References and Notes

1. F. A. Beach, in *Reproduction and Sexual Behavior*, M. Diamond, Ed. (Indiana Univ. Press, Bloomington, 1967), pp. 83–131.
2. The male's mounts without insertion, with insertion, and with insertion and ejaculation are clearly distinguishable by the morphology of the behavior, especially by variations in the movements of the hips and forelegs. Ventral views have amply confirmed the validity of the distinctions. The morphology of the female's masculine responses is identical to that of the male. However, we lack confirmation from ventral views that females displaying insertion responses have indeed achieved insertion of their phallus into the stimulus female, although in some cases they have an adequate organ to accomplish this. In this report the terms mount, insertion (intromission), and ejaculation refer only to the motoric pattern of behavior.
3. R. E. Whalen and D. A. Edwards, *Anat. Rec.* **157**, 173 (1967); R. E. Whalen *et al., Physiol. Behav.* **4**, 33 (1969).
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5. B. D. Sachs and R. J. Barfield, *J. Comp. Physiol. Psychol.* **73**, 359 (1970). The clustering of mounts in a bout is determined for scoring purposes by the mounting animal's behavior, rather than by elapsed time. If after a mount the animal does anything other than mount again, groom its genitalia, or orient itself toward the stimulus animal, then the preceding mount is assumed to have terminated the mount bout. The mount-bout period is the time from the first mount of one mount bout to the first mount of the next mount bout. This measure was termed the "inter-mount-bout interval" in Sachs and Barfield. Time out is the time from the last mount of one bout to the first mount of the next bout.
6. This experiment was conducted at Rutgers University. Long-Evans hooded rats were from Marland Farms, Wayne, N.J. Hormones in all three experiments were donated by P. Perlman, Schering Corp., Bloomfield, N.J.
7. The criterion for maters was a continuous display of mounting activity for at least 12 minutes after the first mount, or until ejaculation. Mating activity was considered discontinuous if there were more than 5 minutes between successive mount bouts. To be included animals must have achieved criterion in at least two tests. Of the animals that were excluded for failure to meet criterion, three females and one male did not mount at all, three males achieved criterion in one test only, and three females and one male mounted sporadically.
8. This experiment was conducted at the University of Connecticut. Long-Evans hooded rats were from Blue Spruce Farms, Altamont, N.Y.
9. The males had received two precastration tests. In order to better equate experimental variables, the first postcastrational test was omitted from analysis.
10. Further analysis revealed that those measures (ejaculation latency, number of intromissions, postejaculatory interval) that normally vary as a function of ejaculatory series did vary significantly with series in this experiment, indicating that the data were sufficiently reliable to detect expected changes in behavior. The obtained differences between groups in ejaculation latency and number of intromissions may again be attributable to differences in genital sensitivity. However, there were no significant differences between the two groups in phallic length, weight, or number of papillae (E. I. Pollak and B. D. Sachs, paper presented at Eastern Psychological Association convention, May 1973).
11. Holgate Ultrasonic Receiver, Holgate's of Totton, Southampton, SO4 3ZF, England.
12. R. J. Barfield and L. A. Geyer, *Science* **176**, 1349 (1972).
13. Supported by PHS research grants HD-04048 to B.D.S. and HD-04484 to R.J.B.

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Precision Selenodesy via Differential Interferometry

Recently (*1*), we described some astronomical applications of differential interferometry and the results from tracking the Apollo 16 Lunar Rover. The accuracy of this tracking and of similar interferometric observations of ALSEP (*2*) telemetry transmitters was degraded mainly by instrumental errors corresponding to uncertainties of tens of meters on the lunar surface. We report here the first results from the development and use of a new type of differential receiver to determine the relative locations on the lunar surface of two ALSEP transmitters. This receiver has made it possible to reduce random and systematic instrumental errors to nearly negligible levels—the equivalent of displacement uncertainties of centimeters on the lunar surface.

With the new differential receiver, the same S-band antenna, radio-frequency amplifier, frequency converters, and intermediate-frequency (IF) amplifiers are used to receive the signals from two ALSEP's simultaneously at each tracking station. Thus, the ALSEP signals, which originate at frequencies between 2275.5 and 2279.5 Mhz, appear at corresponding frequencies within an IF band centered at 10 Mhz. Any phase noise or drift introduced by the receiving system before this point (which includes all of the critical high-frequency portions) affects both ALSEP signals equally. From the IF signals, a system of phase-locked oscillators and single-sideband frequency converters then generates a frequency equal to 360 times the difference between the two ALSEP carrier frequencies, minus a constant bias (*3*). Cycles of this multiplied difference frequency are counted digitally. Subtraction of the numerical values of the counts obtained simultaneously at separate receiving stations yields the differential interferometric phase-delay observable.

This technique was used to observe the Apollo 12 and Apollo 14 ALSEP transmitters from stations in Merritt Island, Florida, and Goldstone, California (*4*), between approximately 06:30 and 12:30 U.T. on 28 October 1972. From these data we estimated four parameters representing the selenographic latitude and longitude of one ALSEP (*5*), the arbitrary initial value of the differenced counter readings, and the zenith delay of the atmosphere (assumed the same at both stations). The estimates for the relative positions of the ALSEP's are given in Table 1 and the postfit residuals in Fig. 1. The root-mean-square of the high-frequency "noise" in the residuals, equivalent in displacement on the moon to less than 15 cm, could easily have been lowered. The observations, spaced 1 minute apart and representing merely 0.05 second of signal averaging each, yielded formal standard errors of 50 cm for the components of the position on the lunar surface of ALSEP 14 relative to ALSEP 12. Had each point represented the full minute of averaging, the formal error would have been about 1.5 cm and the high-frequency "noise" correspondingly reduced.

With the random and instrumental errors reducible to such a low level, the accuracy in the determination of the relative positions of the ALSEP's becomes limited by other factors. We discuss these in order of increasing importance.

Differential effects of the neutral atmosphere influence the observable. These were modeled by a modified secant-zenith-angle law. At the beginning of the observation period when

Table 1. Solution for selenographic coordinates of ALSEP 14 from differential interferometry and coordinates of ALSEP 12. All coordinates except those describing the selenographic latitude and longitude of ALSEP 14 were held fixed at their nominal values, derived from analysis of Apollo Lunar Module tracking data (*13*). See text for a discussion of errors.

Site	Selenographic Latitude (°S)	Selenographic Longitude (°W)	Radius (km)	Baseline (km)
ALSEP 12				
Nominal	2.9903	23.4031	1736.000	
ALSEP 14				
Nominal	3.6656	17.4783	1736.393	
New minus nominal	−0.0412*	− 0.0221†		
ALSEP 12 to ALSEP 14				
Nominal				180.315
New minus nominal				0.531

* 1.249 km. † 0.668 km.

the elevation of the moon at Goldstone was 6°, the calculated value of the differential atmospheric delay was 0.2 nsec, equivalent to a 6-m displacement on the moon. One hour later, when the moon had risen to 17°, the equivalent displacement was less than 0.8 m. The accuracy of the differential interferometric phase measurements is so high, however, that using only the one data sample per minute we obtained for the estimate of the (undifferenced) zenith atmospheric delay a value of 7.1 ± 0.3 nsec, in good agreement with the expected average delay of about 7 nsec for these stations. Thus, inadequacies in our atmospheric model probably make only a small contribution to the error in ALSEP position determination.

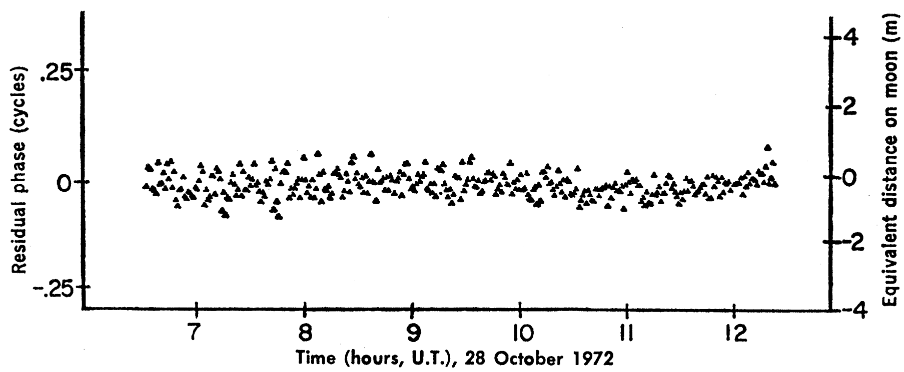

Fig. 1. Residuals (observed minus computed values) for differential interferometric phase delay observations of ALSEP 12 and ALSEP 14, expressed directly as fractions of a cycle at S band (wavelength, 13.2 cm) and as the equivalent (projected) displacement of an ALSEP transmitter on the surface of the moon. Each point represents 0.05 second of averaging but only one point is shown here for every minute of time (see text).

Systematic errors equivalent to about 30 cm of displacement on the moon may be introduced by differential ionospheric effects, which were ignored in our simple model. In fact, the abrupt increase of ionospheric density produced by sunrise at the Florida station may be responsible for the slight systematic trend of the residuals in Fig. 1. The failure of ionospheric effects to cancel completely in the differential observable is due mainly to the slight difference, about 1 Mhz, between the frequencies transmitted by ALSEP's 12 and 14. Use of a simple model to account for the ionosphere might reduce this error by 70 percent, the remainder being equivalent to a 10-cm uncertainty on the lunar surface. But this refinement will be of little value until improved tracking station coordinates and an improved lunar ephemeris are available (*6*), as discussed below.

Uncertainty in our present knowledge of the receiving station locations is believed to be of the order of 10 m; the corresponding error introduced into the determination of the relative ALSEP positions is about 1 m.

Errors in the lunar ephemeris (*7*) probably introduces errors on the order of 1 to 3 m in the differential interferometric determination of relative ALSEP positions. This estimate for the contribution of the lunar ephemeris errors to the uncertainty in the relative ALSEP positions follows from our assuming an uncertainty of 1 km in the position of the moon's center of mass and in the position of ALSEP 12 relative to the center of mass.

The largest uncertainty of all is concerned with the expression of the relative ALSEP positions in terms of a particular set of selenographic coordinates. One must know the relation of this coordinate system to those defined by the earth's rotation and the moon's geocentric orbital motion since the latter two most strongly affect the time variations of our observations. This relation is determined in essence by the lunar libration model used (*8*); differences between currently used models of the libration and the "correct" model might correspond to changes in the ALSEP 14–ALSEP 12 relative selenographic coordinates as great as 30 m (*9*). Of course, this strong dependence implies that similar ALSEP observations, if continued over a long period of time, would provide an excellent means for attacking the problem of determining the moon's physical libration (*1, 10*).

We should emphasize that the important sources of error discussed above, with the possible exception of the ionosphere, do not impose any intrinsic limit on the ultimate accuracy achievable. Thus, for example, when improved ephemerides become available for the moon (*11*), the differential interferometric data can be reprocessed to yield a corresponding improvement in the determination of the relative positions of the ALSEP's.

We conclude by listing the important advantages of this differential technique:

1) Tape recording of raw signals and subsequent cross-correlation of the recordings, the time-consuming hallmark of conventional very-long-baseline interferometry, are eliminated.

2) The experimenter can tell at the start of observations whether valid data are being obtained (*12*).

3) Neither highly stable local oscillators nor atomic frequency standards are required.

4) The cost of the accessory IF differencing and multiplying device, which makes it possible for nearly error-free differential interferometric data to be obtained by an STDN tracking station (*4*), is less than $200.

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1. C. C. Counselman III, H. F. Hinteregger, I. I. Shapiro, *Science* **178**, 607 (1972).
2. ALSEP is an acronym for Apollo Lunar Surface Experiments Package. These ALSEP observations, suggested by us early in 1969, were made in 1971 by the Spacecraft Tracking and Data Network when the presence of two ALSEP's made such differential observations possible.
3. C. C. Counselman III and H. F. Hinteregger, *Proc. IEEE* **61**, 478 (1973).
4. Stations of the Spacecraft Tracking and Data Network (STDN) operated by the Goddard Space Flight Center of the National Aeronautics and Space Administration.
5. By differential interferometry we are able to measure directly only the relative angular positions, that is, the relative ALSEP positions projected onto a plane perpendicular to the line of sight. Thus, we cannot yet determine the differential selenocentric radii of the ALSEP's. However, computer simulations show that the radius difference may be determined also, with uncertainty increased by about a factor of 3 over that for the differential surface coordinates, by combining observations made from different directions.
6. At such time, a further error reduction can be effected by observing all of the ALSEP's simultaneously and using the known frequency differences to separate ionospheric from ALSEP position effects. A multiplexing device, presently under construction, will enable all five ALSEP's to be monitored simultaneously at each STDN station.
7. We used the lunar ephemeris obtained by M. Slade [thesis, Massachusetts Institute of Technology (1971)] from analysis of about 50 years of optical observations, coupled with modern radar and spacecraft data.
8. The relative ALSEP position reported here is based on the physical libration model of D. H. Eckhardt [*Moon* **1**, 264 (1970)], with parameter values $\beta = 6.30 \times 10^{-4}$ and $\gamma = 2.28 \times 10^{-4}$.
9. This estimate is based on information provided by P. L. Bender (personal communication) on the effect of the libration model on the estimated selenographic coordinates of the laser retroreflectors.
10. The moon's physical libration is also ex-

pected to be determined with high accuracy from the lunar laser retroreflector data [J. D. Mulholland and E. C. Silverberg, *Moon* **4**, 155 (1972)].

11. The laser ranging experiment is expected to yield a significant improvement in the lunar ephemeris.
12. With this differential technique, relevant numerical data are displayed instantaneously and can be checked, for example, by means of a telephone conversation between the stations; with conventional very-long-baseline interferometry no such information is available until after the tape recordings are brought to a common location and processed.
13. Provided by I. M. Salzberg, personal communication.

14. Supported by contract NAS 5-11947 with the NASA Goddard Space Flight Center. We are indebted to J. Ryan, I. M. Salzberg, and W. Stonesifer of Goddard; J. McAllister of the Bendix Corporation; and personnel of the STDN for their essential contributions to these experiments.

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Short-Range Order and Crystallinity?

The substance of the report of Konnert *et al.* (*1*) is stated in their conclusion that "the comparisons with the functions calculated from crystalline phases of nearly the same density as the glasses imply a great similarity between glasses and crystals on the atomic level." Essentially this same conclusion was reached by Zachariasen (*2*) 40 years ago and experimentally supported very shortly after. In his abstract of a 1933 paper Warren (*3*) stated: "On the random network hypothesis it is postulated that the atoms are bound together in the same way as in the crystalline forms of silica, but forming a continuous noncrystalline network."

In the intervening years controversy has periodically raged, and silica glass has been called quartz-like, cristobalite-like, and now, by Konnert *et al.*, tridymite-like. One wonders what agreement might be found between their data and broadened Bragg diffraction peaks of keatite, a silica polymorph of known structure (*4*) with a density between that of quartz and that of cristobalite and a thermal expansion coefficient more nearly like that of vitreous silica. We are disquieted by the fact that fitting the x-ray data according to the tridymite model required a mixture of 11-Å and 20-Å particle sizes of a crystal whose unit cell size is about $82 \times 10 \times 17$ Å. Even more disquieting is the fact that the cristobalite structure must be added since "details at large *r* [interatomic distance] suggest the possibility of a small amount of cristobalite-like ordering." Konnert *et al.* have therefore proposed a crystallite model of at least two different sizes for regions having at least two different kinds of crystallites. This model is less satisfying to us than a random network model in which the Si–O–Si angle is the only structural variable. Random network models have been built and reported upon (*5*). It is clear that they can be extended indefinitely and that they may have an average density of 2.2 g/cm^3. It is also clear that peaks in the distances between Si–O, O–O, and Si–Si atoms taken in pairs in the largest of these models extend up to at least 12 Å (*6*). Mozzi and Warren (*7*) used a technique which eliminated the troublesome Compton scattering, thus allowing them to collect usable data over a larger range of data collection *s* than Konnert *et al.* They did not report structurally significant detail beyond 12 Å.

This lack of detail beyond 12 Å suggests that the extra detail comes from the data reduction procedures. Clearly then, either the procedures of Konnert *et al.* are a significant advance or the extra detail is spurious. It would therefore be of interest to know just how this detail changes with physically reasonable changes in the constraints imposed. In particular, will it change if the distance between near-neighbor Si pairs is allowed to vary as it does in the random network hypothesis? It is also of interest to inquire how the differences in fine detail, at all values of *r*, arise between the silica glass radial distribution function of Konnert *et al.* and that first published by Konnert and Karle (*8*).

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26 January 1973; revised 5 March 1973

We find the comments of Evans *et al.* to be a serious misrepresentation of the existing literature. On the one hand, they question the validity of the analysis of our experimental results and, on the other hand, they improperly attribute a significant portion of our results [the details in the pair function or radial distribution function (RDF) between 7 and 12 Å] to other investigators. In addition, they incorrectly imply that early investigators were aware of our new experimental results and the resulting implications concerning glass structure. We shall demonstrate here that Evans *et al.* have both quoted the literature inaccurately and have neglected to fully quote from pertinent sections of the cited work.

In our report (*1*) we showed that with the use of careful data collection and data reduction procedures we have been able to detect significant details in the RDF's of silica and germania glasses at considerably larger interatomic distances (to at least 20 Å) than have been previously reported by other investigators. This new detail is not compatible with the current concept of a complete random network, which, according to (*2*), could probably not produce detail in the RDF beyond 7 Å. Our diffraction data, however, are compatible with a structure in which the atoms are ordered over distances up to about 20 Å in arrangements similar to those found in the crystalline polymorph tridymite. No new experimental or theoretical data are presented by Evans *et al.* for comparison with our results.

We now point out a misleading citation of the literature. Evans *et al.* state that the authors of (*2*) report no structurally significant detail beyond 12 Å. This, we believe, implies that these authors reported significant detail out to 12 Å. This they did not do. They state that ". . . the vitreous silica curve showed no detail beyond about *r* [interatomic distance] = 7 Å. . . ." They also state, "This seems to be the last peak [the peak at $r = 6.4$ Å in the RDF for their random network model] which could be produced in the random type of network which we have been considering, and in fact no further peaks are observed on the measured pair function distribution curve."

Another inaccurate citing of the literature is the reference of Evans *et al.* to the model random network constructed by Evans and King (*3*). Evans