with O-code limit 0 take about 400 kilobytes, or about a third of that for a compressed (pkzipped) file. I do not have incoming ftp access; possibly some of the other coordinators have that.
- You can request predictions from the International Lunar Occultation Centre; Geodesy and Geophysics Division; Hydrographic Department; Tsukiji 5-3-1, Chuo-ku; Tokyo 104, Japan; Telephone 81-3-35413811; Fax 81-3-35452885; ILOC does not have e-mail. ILOC's predictions do not have many of the features of the Evans-program predictions.
- If you have a 386 or 486-compatible PC, you can generate your own predictions with the OCCULT program. See **ON 6** (3), pp. 56-57 for more information about OCCULT, and how to obtain it.

Lunar occultations of major planets are not included in the Evans-program predictions for 1995. Predictions for these can now be generated by your regional coordinator using the OCCULT program. Maps showing the regions of visibility of the few lunar occultations of major planets during 1995 were published in **ON 6** (4), pp. 71 and 72 (September 1994); none of these events will be visible from the USA, except for an unfavorable daytime occultation of Mercury in Alaska on June 26.

The following need to be added to the list of regional and national coordinators that was published in **ON 6** (3), pp. 55 and 56; since ILOC has already supplied predictions for these areas, Evans predictions for 1995 will be supplied only upon request by them:

Australia and New Zealand (N, T, V, X1) - Peter Northfield; P.O. Box 234; Strathfield, NSW 2135; Australia
Japan (O) - Toshio Hirose
Russia, Ukraine, and other former Soviet Union (G, R, XH, XI, XJ, XK, X6, Z3) - Prof. Evgeniy M. Trunkovsky; Sternberg Astronomical Institute; Universitetskiy Prospect 13; 119899 Moscow, Russia; E-mail tem@sai.msk.su

1995 Evans predictions for observers outside of these areas, and also outside of North America, Europe, and southeast Asia, will be supplied upon request either by Walter Morgan or Richard Wilds.

Many IOTA members have reported accurate geographical coordinates to IOTA, but some of them are not in the Evans total occultation prediction system. They will be added early in 1995. Observability code and coordinate forms will be distributed to start this process.

On December 20, I visited Marie Lukac at the U. S. Naval Observatory to help her package the paper files that she had accumulated during the approximately 20 years of USNO control of the predictions. The packages are being sent to the regional coordinators. They include original correspondence, O-code and station coordinate forms, annual verification forms, and some station records from the Royal Greenwich Observatory from when H. M. Nautical Almanac Office worked with USNO to compare their station files.

Grazing Occultations: The 1995 profiles with "Profile with Grazereg-Ver. 3.4, IOTA/ES, E. Riedel" at the bottom, now sometimes say: "Cassini-Region Warning. Profile is not Reliable". In these cases, the profile should be ignored and the ACLPPP profile used instead. If an ACLPPP profile is not available, it is recommended, based on previous graze observations, that the following distances from the predicted limit should be covered:

- Northern-limits: The observations indicate that the true profile is near the lunar mean limb, not far below it. The range should be +0".3 to -0".7 (arc seconds given on the left side of the profile, with + indicating distance north of the limit).
- Southern-limits, waxing-phase dark limb (WA less than 180): 0" to +1".
- Southern-limits, waning-phase dark limb (WA greater than 180): +0".5 to +1".5.

Whenever you use an ACLPPP profile, you should apply the corrections given by Wilds on pages 111 and 112 of the last issue.

For northern-limit grazes not in the Cassini region, one should consult both the ACLPPP and Grazereg profiles (if available), since the differences give a better indication of the true possible error than the usually much too small error of the star's declination given in the prediction headings. To be safe, observers in small expeditions should set up according to the southernmost of the two profiles, to reduce the chances of seeing no occultation. But if there are many observers, there should be some coverage of the total range of possible multiple events indicated by either profile, with at least ⅔rds of the stations located in the southern half of the range.

Starting with the predictions for 1995, the graze computors will normally distribute predictions for the whole year, rather than the previous practice of making two mailings for predictions for the two halves of the year.

Eberhard Riedel and I will work during the next few months to incorporate the observed-graze (mainly Cassini-region) data and corrections now in ACLPPP into the Grazereg profiles. Also, Reinhold Büchner will try to reduce available graze observations to obtain improved corrections.

Asteroidal and Planetary Occultations: The graze computors will also distribute local circumstance asteroidal/planetary appulse predictions for 1995 to IOTA members sometime in January. We are a little behind on that, but not nearly as much as we were for 1994, when the appulse predictions were distributed in July.

## ASTEROIDAL OCCULTATION NEWS

David W. Dunham

Finder Scopes: The hardest part about observing asteroidal occultations is locating the target star with your telescope. Most telescopes are sold with small finder scopes that are fine for locating the Moon (all that's needed for lunar occultations) and the major planets, but are quite inadequate for homing in on faint stars in areas with no bright stars within a main-scope field including the target star. I recommend a finder with an aperture of at least 50 mm. Even better would be one with a 3-inch aperture, but these normally cost over $300.

Although IOTA does not normally endorse any manufacturer's products, there are cases where we must name suppliers of products that are uniquely suited to IOTA's needs. An example is the TimeKube WWV receiver that used to be sold by Radio Shack, but is no longer available. Another is Stano Components, which sells relatively inexpensive image intensifiers. Now I want to mention that Black Forest Observatory in Colorado Springs sells 3-inch aperture finder scopes for only $49.95, a real bargain for speeding up the process of locating that faint star. It includes an extension tube for straight-through viewing, but does not include a 1¼-inch eyepiece or mounting brackets, which are not difficult to obtain elsewhere. Their telephone is 1-719-495-3828, and ads are on p. 83 of the January 1995 issue of **Sky and Telescope** and on p. 13 of the February issue of **Astronomy**. I called them recently, and they noted that the objective lenses are not of high optical quality, so they are unsuitable for high or medium-power eyepieces. However, they have had no complaints when used with low-power eyepieces for finder scopes.

Asteroid PRO: Nothing adverse is mentioned in John Mosley's review of this software described on pages 57 and 58 of the January 1995 issue of **Sky and Telescope**. But Mosley was an IOTA member for only one year nearly a decade ago and has relatively little experience with occultations, as far as I know; I think that there are many others who could have written a better review. I gave a more critical assessment, mentioning Asteroid PRO's shortcomings, in **ON 5** (4), p. 75 (Sept. 1994). But I believe that Asteroid PRO would be quite valuable for serious asteroid observers, such as for its ability, described by Mosley, to find all asteroids in a certain part of the sky (such as on a photographic plate) at a given time. Asteroid PRO is good at finding dozens and even hundreds of potential asteroidal occultations in a region per year, but the chances of really seeing these events, especially the ones not also identified by IOTA, is very small. I don't know about the software's ability to support updating predictions from "last-minute" astrometry, and don't think that it produces either local circumstance appulse predictions or lists of possible observers arranged in "track" (or distance from the updated central line) order like IOTA supplies. It's best to be affiliated with IOTA so that you can be notified of astrometric updates that show an asteroidal occultation path has shifted into your region, and can participate in an organized effort to cover the event in the best way. The cost of Asteroid PRO is over five times IOTA's annual membership. I understand that Asteroid PRO uses an asteroidal orbital element database that apparently needs to be updated each year, and I don't know the cost of those annual updates.

## USE OF GPS RECEIVING DEVICES TO SUPPORT SOLAR ECLIPSE EXPEDITIONS

Paul Maley, IOTA and
Chuck Gilbert and Art Fluter, Trimble Navigation

The following constitutes a first attempt to address IOTA's needs for GPS equipment in the field. If readers of this article have any questions that they would like to see answered either on the material here or new questions, please e-mail them to Paul Maley at the following Internet address:
pmaley%jscdo6@jesnic.jsc.nasa.gov
[Note added by D. Dunham: After reading this article, I had several questions, mainly about how IOTA positional accuracies might be achieved with less expensive GPS receivers. The authors' answers to these questions, and some information about a promising new receiver that came on the market after this article was written, are given in the next article. You should read that, since many of the rules given here are modified by the new information.]

Introduction: The International Occultation Timing Association (IOTA) conducts field expeditions to remote locations which are often poorly mapped. For solar eclipse ventures, the worst case accuracy required to identify a position in latitude, longitude and altitude is 30 meters in order to properly determine changes in the polar diameter of the Sun. With the advent of Global Positioning System (GPS) technology, IOTA expeditions are now faced with a new way to establish levels of accuracy that far exceed this minimum requirement. In order to provide a first look at GPS methods, the following describes some basic uses.

A Primer on the Global Positioning System: The GPS system is a highly accurate, fast, and 3-dimensional navigation and positioning system available worldwide, without any fees. The satellite-based global positioning system has been in development since the mid-1960s. In 1973, GPS and NAVSTAR (NAVigation Satellite Timing and Ranging) merged into one program. Run by the U.S. Department of Defense (DoD), GPS is now a major navigation aid for all military services. Civilian use followed closely behind military users and today there are more civilian users than military in every country of the world.

The 24 GPS satellites are in very high orbits of 20,183km (12,545 miles). Their orbit period is 12 hours, so any one satellite is visible for approximately 6 hours every day. Ground stations, all managed by the U.S. DoD, monitor the satellites, and upload orbital prediction data, clock corrections, and ionospheric models. GPS works by a process called trilateration where distances between the satellites and the receivers are determined. Once a receiver obtains signals from at least 4 satellites, timing ambiguities are resolved and the distance to the satellite is calculated. The receiver then transforms this data into a standard 3D position coordinate.

GPS provides continuous 24 hour, worldwide coverage providing latitude, longitude, height, and time. For civilian users, the accuracy of any one receiver by itself is about 100m. When any one receiver is used by itself to compute positions, this is known as autonomous positioning. By using a technique called differential GPS, an accuracy of less than 1m can be achieved. By using more sophisticated carrier-phase receivers and differential techniques, an accuracy of 1-2cm can easily be achieved.

The signals from the satellites are complex and broadcast on two frequencies termed L1 and L2. The information on the L2 frequency is usually encrypted and its use denied to civilian users. Some survey-grade receivers can make use of these signals. The L1 signal operates at a frequency of 1575MHz with a wavelength of 19cm and is not encrypted. It is, however, subjected to the degradation effects of Selective Availability or S/A (explained below). Two parts of the signal may be used for positioning: the Coarse Acquisition Code (called C/A code or just code ) and the carrier signal itself (typically called phase or carrier ). Older mapping receivers and many navigation receivers only receive C/A code. Newer mapping receivers and all survey grade receivers receive C/A code and carrier. For a variety of technical reasons, carrier receivers can obtain more accurate positions than receivers using just C/A code.

Two good general booklets about GPS are **GPS - A Guide to the Next Utility** and **Differential GPS Explained** by Jeff Hurn. They were published by Trimble Navigation; 645 N. Mary Ave.; P.O. Box 3642; Sunnyvale, California 94088-3642; phone 1-408-481-8000.

Autonomous GPS versus Differentially Corrected GPS: A civilian-use, single GPS receiver cannot guarantee accuracy of less than 100m no matter what the advertised quality of the unit happens to be. This is true for all manufacturers and is because the US government intentionally degrades the signal of the GPS constellation so that it is only accurate to 100m 95% of the time. To improve on this, a technique called differential GPS (DGPS) is used. DGPS requires the use of two GPS receivers at the same time. This provides IOTA GPS rule #1:

**Rule #1:** To achieve a position in latitude and longitude better than 30m accuracy you must use 2 GPS receivers -- a base station and a rover system -- in combination with one another.

One receiver (the base station) must remain stationary at a location of known coordinates. The other receiver (the rover) can move around to collect data at various observation sites. If an observer has only a single GPS receiver, it may still be possible to perform differential correction. The only IOTA-usable single-receiver solution is to obtain base station data from a GPS base station operated by another user. At the base station, data must be collected at the same time that work is being done with the rover. It is a sad fact of GPS life that no single civilian GPS receiver alone can be used to obtain a position whose accuracy is better than 100m with short observation times.

Differences between Types of GPS Receivers: Not all GPS receivers, even from the same manufacturer, are equal. It is important to understand the differences between the classes of receivers to better understand their capabilities and their required operations. In general, there are three grades of receivers: navigation, mapping, and surveying. The general distinction between these is price, their inherent accuracy, and their ability to receive various components of the GPS signal. Mapping receivers cost around US$3000, while survey receivers typically start at $20,000 and can approach $100,000. Mapping receivers are a natural for the needs of IOTA. Navigation receivers are usually too inaccurate for IOTA work because many cannot be differentially corrected. Survey grade receivers are usually too cumbersome, expensive, and power hungry for the rigors of remote eclipse watching. Finally, to make matters more confusing, the features of the lower cost mapping units are beginning to approach that of survey grade instruments.

Survey-grade receivers are carrier phase which uses the GPS radio wave to achieve the higher level of precision (centimeter accuracy). Mapping units can achieve horizontal accuracy ranging from 0.2 - 15m after differential correction, depending on the manufacturer. The least expensive systems are accurate only to several dozen meters. Under nominal conditions position data with a 2-5m accuracy may be obtained at eclipse sites after differential correction has been applied. Table #1 below summarizes the differences between the three types of systems:

-- TABLE #1 --

| Type | Cost | Accuracy WITHOUT Differential Correction | Accuracy WITH Differential Correction |
|---|---|---|---|
| Navigation | Low | 100m 95% of time | Not Available |
| Mapping | Medium | 100m 95% of time | 0.2-15 m |
| Survey | High | 100m 95% of time | 1-2 cm |

C/A Code Verses Carrier Phase Positioning: The primary difference between the survey-grade and mapping-grade receives is the type of data the receivers collect and process. Most mapping receivers including Trimble's Pathfinder ProXL and GeoExplorer units can process either code or carrier.

In general, recording carrier data is more accurate than code data. Code data only provides a position accuracy from 0.5-5m, after differential correction. By comparison, recording carrier data (often with the same receiver) can provide a 0.01-0.30m accuracy. But, this increased carrier accuracy comes at a price of increased occupation times. Occupation time is defined as the length of time the receiver must record data before it achieves its ultimate accuracy. Most code receivers need only 1 second for 5m accuracy and perhaps as much as 1 hour to reach 2m accuracy. The latest, state-of-the-art code receivers may require 1 second for 0.5m and 1 hour for 0.3m.

By comparison, carrier phase receivers need longer occupation times with 10 minutes as a minimum. After the first 10 minutes, the carrier receiver's accuracy could be as bad as 30m. The receiver needs this time to determine the number of wave cycles between itself and each satellite. The process is called resolving integer ambiguity. Then, at the end of 10 minutes, a typical receiver might have a 20% chance of having an accuracy of <0.01m and a 90% chance of having an accuracy of <0.30m. At the end of 1 hour, the accuracy might improve to a 90% chance of being <0.01m and 10% of being >0.01m and <0.30m. Table #2 below summarizes the shortest rover occupation times.

-- TABLE #2 --

| GPS Receiver Type | Shortest Occupation Time & Accuracy | 1 Hour Occupation Time & Accuracy |
|---|---|---|
| Old Code Receivers | 1 second, 5m | 1 hour, 2m |
| New Code Receivers | 1 second, 0.5m | 1 hour, 0.2m |
| New Carrier Receivers | 10 minutes (Minimum) 20% <0.01m 80% <0.30m | 1 hour 90% <0.01m 10%>1cm<30cm |

Horizontal Accuracy Versus Vertical Accuracy: In just about all GPS applications, horizontal accuracy is 2-3 times better than the vertical accuracy. This is mostly due to the lack of a GPS signal from below the horizon. If horizontal accuracy is 100m, the vertical accuracy could be between 200 to 300 m. If horizontal accuracy is 1m, then vertical accuracy should be 2 to 3m.

Designers are working on the vertical control problem. One solution being developed at Stanford University creates extremely accurate vertical control for aircraft landing applications. They increase the vertical accuracy by using pseudolites, which are terrestrial GPS transmitters broadcasting from a fixed position.

Real-Time Differential GPS versus Postprocessed Differential GPS: Differential correction can be accomplished in two ways: In real time and by postprocessing. Both types of system are equally accurate. Real-time systems are impractical for IOTA expeditions because:

- Real-time systems require a telemetry link between base and rover receivers.
- The cost of such a link is very high.
- The link requires more power in the field than typically is available.

For IOTA applications, postprocessing is the standard recommended GPS observation method.

GPS Receiver Compatibility between Manufacturers: The hardware manufacturers of both the rover and the base do not have to be the same. However, they should be in order to simplify compatibility of postprocessing software and data formatting and to insure the probability of differential correction success. It is usually more difficult to obtain accurate differential correction from a mix of receivers from different manufacturers. When receivers are not the same, the user is forced to use data in a format that is compatible with both receiver manufacturers and with the postprocessing software. For IOTA, GPS rule #2 becomes:

**Rule #2:** Both the base and rover should be manufactured by the same vendor.

Satellite Sharing by Base and Rover Systems: The maximum distance between base and rover is a function of satellite locations and error that can be tolerated. The same satellites should be tracked by both base and rover. The restriction (for all GPS receivers by all manufacturers) is that the satellites used by the rover must be a subset of those tracked by the base.

Note that there are some receivers on the market today that are quite primitive by today's design standards. These receivers are limited by a restriction that exactly the same satellites must be observed at both the base and rover at exactly the same time. Please avoid using these types of receivers as successful differential correction will be a rare occurrence.

Setting a parameter called the elevation mask (mask angle) on both units can help assure that the same satellites will be rejected or tracked as appropriate. The elevation mask is set so that satellites low on the horizon will be rejected. These satellites are subject to signal problems due to the longer signal length in the ionosphere and to obstructions. In general, the base's elevation mask is set to a lower value (typically 10° above the horizon) than the rover's value (typically 15°). That way, the base will begin tracking satellites first as they climb to elevations greater than 10° above the horizon.

However, the rover will begin tracking after the base, when satellites rise above 15°. Note that if the rover uses a satellite that was not tracked at the base, differential correction will likely fail. So next rule for using GPS for IOTA observations is:

**Rule #3:** All satellites used by the rover must be a subset of those used by the base receiver.

Base to Rover Distance Limits: The distance between the base and rover is called the baseline and the error which is imposed by separating the two units is linear. The error can be characterized as 10 part-per-million (ppm) of the baseline length. Thus, an 80km baseline adds an error of about 80cm, while extending the baseline distance to 500km results in an added error of as much as 5m. To keep these unavoidable errors to a minimum, the baseline distance must be less than 500km or 300 miles. This error is in addition to other error sources described below.

**Rule #4:** A position error of 1.0 cm is imposed for every kilometer between base and rover.

Pushing Baseline Limits beyond 500 km: Under some circumstances, baseline lengths can be extended beyond the recommended 500km. This may be necessary in less developed parts of the world where there are fewer base stations. However, in order to do so, you must be aware of the factors and tradeoffs involved. Assuming you are using a receiver with a differentially corrected accuracy of 2 to 5m, that leaves you with a 25 to 28m accuracy range that can be used in a longer base line. For IOTA use, remember that a ±30m accuracy is all that is needed. Again, recall that the accuracy of the baseline degrades with about 10 ppm of its length. A good rule of thumb here is you will lose 1m of accuracy for every 100km of length. Theoretically then, you might be able to extend the baseline length to as much as 2500km and still get your necessary 30m accuracy.

It might work, but you have to member that the satellites used by the rovers MUST be a subset of the satellites used by the base. To keep the rover watching a subset of the base's satellites, the rule of thumb is to increase the rover's elevation mask 1° in addition to its usual 15° for every 100km over 500km. Thus, if you had to push your baseline length to 2500km, you should raise your elevation mask by an additional 25° or for a total of 40° (15° plus 25°). This might work, but now the problem is that the rover's view of the sky with a 40° elevation mask, there may not be enough satellites to obtain a good fix. The satellite geometries would be bad and the position accuracies would be poor.

The only way to think about trying this technique is to preplan the survey and use satellite prediction software, such as Trimble's QuickPlan to view the satellite geometry at the date and time in question with a high elevation mask. For IOTA purposes, the practical limit of baseline lengths is probably about 1500km, with the rover's elevation mask set to 30° at the extreme length.

Recording Data at the Base and Rover Sites: If the base collects data when the rover is not and vice versa the rover data will not be differentially correctable. This brings up our next rule:

**Rule #5:** The rover and the base station must collect position data at the same time.

The general solution -- and one of the easiest to implement -- is to set up the base station over a known point and start it recording data BEFORE any data is recorded by the rover. Continue to record data at the base until all rover observations have been completed. After the base begins to record data, and assuming one rover unit will record positions for several observation sites, move the rover to the first observation site. Find a marked spot, open a file on the rover and start recording data. The longer the recording session the better, but get at least five minutes of data. Close the file, and move on to the next site for another recording session..

Be sure to check the recording capacity of the both receivers, but especially the base unit. Remember, a typical base will record and store in the receiver's memory about 50-100 Kilobytes (Kb) of satellite data every hour. For long observation sessions, many GPS receivers have the capability to record data directly to a PC via a serial-link.

Selective Availability and GPS Base Stations: The purpose of the base site receiver and the later postprocessing session is to eliminate position errors put into the GPS system by the U.S. Department of Defense as a security measure. The errors are an intentional signal degradation called Selective Availability (S/A). When S/A is off -- a rare occurrence these days -- the civilian GPS code is accurate to 10-15m. The exact operation of S/A is classified. It is thought that the signal is degraded when the clock error (called dithering) and/or the orbital element data in the satellite's ephemeris (called epsilon) are intentionally shifted affecting the receiver's calculated position. The most common observation of S/A is from a stationary receiver where a S/A generated velocity component can easily be seen.

Differential correction negates the effect of S/A. The base site receiver -- which occupies a known location during the entire observation session -- computes the errors associated with every satellite measurement it receives. Once determined, these errors can be applied to rover data and in this way the errors in that unit can be removed. Other GPS error sources include atmospheric and ionospheric errors, satellite clock, and orbital errors.

A base station must be able to track all the satellites that will be used by all of the rover units. In practical terms, this means the base station receiver must be able to observe all satellites in view, typically between 8 and 10 satellites. If the base unit cannot track all the satellites used by the rover, the differential correction will probably fail due to roving units tracking satellites that were not tracked by the base.

Obtaining Base Station Correction Information: Base station locations must be known very accurately. Any position error in the base's coordinate will be transmitted in its entirety to the coordinates of the rover units. The easiest way to obtain base data is to run your own. However, if you don't have your own base unit, you may be able to obtain base data from government agencies, consulting companies and universities provided you can find one within the appropriate distance. Another possibility is to call GPS manufacturers. Some manufacturers may know about sources of base data near your work area. Fees are charged by some sources on an hourly or daily basis ranging from as little as US$10 per hour to US$400 per day.

The US Coast Guard is set to provide beacon transmitters from 283.5 to 325Khz with ranges from 160-500km some time in 1996 as part of a program to provide differentially corrected GPS accuracies in all harbor approach areas of the USA. A nearly identical beacon system is being set up in Europe. These transmissions are receivable at no charge but you need a radio beacon receiver to accompany the GPS receiver (cost is $3000 or less). A power source is also mandated that will power both beacon receiver and GPS receiver. The primary problem is that unless eclipse expeditions are within 320km of the coastline the use of the beacons is impractical for IOTA.

Accuracy versus Occupation Time for Rover GPS Units: Occupation times at an eclipse site can vary. In most cases, the correct answer is that the more data that is taken, the higher the precision. For IOTA purposes our expeditions usually do not remain at an eclipse (rover) site for more than a few hours and most sites are never revisited if located very far from the observer's home town. The location of both base and rover would generally not be known to the required level of precision.

Assuming that S/A remains approximately constant, the averaging assumptions will probably hold true. Be aware that S/A is not random and cannot be predicted statistically. You cannot expect that averaging will negate its effects. One can also see how using a cheap hand-held navigation type receiver and simply copying down each position as it appears on the screen instead of storing them in a file is time consuming and would require hundreds of positions to average. This demonstrates in practical terms why a navigation receiver cannot be used by IOTA, in addition to its lack of DGPS capability.

Guidelines for Occupation Times: The question on how long data needs to be taken requires a two part answer. The following tips are guidelines and not absolute rules. If the base site is known (that is, its coordinates are already known to either centimeter or meter accuracy) then the base site should take data for about two minutes and the rover can take data simultaneously for the same length of time. If the base and rover sites are both unknown, the problem is different.

Since most IOTA expeditions involve 2 unknown sites, the rover site position can only be known to the same level of accuracy as the base. Assuming an average S/A about 10 hours of base data is the minimum required to achieve 30m accuracy assuming an average S/A between the best and worst case curves. The GPS receiver must continuously operate and record data for 10 consecutive hours. The rover can take data for a few minutes and after the post processing phase the same level of accuracy as the base will be obtained. This brings up rule #6:

**Rule #6:** For both an unknown base and an unknown rover site a minimum of 10 consecutive hours of data must be taken at the base site.

When you don't do differential correction and you only have one receiver to work with, the data confidence can range from 8 to 53 meters with 95% confidence in the first two hours of data collection. If you can find out the performance of a known base station during that same period, you can find out if the GPS signal was gravitating toward the worst case or best case S/A. Remember, the objective is to stay within 30m or less. To know when S/A was on the date you took eclipse data, find a base site at a known location and get copies of their base files along with the true coordinates of that site. S/A is the same everywhere in the world at any given time. For example, on 10 May 1994 S/A was within 50m for 1 sec of data collected and within 23m for 1 hour's worth of data. Since a known base site was used to correct the rover data and differential correction was applied, the true level of accuracy was found to be within 4.5m.

Provided the observation site is a rover site, the length of time to achieve sub-meter accuracy is on the order of 1 second with C/A code-based receivers, and 10-20 minutes with a carrier based receiver (survey grade instrument). This means the much more accurate units (0.01-0.02m accuracy) takes much longer site occupation times to achieve this level of accuracy. For IOTA purposes, our next rule is:

**Rule #7:** Mapping grade GPS C/A code receivers are the minimum type of GPS units acceptable for IOTA work. (The cheap $500. navigation models are not acceptable!!).

Data taken by P. Maley at Lenexa, Kansas USA on 10 May 194 at the annular eclipse was obtained with a Trimble Navigation GPS Pathfinder Basic Plus receiver. Data were collected for two 18-minute periods. The data were then differentially corrected with a data station 500km away in Chicago, Illinois using Trimble's differential processing software, PFINDER Version 2.5.0. The data were averaged and the two files agreed to within 4.5m. From the individual quality of the base and rover data, it is believed that the worst case error in the averaged position is about 7m. The typical accuracy of the receiver used is about 2m plus 5m accumulated potential effort due to the 500km baseline length.

These results are an example of a representative analysis of a particular set of data at a point in time. Readers who use GPS will experience uniquely differing situations and should endeavor to understand the post processing requirements and interpretation of such data. One advantage of carrier based units is that their initial precision should be far superior to that of the C/A code receivers.

Working with Weak GPS Signals: Sites that have unobstructed horizons are ideal for GPS units. But when venturing into jungle or forest canopies it is important to note that the 1575MHz signal (a wavelength of 19cm) generated by the satellites are very weak--about 100 times weaker than the background radiation at that frequency. The signals are easily obstructed or corrupted by reflected signals.

Leaves can attenuate the signals and solid metal objects block them entirely. GPS signals cannot go through solid wood more than a few cm thick, and a typical obstruction that the signals fail to pass through is a chain link fence since those openings are very small. A nearby branch may pose more of an obstruction than a larger distant tree trunk. The greater the density of a jungle canopy, the worse the reception of GPS signals.

Another GPS problem is caused by the reception of reflected signals off large metal objects. Although the 19cm GPS signals can penetrate metal objects that have openings at least 19cm in diameter, most large metal objects play havoc with the signals because of a phenomenon called multipathing. Multipathing typically occurs when the receiver is operated near objects that can reflect the GPS signals. The best rule of thumb for GPS work is to stay as far away as possible from reflecting metal objects such as roofs and metal sided buildings.

Two other common reception problems are tripods and the observer's head. Setting up the observation telescope and its tripod right over the GPS unit will probably obscure satellite signals. A similar effect occurs when the observer bends over a ground mounted receiver to see what's going on. The best way to use the receiver is to mount it conveniently at eye level on its own tripod. If necessary, mark the GPS position with a stake and then measure offsets and bearings to each instrument with a tape measure.

Operations under a Jungle or Forest Vegetation Canopy: If you are having or suspect reception problems, the degradation of satellite signals can be monitored by a signal strength display on most GPS units. On most receivers, a high value is good; a low value is bad. One way to increase signal level may be to elevate an external antenna (each unit typically has an internal antenna) high in the air on a pole (called a range pole).

Since most receivers are battery operated, it is also important to know how long a unit can operate from a battery set. It is advisable to carry at least one backup set of batteries. A typical operating time is about 8 hours on one set for a unit consuming from 2-3 watts. If you need to take 10 hours of data and the battery fails after 6 hours the file is automatically saved. You need to begin with a fresh battery and new file initiated which will record for another 4 hours to achieve the minimum level of 10 hours.

Checking Received GPS Data: How do you know that the rover data are valid before you depart the eclipse site? We define an eclipse site as a rover site here. About the only way to be sure is to perform real-time differential correction, or to postprocess on site with a laptop computer. When properly collected, GPS data are rarely of poor quality. So, if real-time GPS is not used and a laptop computer not available, one has to leave the site with receiver files stored in memory with data taken over the most feasible time and hope for the best.

If being chased by headhunters or hungry crocodiles, one second should be enough data for an accurate position at the eclipse (rover) site. While most GPS receivers are rugged and probably crocodile-resistant and should pass through with little damage, no warranty is made about the GPS operator.

Postprocessing GPS Data after the Eclipse: After an eclipse receiver data can be downloaded from both the base and rover units. Correction data are stored at the base and special software is applied to the files after they are downloaded to a PC or workstation. Software varies from one vendor to another. Some packages can apply accurate correction only if the rover is stationary. Most GPS receivers for IOTA applications are C/A code (mapping grade) receivers. They tend to perform better than carrier phase (survey type) receivers under trees and also are more portable. Some manufacturers do not have software to perform post processing. So our next rule: **Rule #8:** Prior to selecting GPS base and rover units, be sure postprocessing software is available and that you have access to it!

RINEX Standard GPS Data Format: One standard in the GPS industry is the Receiver INdependent EXchange (RINEX). RINEX stores 3 types of data files: observations (GPS time, carrier phase, and satellite pseudo ranges), navigation (orbit details from each satellite), and meteorological (site specific meteorological details). RINEX is used only for postprocessing data. But, unfortunately, RINEX is not without problems.

RINEX theoretically lets data received by various GPS manufacturers be stored in a common format. However, in some cases the RINEX format used by one company is not completely compatible with that of another. If you plan on using RINEX data from one manufacturer, make sure it is compatible with the RINEX or postprocessing software of the roving receiver.

Although RINEX is a format used for data interchange, the manufacturer-specific formats are better suited to differential correction post processing. RINEX is an ASCII-based file and is not as space-efficient as many manufacturer's binary formats. For example, if a base station records all satellites in view at a rate of one-per-second, the RINEX base file for a single 10-hour work day requires 16 megabytes of disk space. Data for the same period in a manufacturer-specific format could require less than 1.4 megabytes--easily fitting onto a floppy diskette.

Using GPS to Navigate to the Limits of the Eclipse Path: IOTA and USNO produce detailed predictions at various longitudes which define the limb corrected northern and southern limit lines for eclipse paths. The GPS receiver, used in a navigation mode, can maximize the utility of such data as never before.

Coordinates of the eclipse limit line(s)can be manually entered into the receiver for selected geographic locations so that a user can navigate relative to the limit without needing anything but a very coarse map (or no map at all). The typical procedure to navigate to the limit line is to first store waypoints a degree of longitude apart. The number of waypoints that can be entered varies with manufacturer and model; Trimble's mapping receivers can have up to 999 waypoints. Each waypoint is identified by number, an optional name, a latitude and a longitude.

A pair of waypoints are selected; one is designated FROM and the other TO. The receiver then automatically calculates an imaginary line called the desired path between the two points. When the receiver begins to calculate real-time positions, it does so relative to the desired path between the two waypoints. Again, in real-time, the receiver calculates the offset distance between the current position and the desired path and displays it as a cross-track error distance, usually in units of kilometers or miles. By using this technique, one can navigate to any required offset between the interior and exterior boundaries of the limit to an accuracy of about 100m, the best that can be done with S/A.

Remember that this is navigational accuracy for the purpose of setting up individual observing sites. As long as there is a base station elsewhere continually recording data, once arriving at the site, the bare minimum time for satisfactory positional readings is a few seconds with at least 4 satellites being received It is recommended that at least 5 to 10 minutes of data be received if time permits. If in doubt, get more data. One wonderful feature about GPS is that you can return to a site days, months or years after the eclipse and resurvey the positions. This applies even to very old eclipses such as that in the 18th century analyzed earlier by IOTA.

Final GPS Tools: A Notebook and a Pencil: Good surveying and mapping practices require a recording notebook for each observation session. You should too. Use the notebook to record lots of different information. Here is just some of the information that should be recorded:

- A listing of all the waypoints used.
- Driving directions or locations of all the observation sites.
- A rough map of the observation and base station locations.
- The name of the base station file, if known.
- The name and a description of each rover site.
- The rover file name for each observation site.
- The GPS receiver's manufacturer, model number, serial number, and firmware number and revision, if known.
- Contact information for third-party base station data including name, phone, base station manufacturer, software used and revision.
- If you are using a laptop computer to postprocess on site, listings of the AUTOEXEC.BAT and the CONFIG.SYS files.
- The postprocessing software used, its number and revision.
- The names of everyone on the eclipse team.

The notebook and its information becomes invaluable when you are trying to remember which file was supposed to go with which site, at what time. In case of postprocessing problems, it can help with data recovery.

Summary: GPS is offering IOTA and its members some significant benefits: help in navigating to observation sites, and increased precision in determining the coordinates of observation sites. Like any precision tool, its limits must be understood before deriving its maximum benefits. Once used, the benefits of GPS positioning will continue to payoff into the future.

## MORE ON GPS

David W. Dunham, Chuck Gilbert, and Paul Maley

After reading the above article, Dunham had several questions about how IOTA accuracies might really be achieved using GPS. The questions, answered by Gilbert at Trimble Navigation, were relayed by Paul Maley on October 4th. Each question is given below, followed by the answer.

Question 1: The article notes that 10 hours of data are needed by the base station receiver to establish the base station's position to IOTA's accuracy.....
Answer: I don't think that the word"needed" is correct in the context of the sentence above. The nature of Selective Availability is such that the position wanders continuously with the positions within 100 meters of truth at least 95% of the time. A certain percentage of your positions are already within 30 meters (the IOTA requirement). When this is true (e.g. when you are lucky), a one second occupation will suffice.

Unfortunately it is not possible to know when you are so lucky. Therefore, it is really an issue of, "How long do I have to stay in order to be 'reasonably certain' that the average is within 30m?" and "How severe is the penalty if I am not within 30 meters?"

Because I do not know how others define 'reasonably certain' (50%?, 68%?, 95%?, 99.999%?) I am reduced to making ridiculously conservative estimates such as "10 hours". (Especially for a venue that will certainly see wide publication.) After a 10 hour occupation, I am willing to say that I am 100% certain that your average will ALWAYS be well within 30 meters. Personally, I expect that you would usually be within 30 meters after only 30 minutes. Is "usually" good enough for your application? Only you can answer that question. How severe will the penalties be if you occasionally miss? [Further on this added by D. Dunham, after discussion with Tom Van Flandern: More than 30 minutes is desirable, since the S/A is different with different satellites. So a variety of combinations of satellites should be sampled to be reasonably certain that the S/A effects will average out. Since the satellites' period is 12 hours, that much time would surely sample all possible combinations. But a reasonable fraction of this, for example, 4 hours, should give sufficient variety. If possible, it would be useful to record data for two or three hours, and then record data again about six hours (or 12h + 6h = 18h) later, when different satellites are above the horizon. With the GPS receivers that we now have, we plan some field tests and will report the results in a future issue; for now, we think that 4 hours is a reasonable time for collecting data. The data do not have to be collected frequently; recording at 1-second intervals would soon create very large files. Recording at 15-second intervals should be sufficient.]

Question 2: It seems to me that any GPS receiver that can receive and record the signals from at least 4 satellites for this amount of time could achieve the necessary accuracy, without even the need for base-rover DGPS.
Answer: The above is true.

Question 3: The disadvantage is that each site needs to be occupied for 10 hours [4 hours is probably sufficient, see question 1 above], but that may be worth it if a cheaper receiver can be used.
Answer: Again, you can probably get by with much less than 10 hours. It is all a function of your personal comfort level. If this lower cost route is the most appealing to you then I would suggest either a Scout, a Flightmate, or an Ensign GPS receiver. All three of these can be found from $800-$1000 dollars in stores like REI, marine shops, and catalogs.

It is important to note that there is little benefit to "guessing" at the reference position of a base, then using that base for a differential correction. Remember that the "differentially corrected" data have only relative accuracy. Relative to the base location that was provided for the differential correction.

Question 4: If one of the mapping receivers, such as the Trimble GeoExplorer, is used as a base, would it be possible to get accurate-enough DGPS data using them in conjunction with the Magellan 5000 DX? That is, can the data collected by both units be post-processed to get DGPS results?
Answer: No. The 5000DX is not capable of storing data for post processing

Question 5: Does the Trimble Ensign XL also have these features, and would its cost and/or better compatibility with GeoExplorer receivers give it some advantage?
Answer: No. The Ensign is similar to the 5000DX in capability but superior in terms of performance. (By performance I refer to speed, ability to work under trees, lower price, "time to first fix", and other similar properties.)

Question 6: Do the S/A errors translate into the same geographical position errors when the same 4 GPS satellites are used with different receivers? It seems to me that they would, at least to IOTA accuracies. Then, it seems to me that the position of a rover site might even be recorded, or just written down, at a specific time with the 4 GPS satellites used for determining the position also noted.
Answer: Absolutely correct.

Question 7: Then, the data for those 4 satellites received by the base station at that time could be used to determine the base station's position with the same error as the rover site. The difference of the observed base station position minus its accurately-known (from 10 hours of data, or from prior geodetic survey knowledge) could be applied to the observed rover position. Couldn't then even cheap navigation receivers be used at the rover sites?

Answer: Yes. Absolutely. As long as you don't mind the inconvenience of doing GPS with paper and pencil. Also you must be very careful that base and rover(s) are using PRECISELY the same satellites at precisely the same time. Be sure to think ahead about how you plan to ensure that the receivers are all choosing the same set of satellites simultaneously. This is not a new idea. In general, it works well as long as you have:

1) continuous communication between all of the parties involved so that they can speak in 'real-time' (They must be able to communicate things like, "Right now I'm using satellites 1, 13, 23, 17, and 9. Which ones are you using now?")

2) receivers that ALL allow users to manually disable individual satellites so that they can force a specific receiver to track a specific set of satellites that somebody else is using...

3) you are able to tolerate the additional errors from occasionally using the "less than optimum set of satellites" because "the best set of satellites was not 'common' between receivers.

4) tolerance for the inevitable failures that will occur when one receiver simply cannot see a certain satellite that is absolutely required by the other receiver. This is a very common occurrence if any of the observation sites have any sky obstructions; such as mountains, trees, buildings, canyon walls or cliffs, etc.

Question 8: Would the accuracies be improved if this were done 5 or 10 times rather than once, over a period of an hour or more?

Answer: Probably no appreciable improvement. The accuracy from one observation would probably be better than 10 meters. Subsequent observations would have a similar accuracy.

Question 9: Of course, the base site would need a mapping-type receiver recording all of the observable GPS satellites.

Answer: In order to dependably record all observable satellites requires a minimum of 12 channels. (On brief, rare occasions, even 12 isn't quite enough.) A base that can track up to 8 satellite will work if you plan your work ahead of time.

Question 10: In the article, you mention multipath errors and the need to avoid large metal-sided buildings. A car parked too close to the receiver would also cause such errors, I would think. How far from the receiver should the car be parked to avoid this problem?

Answer: A car that is 10-15 meters away will probably not pose any significant problems. Given the much more significant problem of the unknown reference coordinates I wouldn't worry about this too much. Without a large glass building, I doubt that multipath will hurt you much. There should be no problem if the receiver is mounted on top of the car, since the car's roughly convex shape will reflect the signals away, and even if there were some multipath, the distances involved would be well under the IOTA requirement.

Question 11: GPS receivers can obtain UTC much more accurately than any foreseeable IOTA requirement, which I would say would be one millisecond. It would be valuable if a GPS receiver interface could be set up to provide audible WWV-like time signals and/or a video-recordable time display. Do you or the people at Trimble know of any such planned or existing interface?

Answer: Already done. If you call 1-408-481-7704 you will reach an automated faxback system. Ask for catalog three. One of the documents available in the catalog is a detailed description of the video interface.. As to the time code, the mapping receivers are all capable of generating and outputting a very stable 1 pulse per second (PPS) signal. Typically the lower cost receivers will not provide this... Be aware, by the way, of the 9 second offset (or is it 10 sec. now?) between GPS time and UTC. This is due to occasional leap seconds to UTC. Some receivers output UTC, but some give GPS time.

Question 12: Finally, I wonder if some arrangement to rent the expensive units, rather than buy them, might be worked out for eclipse trips, especially if my ideas above are impractical or won't work.

Answer: Many of the distributors who sell equipment offer rental programs. Some even offer "rent-to-own" deals!

Well, David (and Paul too), I hope this info helps. I think that you are on the right track. Your ideas are sound and I think that the lower cost equipment, such as a Scout or an Ensign, could be used creatively to obtain the 30 meter accuracy you require. The trade off would be for convenience and flexibility (considering time codes, etc.). Cheers, Chuck

[Relayed by Paul Maley, 1994 Oct. 4]

The following is from Mark Trueblood:

1. Concerning question 6 above: The numbers generated by a GPS receiver usually are not the result of a simple geometric calculation. Instead, they are an estimate generated by a complex algorithm that is not the same on all receivers from different manufacturers. It is highly likely they will agree for the same 4 satellites within IOTA accuracy needs, but not guaranteed. Different receivers track different numbers of satellites -- e.g., my

TRAXAR tracks 6 at a time.

2. The paper suggested that cheap, hand-held GPS receivers could not be used to record data. My TRAXAR has an RS-232 port that could be connected to a notebook computer and used to record positions and times, as well as the satellites used in the position estimate.

3. I use my GPS receiver inside a large metal van with an external antenna on top of the van. While multipath signals can introduce errors, this effect may be a bit overrated in the paper.

4. Although it is possible to get "GPS" time from a GPS receiver, often this is an extra-cost option. All the receivers I own or have used put out UTC. The GPS signal contains the offset between UTC and GPS time, and almost all receivers use this to generate UTC.

New PC-based GPS Receiver: Tom Van Flandern, Meta Research, purchased two GPS receivers, one that he used at his Eclipse Edge expedition site near the southern limit south at Codpa, Chile, on Nov. 3, and the other which Dunham used at his northern-limit site in Bolivia. It is a new model, PV6-EVAL, by Motorola, which seems to have the main features (recording for post-processing the signals of six observable satellites) of mapping receivers like the Trimble GeoExplorer, but with a price of about $1200 each. The unit is small, like many of the navigation receivers, but works with a laptop PC through a serial port, using the PC keyboard and display for control and its memory (and/or disk drive) for data recording (its reliance on the PC permits the lower cost). Tom saw one of the units demonstrated at the U.S. Naval Observatory in early October. Presumably, the recorded data will not be in a format compatible with the GeoExplorer data and post-processing software. But we hope that the post-processing software for both units will enable positions to be calculated at the same specified times and with the same specified set of satellites, in which case, it should be possible to calculate differential positions to 10m or better, at least well within IOTA's requirement of less than 30m. Of course, this assumes that data are recorded simultaneously by both units.

Mark Trueblood commented on the PV6-EVAL: It's interesting that Motorola used the serial port instead of a PCMCIA interface. That means they used the guts of the Traxar (which has a serial output) for this new box, and developed their software based on the National Marine Electronics Association (NMEA) standard (of which I have a copy, if you need it).

Data were successfully collected at both sites with the PV6-EVAL units at simultaneous agreed-upon times for three hours around the eclipse. One problem with the units is that they do not display the satellite ranges, as they are advertised to do. It is not obvious how, or if, the distance from a desired line of position can be determined without external calculations. We have not yet done the postprocessing. We will describe the results of that in a future article.

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## OBSERVATION REPORT: APPULSE OF PERIODIC COMET SCHWASSMAN-WACHMANN-1 TO GSC 1918 0124

by Roger Venable

Introduction: Periodic comet Schwassman-Wachmann 1, a large comet in a relatively circular orbit between the orbits of Jupiter and Saturn, is too faint to be seen visually with most telescopes. As seen from Earth, the comet passed close to two stars in early 1994: GSC 1918 0124 on January 20 and GSC 1904 0003 on February 10. The author observed the former appulse visually by recording the changes in the visual magnitude of the star during the appulse. Weather did not permit observation of the second appulse.

Methods: The prediction used for the appulse was published in the **1994 Asteroidal Occultation Supplement for North American Observers**. The prediction data made possible the identification of the appulse star. Comparison stars were found within the same telescopic field of view as the appulse star using the Guide Star Catalog [**Guide**, Version 2, (CD ROM), Project Pluto, Bowdoinham, Maine, 1993]. The telescope was a 40 cm German mount Newtonian with a focal length of 1800 cm, used at 144 magnifications, with a drive. Visual magnitude estimates and WWV time signals were recorded with a tape recorder. A magnitude estimate was made approximately every sixty seconds during the time of observation, from a site at longitude 82° 03'W, latitude 33° 29'N.

Results: The comparison stars were of (photographic) magnitudes 11.1 (GSC 1918 0405), 11.2 (GSC 1918 0211), and 11.3 (GSC 1918 0160). The appulse star (GSC 1918 0124) is of (photographic) magnitude 10.9. Careful comparison of the apparent brightness of the four stars revealed that their relative visual brightnesses corresponded very well, and in the same ordinal sequence, to their published photographic brightnesses. The appulse star was only 14 degrees from the zenith at the time of the appulse. The naked-eye limiting magnitude was about 4.5, and the limiting magnitude in the telescopic field of view was about 14.3. These limiting magnitudes were due to light pollution from the urban surroundings. No clouds or haze were seen or suspected. The seeing was estimated at 1.5 arc seconds. Comet Schwassman-Wachmann 1 was predicted to be at a visual magnitude of 19.7 and was not directly visible.

The star appeared to dim slightly, with a maximum decline of 0.2 magnitude, and this dimming occurred in two or three phases. Figure 1 is a graph of the magnitude estimates versus time. Figure 2 is a graph of the running median of three estimates, each estimate taken with the immediately preceding and following estimates. The mean of the 27 observations prior to 0544 UTC is 10.9, with a standard error of measurement of 0.03 magnitudes. Thus, the two fadings of 0.2 magnitudes represent deviations from the mean baseline of about six times the standard error. A Wilcoxon test for pair differences, comparing the 12 observations of the event from 0544 through 0555 UTC versus 12 observations that immediately preceded the event, yields a significance level of $p = 0.01$, one-tailed.

The time of closest approach of the comet to GSC 1918 0124 cannot be precisely determined, but would appear to be within a few minutes of 0550 UTC. This should be compared to the predicted time of closest approach of about 0551:35 for the observer's location.

Discussion: With a magnitude variation as slight as that detected here, one can question whether any change actually occurred. However, the technique of continuous observing allowed ample time to carefully consider magnitudes and the possibility of illusion. Using comparison stars both dimmer than and brighter than the index star would have been better, but the comparison stars available were quite good for this particular observation. The low standard error of measurement is consistent with this fortunate proximity of closely matched comparison stars. The perceived change in magnitude occurred at the correct time to correspond to the predicted appulse. The running median, the comparison of the standard error with the amplitude of the perceived variation at the time of the event, and the Wilcoxon test for pair differences all suggest that the variation in magnitude is real. It is thus likely that the observed magnitude variation was indeed caused by the obscuration of the star's light by the comet's coma.

It is common for a bright comet to pass close enough to a faint star that its coma or tail will pass in front of the star. At such times, visual estimation of changes in the star's magnitude is hampered by the effect that the surrounding nebulosity has on the estimate. The present observation was not so hampered, because the comet was too faint to be seen.

The images of Halley's comet taken by the Giotto spacecraft reveal that the gas and dust released from the comet emanate from active areas of the surface, rather than from the entire surface of the comet (Whipple, **S&T, 73** (3), pp 242-245, March, 1987). Digitally-processed, high-contrast telescopic images of comets reveal the comae to have spoke-like radial features consistent with streams of material being emitted from active regions on the surface of the nucleus rather than from the entire surface of the nucleus (Bortle, **S&T, 86** (1), pp 107-109,July, 1993). The biphasic dimming in the appulse reported here could have been the result of the obscuration of the star's light by two successive streams of material in the coma of the passing comet. If so, the character of this distant comet may be much like that of brighter comets that have been observed nearer to the Sun.

It is possible that future observations of appulses made by this and other distant comets may prove to be interesting. Magnitude measurements made using CCD's would have greater validity and reliability than visual observations such as reported here.

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## HOW TO OBSERVE 300 GRAZING OCCULTATIONS WITHOUT HARDLY TRYING

Harold Povenmire

In 1963, **S&T** published a map showing where the path of the grazing occultations of the star $\zeta$ Tauri would be visible. I noticed that the path would pass very close to the Perkins Observatory near Delaware, Ohio. On the evening of October 8, I went there and set up to observe this event. I saw the star appear to approach the edge of the Moon, hang there many seconds and then move away. I had just observed a MISS. If I had been a quarter of a mile farther south, I would have seen the star disappear and reappear behind the lunar mountains. I was disappointed but fascinated by the event and hoped to see other events in the future.

In late December 1966, I was visiting the Sacramento Valley Astronomical Society. Several of their members mentioned that there were going to be two grazes on December 18 and 20. I observed the first one, but the poor recording equipment prevented getting any good data. I spent the next day learning how to lay out the predicted limit from the predictions. I also observed the second graze, but still did not have good recording equipment, so the data were only of marginal value. By this time, I was hooked on grazes. The graze predictions were the product of an astronomy graduate student, David Dunham, who was sending them to interested observers.

My next goal was to set up and lead an expedition for a favorable graze. This came on August 25, 1967. We set up our equipment along the railroad tracks in Danville, California just before dawn. We made about 30 timings as the star disappeared and reappeared behind the lunar mountains. After seeing the results, I went around to the other astronomical societies and gave lectures to recruit more observers.

Only a few grazes occur in an area each year. If you are observing grazes, you have two choices; stay close to home and hope for clear skies for those few events or travel to where the other grazes are. Soon it was routine for us to pack three or four cars with observers and telescopes and take off for a graze 300 miles away to watch a star dance in and out of the lunar mountains for three minutes.

Our next chance came on September 30, 1967. A favorable graze of a 6.7-magnitude ZC 1436 was predicted to pass 20 miles south of San Jose, California. However, that area usually had fog and clouds off the Pacific Ocean at that time of the morning. I convinced other observers to drive out into the flat country east of the mountains to get better weather near Mendota, California, a 150 mile drive one way. The team decided that it was worth it and a large caravan made the trip.

The skies were clear and we had observers set up for a mile across the predicted limit. Nothing could go wrong. WRONG! About half of the observers had a MISS due to a bad star position. The good news is that we discovered that the star was a previously unknown binary and that we had very accurately determined the profile of the northern limb of the Moon. We also obtained about 49 timings which put us in the number ten place in the top ten best observed grazes.

We were still bragging three weeks later when the Santa Barbara, California graze team observed a very favorable graze and pushed us into eleventh place. Such is life.

Shortly after this, I returned to Ohio to finish a Master's Degree. I had been informed that there was a very spectacular graze of Antares with a crescent Moon predicted for January 25, 1968 through central Ohio. I did not get overly excited because winters in Ohio usually mean weeks of cloudy weather. The altitude of this graze was also very low at my location, but more favorable around Washington, DC where there was a large graze team. This graze also occurred on the morning of the day after final exams. I had three exams scheduled, so I couldn't really think about much else.

I laid out the graze path near Fairmont, West Virginia several weeks before the graze, but then put it out of my mind. The day of final exams came and a cold front had pushed through leaving clear skies and temperatures near zero. My area was clear and the Washington DC area was totally clouded. This meant that David Dunham and his team would be joining my little team.

We observed the spectacular graze and saw a new phenomenon, the spectacular 7-10 second dimming of the giant red star. This is caused by the lunar limb slowly cutting into the large angular diameter of the star. We also timed many events involving the secondary star.

On June 10, 1968, I was scheduled to receive my Master's Degree. The only problem was that there was another graze of Antares near Washington, DC at the same time. I did the only reasonable thing: I skipped the ceremony, assembled a small team, and headed for USNO.

We saw the graze and I headed for Cape Canaveral to work on Project Apollo. This allowed me to chase grazes up and down Florida and Georgia. On November 16, 1968 after driving all night through the rain, we attempted a marginal graze in the morning twilight near Indiantown, Florida. The weather cleared and the magnitude 7.6 star disappeared early. Shortly thereafter, I noticed a tiny speck of light grazing along the earthshine. We had just discovered that the star Z 11685 (SAO 138613) was a previously unknown binary.

The national goal of landing a man on the Moon was going to be attempted in July, 1969. This meant massive layoffs at the Cape and I was surely going to be one of them. I went to USNO to work for a month to learn about the observatory and its work, and to reduce some of the graze observations that had been made. I was already in the Washington DC area when Apollo 11 landed on the Sea of Tranquility on July 20, 1969.

One of the jobs I did at USNO was to assist Peter Espenschied, Joan Bixby, and Alan Wentink in reducing northern-limit grazes. It was obvious to us that the northern grazes were shifted in position angle around the Moon by about 0.3. This is the same shift that was known to occur with grazes on the southern limb but was then unknown on the northern limb. This discovery became a part of a paper which was published in the **AJ.**

While at USNO, I saw a tabulation of the total number of grazing occultations observed and the number of scientifically valuable timings made. I found that I had observed more grazes and made more timings than any other observer. This had not necessarily been my goal, but, rather, I wanted to be the most accurate grazing occultation observer. However, after seeing the numbers, I decided to keep the lead. If somebody else wanted to lose more sleep, get more mosquito bites, buy more gasoline and have a heart attack sooner than myself trying to break the record, I would accommodate them. So far, this has not happened.

On August 6, 1969, the waning crescent Moon was going to make a spectacular Pleiades passage. I made the trip to the vicinity of Kansas City, Missouri to join a local group to observe a very favorable graze of 19 Tauri, better known as Taygeta.

On the graze line, the view was beautiful. Taygeta was a bluish gem with the bright earthshine of the Moon moving up to it. As I saw the star disappear, I said to myself "this was a long drive but it was worth it". On the sixth event, Taygeta reappeared but only with half the brilliance. With an incredible surge of adrenaline, I realized that Taygeta was a binary. It was one thing to find that a faint, undistinguished star was a new binary, but not a naked-eye star named in Biblical times. This discovery was announced by the IAU telegram number 2168.

In the fall of 1969, I started teaching space science in a junior high school in the Cape Canaveral area. This gave me more opportunities to chase grazes and recruit smart students to be graze observers. These were the sons and daughters of men who were working on Project Apollo; they were a superior group of young people.

In the fall of 1970, I learned that there would be a spectacular graze of ι Capricorni over the junior high school on December 4, 1970. For five weeks, we mobilized every Cape worker, amateur astronomer, student, and anyone else who would listen and get a telescope to be on the four mile long line we had painted along the railroad tracks through Titusville, Florida. The skies were clear and we made 235 accurate timings of the event. I was back on the top ten, but this time we were Number One.

This record held for several years. On February 10, 1973, there was a favorable graze of Merope across Texas and the Florida Keys. I took my team to the Keys and we made a good observation. Large expeditions in Texas led by Paul Maley (Houston) and George Haysler (Austin) were very successful. The combined number of timings was slightly greater than that of the ι Capricorni graze.

In 1974, a friend who was in a sarcastic mood said to me, "You have worked hard on your graze work, but you don't even know what you know". I realized that he was right. I did feel like I had learned a lot about observing techniques and equipment, but it was not written down anywhere. When I realized this, I immediately went to the local drug store and brought a large package of cheap typing paper. During the next 23 days, I wrote the manuscript for the **Graze Observer's Handbook**. Once it was written, I put it away with no intention of publishing it. As events worked out, it was published the next year. The second edition followed about five years latter and, together, several thousand copies of them have been sold.

On early Sunday morning, September 6, I had a favorable graze of 119 Tauri near Key Largo. I set up along the famous Route 1 with the Atlantic Ocean on the east and the Gulf of Mexico to my back. As I set up, I noticed a "log" about 150 yards out in the Gulf. I observed the graze intently and, when it was over, I stood up to stretch. I noticed that the approximately 13-foot "log" was gone, but, barely 40 feet from me, were two eyes and two nostrils coasting in towards me without causing even a ripple in the water. I also recognized this very clearly to be the largest alligator I had ever seen. My next memory was of bolting out through the traffic on Route 1 and being quite shaken. I never saw the alligator again, but I have sincere doubts that he had good intentions.

On March 14, 1988, a graze was predicted to occur over Cocoa, Florida. There had been an aurora borealis the night before. When I turned on the WWV receiver, there was only static. I looked carefully at the northern sky and there was no sign of any activity. I walked back to the car to get my telescope. When I turned around, the whole northern sky exploded in a brilliant orange aurora that finally went deep into the southern sky. We observed the graze. The aurora was considered to be one of the top three of this century.

Another observation of special interest occurred on September 16, 1991. There was a graze of the bright star 151 G. Ophiuchi (ZC 2524) just south of Jacksonville, Florida. Several groups from around the state had mentioned that they were going to try to observe this graze. As I drove toward the observing area, the skies began to deteriorate and my expectations for clear weather were not high. At the site, the wind came off the ocean, as the sun went down, and dramatically cleared the clouds. The twilight was still so strong that the star was not visible until seven minutes before the first event occurred. After the star was in deep occultation, I noted a faint companion riding along the earthshine. This previously unknown companion remained visible for 119 seconds until the primary star reappeared and flooded it out.

On July 4, 1994, there was a barely-favorable graze of SAO 93376 over Ormond Beach, Florida. At the same time tropical storm Alberto was moving up the west coast of Florida. The skies stayed cloudy until a few minutes before the first contact. The profile indicated that only about two events were likely to be observed. When the graze was over, 18 events had been recorded and the star is almost certainly a binary as indicated by the multiple dimming events. It was also especially memorable as this was my 300$^{th}$ successful grazing occultation.

In all long-term observational endeavors like these, there are interesting statistics. Below are some of the more interesting ones.

1. By chasing grazes you can increase your chances of success over only attempting nearby, favorable events. I chase many marginal ones and over very long distances.

My success rate is only slightly above 50 percent. I have led more successful graze expeditions than anyone else. I have also led more failure expeditions than anyone else. In all, there have been more than 300 of each.

2. The distance to the Moon is approximately 240,000 miles. The distance that has been driven to chase these grazes is about 300,000 miles.

3. The combined magnitude of all the naked-eye stars in both the northern and southern hemispheres is approximately equal to 1024 first magnitude stars. The total combined magnitude of all recorded events from all grazes that this team has reported is approximately the same amount. When a team gets over 100 events by observing a graze of a first magnitude star, it contributes a significant percentage of this total.

4. The expenses of chasing grazes for nearly 31 years has been approximately $60,000. I have often been asked if it was worth the effort. My answer is a very firm "I think so". It will probably depend on how effectively these data are used in the future. Realistically, I have to admit that if I didn't spend the money on grazes, I would have spent it on something else, perhaps on something less productive.

5. I have often been asked if grazing occultation work is amateur or professional astronomy. My answer to this is: "It is professional astronomy which is done by advanced amateurs". Does it matter if a comet is discovered by an amateur or professional? The important fact is that the comet was discovered.

6. What have been the results of this effort? Teams I have led have timed approximately 4,413 grazing occultation events. In addition, about 610 timings have been made of total occultations, solar eclipses, and asteroidal occultations. These have been reported to the ILOC in Japan, David Dunham, and several agencies.

Another question that is often asked is "what factors allowed us to achieve the long string of successful observations". Here are some of these factors.

1. When I receive a batch of predictions, I go over them carefully and select those events which I think might be worth the effort. These I put on the calendar to avoid social conflicts.

2. It is my firm belief that highly successful major graze expeditions don't "just happen". The difference between a successful graze and a failure expedition is careful planning. If the event is close to home, I make a scouting field trip to look for trouble areas. This might include trees, noise, mean or loose dogs, power lines, map changes, or any other factors that might not be evident from a topographic map.

3. Running out of time is the most common source of observation failure. As a team leader, I am always on site more than an hour before the central graze to head off problems. My equipment is always assembled and checked 30 minutes before the first event.

4. Equipment failure is the second-most common source of observational failure. I always use two backup tape recorders and two WWV TimeKubes. Equipment that works fine in your air conditioned, nicely-lit front room does strange things 200 miles away on a country road at 4:30 AM. The success rule is know your equipment and have fresh batteries.

5. The strongest factor for long-term success is the ability to bounce back after several discouraging "cloud-outs". It is very easy to "get mad" at the sky and give up trying for awhile and, therefore, lose a couple of graze opportunities. Only a person who has been there knows the feeling of driving home with a tape recorder full of exciting events. Likewise, only the person who has been there knows the feeling of driving 300 miles to a graze on a week night only to be clouded out, realizing that he must drive back and work eight hours.

6. Weather is one factor which cannot be controlled to a significant degree. My attitude is not to worry about the weather. Often I don't even check the weather forecast. In Florida, the cloud situation can change so quickly that a prediction is of very little value. Determine that you will be on your station ready to observe regardless of the weather. You still may not get the graze, but your chances are surprisingly good. If you stay at home you are assured of no success.

It is a new field and always needs new people and new ideas. Anyone who really tries can do the work. No math or even an extensive knowledge of astronomy is needed. The feeling of success when you make a good observation, reduce the data, and properly report your results is very satisfying

[Ed. note: Harold also had a number of interesting things to say on his many other observations which we hope will be the basis for a future article.]

## PUBLISHER'S COMMENTS

Joan Bixby Dunham

This note gives a few comments on the production of the **ON**. This issue of **ON** is being produced with WordPerfect 6.0a for Windows using a ZEOS 486 computer, and printed with a Hewlett Packard LaserJet IIIp printer. Tony Murray now prints the **ON**, and added a cover to give the newsletter a more polished appearance.

Homer DaBoll designed a two-column format for the **ON** in 1979, using the IBM Selectric Letter Gothic type ball, which was then reduced by 84% in photo-offset reproduction. We have continued to use the two column format Homer established, although we are using the CG Times font, instead of the Letter Gothic font. Also, we no longer need to reduce the newsletter originals, making production slightly faster.

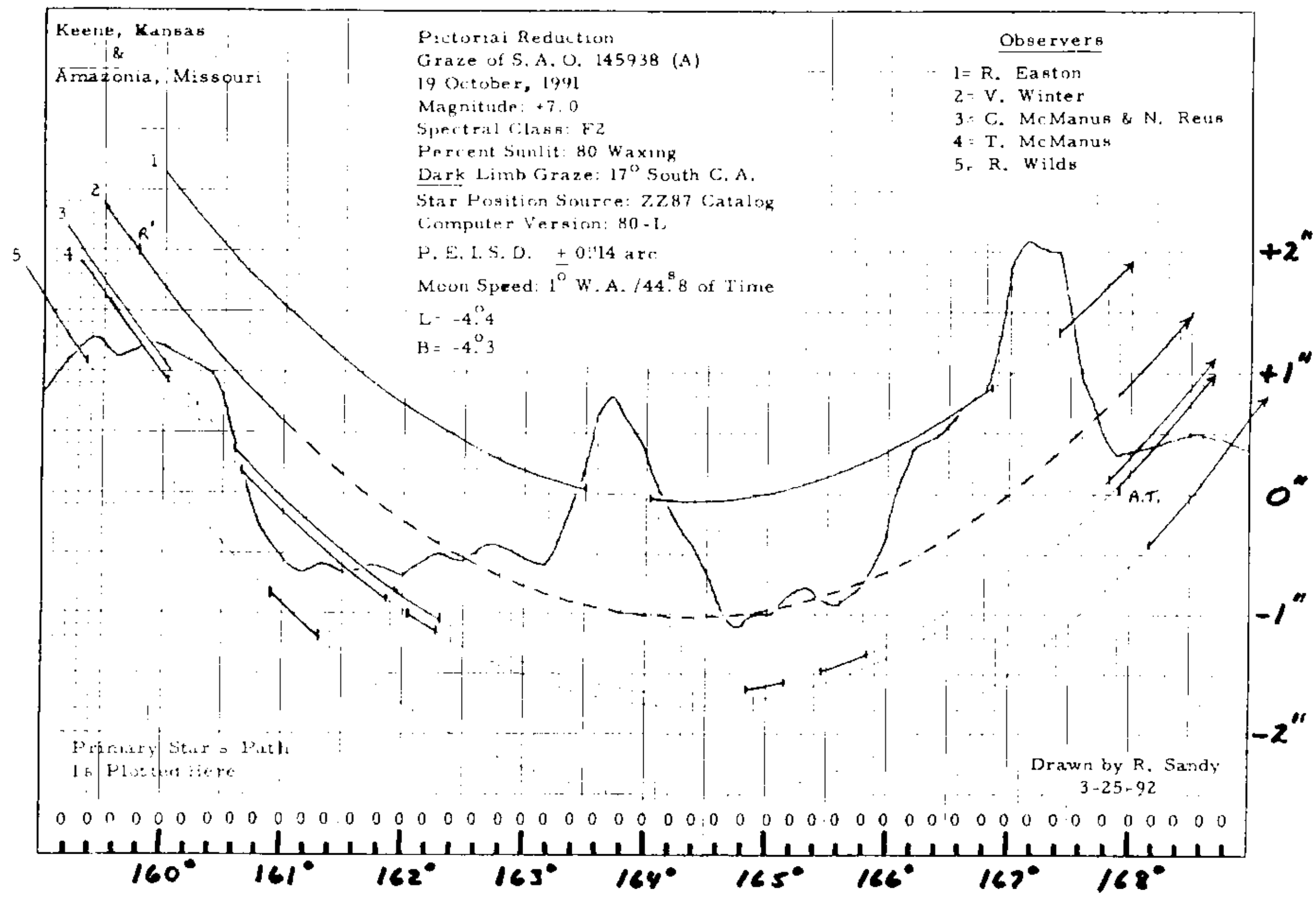
This issue was produced WordPerfect 6.0a for Windows (WPW6.0a). This editor has many powerful features that we do not use yet, such as the ability to embed graphics in the text. We were considering switching to another word processor (such as Word ) due to the great difficulty we experienced with WPW6.0, including a very high number of system crashes. However, the (free!) update, version 6.0a, does seem to have solved many of the problems. Other software we use for **ON** are Quatro Pro for Windows and Fox Pro for Windows. We occasionally resort to PCWrite. We can receive information electronically, including faxes, for inclusion in **ON**.

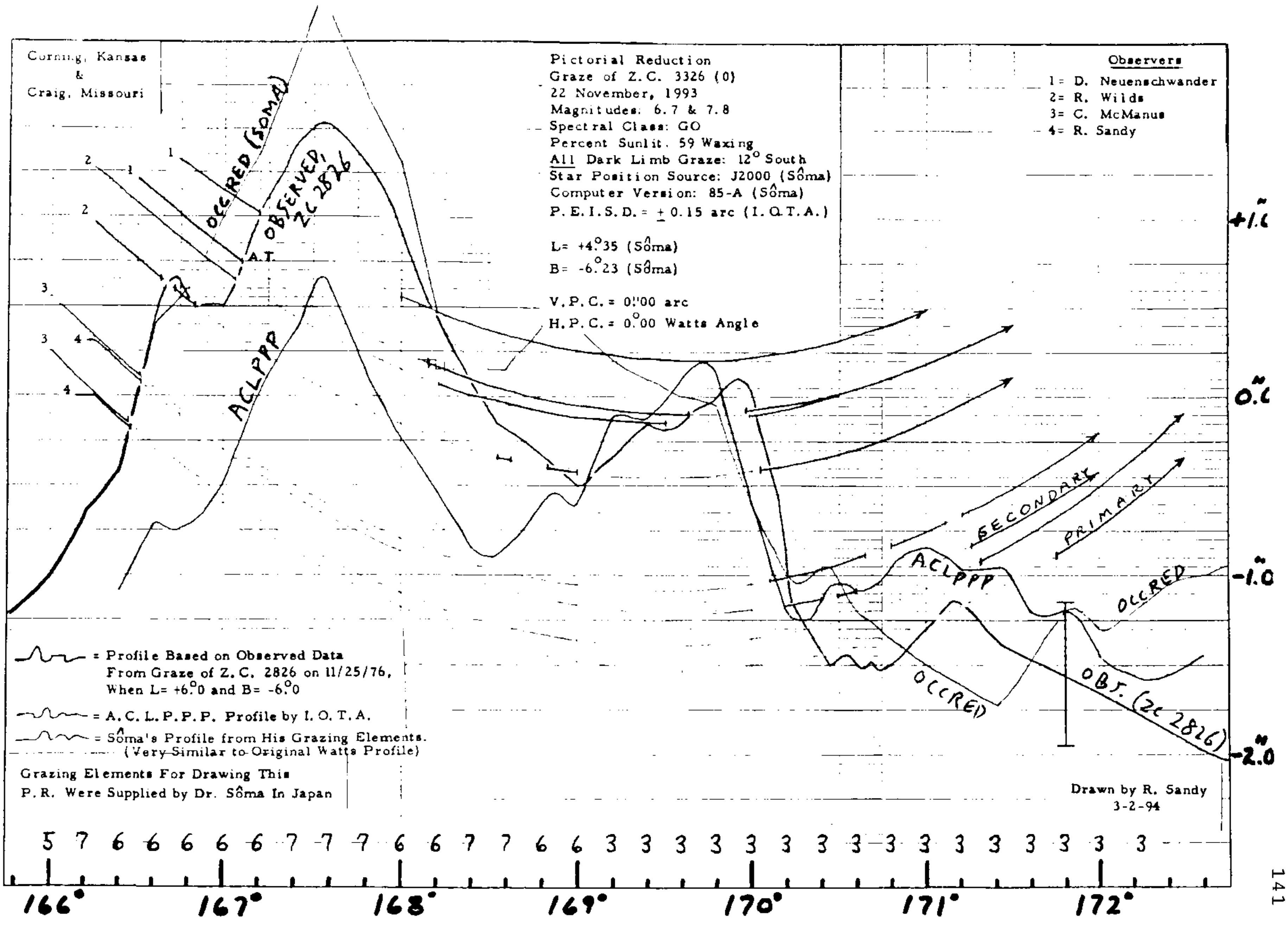
I have recently changed positions within CSC, and now am working on the EOS project after many years of working on various contracts for flight dynamics support at GSFC. I now have an e-mail address, joan@ulabsgi.gfsc.nasa.gov, as well as one through CCmail:

joan_dunham_at_seas-cpo@ccmail.gsfc.nasa.gov
I am currently using Eudora for my mail.

For those who want to exchange information electronically, we can read files from any version of WordPerfect, and from all of the older versions of Word. We have found that Word 6 and WordPerfect 6 are mutually exclusive: Neither recognizes the other's file format. I use Word 6 on the job, and both Macintosh and MS-DOS machines. If you send us a file that is not ASCII, let us know the software and version number that created it, so we do not waste time trying different ways to read it.

The computer firepower we now use, and the more powerful software that comes with it, has certainly eased the job of preparing the **ON**. The major problem with producing the **ON** is the same one it has always been: Writing articles for it. This is a distinctly different problem from taking newsletter input and crafting a snazzy (actually, in this case, rather staid) newsletter. If you have something you want to say, please do not hesitate. It does not have to be in a fancy word processor or format. It can even be in pencil on ledger sheets. And I will be happy to help you polish your text if you do not feel secure in your "wordsmithing" skills.





Corning, Kansas
&
Craig, Missouri
Pictorial Reduction
Graze of Z.C. 3326 (0)
22 November, 1993
Magnitudes: 6.7 & 7.8
Spectral Class: GO
Percent Sunlit: 59 Waxing
All Dark Limb Graze: 12° South
Star Position Source: J2000 (Sôma)
Computer Version: 85-A (Sôma)
P.E.I.S.D. = ± 0.15 arc (I.O.T.A.)
L= +4°.35 (Sôma)
B= -6°.23 (Sôma)
V.P.C. = 0".00 arc
H.P.C. = 0°.00 Watts Angle
Observers
1= D. Neuenschwander
2= R. Wilds
3= C. McManus
4= R. Sandy
OCCRED (SOMA)
OBSERVED, ZC 2826
A.T.
ACLPPP
SECONDARY
PRIMARY
OCCRED
OBS. (ZC 2826)
+1.0"
0.0"
-1.0"
-2.0"
= Profile Based on Observed Data From Graze of Z.C. 2826 on 11/25/76, When L= +6°.0 and B= -6°.0
= A.C.L.P.P.P. Profile by I.O.T.A.
= Sôma's Profile from His Grazing Elements. (Very Similar to Original Watts Profile)
Grazing Elements For Drawing This P.R. Were Supplied by Dr. Sôma In Japan
Drawn by R. Sandy
3-2-94
5 7 6 6 6 6 6 7 7 7 6 6 7 7 6 6 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3
166° 167° 168° 169° 170° 171° 172°

The International Occultation Timing Association was established to encourage and facilitate the observation of occultations and eclipses. It provides predictions for grazing occultations of stars by the Moon and predictions for occultations of stars by asteroids and planets, information on observing equipment and techniques, and reports to the members of observations made. IOTA is a tax-exempt organization under section 509(a)(2) of the (USA) Internal Revenue Code, and is incorporated in the state of Texas.

The ON is the IOTA newsletter and is published approximately four times a year. It is also available separately to non-members.

The officers of IOTA are:

| | |
|---|---|
| President | David W. Dunham |
| Executive Vice President | Paul Maley |
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Addresses, membership and subscription rates, and information on where to write for predictions are found on the front page.

The Dunhams maintain the occultation information line at 301-474-4945. Messages may also be left at that number. When updates become available for asteroidal occultations in the central U.S.A., the information can also be obtained from either 708-259-2376 (Chicago) or 713-488-6871 (Houston).

Observers from Europe and the British isles should join IOTA/ES, sending DM 40.-- to the account IOTA/ES; Bartold-Knaust Strasse 8; D-30459 Hannover; Postgiro Hannover 555 829 - 303; bank-code-number (Bankleitzahl) 250 100 30. Full membership in IOTA/ES includes the supplement for European observers (total and grazing occultations) and minor planet occultation data, including last-minute predictions, when available.

The addresses for IOTA/ES are:

| | |
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