RESULTS OF MARINER MARS TRACKING CALIBRATION EXPERIMENT

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I would like to describe the Mariner-Mars 1971/USB Tracking Calibration Experiment – an experiment in which the Networks Directorate succeeded in using the Apollo Unified S-Band Tracking Network as a tool for determining very high accuracy geodetic parameters.

Early in 1970 the Networks Directorate was faced with the problem of determining center-of-mass station coordinates for the Apollo tracking sites which would be accurate to the ten-meter level. The site coordinate set in use at that time both at Goddard and at the Manned Spacecraft Center was derived from in-depth analysis of the S-Band Doppler data from the early Apollo missions. These coordinates had an associated uncertainty of 50 meters. At that time in 1970 we realized that the further analysis of Apollo data would not lead to ten-meter accuracy coordinates; different, more powerful techniques were required.

The Jet Propulsion Laboratory had used planetary transfer and encounter Doppler tracking data to determine ten-meter accuracy coordinates for the sites of the Deep Space Network. This fact, plus the realization that there was to be a mission to Mars in 1971 with a USB compatible transponder, led us to plan and carry out what came to be known as the MM71/USB Tracking and Calibration Experiment.

The experiment consisted of five tracking periods in which all USB sites tracked Mariner-9 in the three-way Doppler mode: These sites did not radiate the spacecraft, but only tracked the returning signal. The first tracking period began at launch and lasted ten days. The remaining four periods lasted five days each; one in July, two in October, and one in November after the spacecraft had achieved orbit about Mars. In total, well over 2000 hours of station contact time was logged.

In the experiment design phase we carried out error analysis which simulated accurately the type and amount of tracking data which we expected to receive. It also simulated the characteristics of the unmodeled systematic and environmental effects, and the statistical scheme to be used to reduce the data. This error analysis predicted that the resulting geodetic parameters should be in error by no more than five meters.

The reduction of the actual experiment data has proceeded in two phases. The first phase was, so to speak, "quick and dirty," and was completed last December – less than one month after the end of the final tracking period. The geodetic parameters which resulted from this preliminary data reduction were used at MSC to support Apollo-16 and Apollo-17.

This first-cut reduction, because of the speed with which it had to be completed, was not as thoroughgoing as the reduction which was simulated in the prelaunch error analysis. As a result, we could expect up to 15-meters error in the recovered station coordinates. This increased error budget was almost entirely caused by our lack of an ionospheric correction scheme. The final processing is now in progress and is being carried out in accordance with the prelaunch error analysis; in particular it involves sophisticated ionospheric modeling scheme.

I would like to describe some of the characteristics of the set of geodetic coordinates which we recovered in the preliminary data reduction.

We recovered longitude and distance of the earth's spin axis. We did not recover z-height, that is, distance north or south of the earth's equatorial plane. Deep space Doppler data is nearly insensitive to errors in z-height.

Using no a priori constants, we determined the geodetic parameters for all USB sites, both 9- and 28-meter (30 and 85 ft) sites. However, the coordinates of the 28-meter sites were known a priori with an accuracy of five-meters based on the coordinates of the colocated Deep Space Network sites. Figure 1 shows the differences between the Mariner recovered values in the 28-meter site parameters and the values of those parameters based on the DSN positions. The longitude agreement is outstanding. The spin axis discrepancies are within our predicted 15-meter error bound, and moreover they are in the direction indicated by the lack of an ionospheric model. These results suggest strongly that the 15-meter error bound is realistic.

Figure 2 shows the differences between the Mariner recovered parameters for the USB nine-meter sites and the values of those parameters used to support Apollo-14. One overriding conclusion can be drawn: The results of this preliminary data reduction have provided significant improvements to the USB geodetic parameters.

We have been able to compare the Mariner values of longitude and distance of spin axis for the nine-meter sites, with the same parameters derived from the GSFC 71 Geodetic Set. This coordinate set is a worldwide, center-of-mass network of geodetic positions determined at Goddard by Marsh, Douglas, and Klasko. The parameters are based on optical and laser observations of the GEOS satellites. The Mariner results and the GSFC 71 Set agree to

SITE	LONGITUDE DIFFERENCE (METERS)	SPIN AXIS DISTANCE DIFFERENCE (METERS)
GOLDSTONE, CALIF.	0	-12
MADRID, SPAIN	0	- 6
HONEYSUCKLE CREEK, AUSTRALIA	-3	+ 2

Figure 1. USB 28-meter prime sites geodetic differences (MM71 T and CE preliminary set less JPL location set 25).

SITE	LONGITUDE DIFFERENCE (METERS)	SPIN AXIS DISTANCE DIFFERENCE (METERS)
MERRITT ISLAND, FLA.	+33	−32
GREENBELT, MD.	+22	−60
BERMUDA	+64	−35
GRAND CANARY ISLAND	−6	+ 5
ASCENSION ISLAND	+27	+ 5
CARNARVON, AUST.	−22	+18
GUAM	+50	−29
KAUAI ISLAND, HAWAII	+4	0
CORPUS CHRISTI, TEXAS	+24	+17

Figure 2. USB 9-meter site geodetic differences (T and CE values less Apollo-14 values).

within ten meters rms. This is important, since the Mariner and GEOS results are based on very different techniques. The first is based on Doppler tracking of a spacecraft in deep space and is totally uncorrelated with the earth's gravity; the second is based on angle and ranging data of spacecraft in earth orbit and is closely tied to the earth's gravity. The two techniques now appear to be converging on the same world.

To sum up – what we have achieved so far?

One, our preliminary results have provided geodetic parameters with an accuracy of 15 meters for use in Apollo-16 and -17. Two, these preliminary results are in rather good agreement with the GSFC 71 Set. And three, we are on schedule with the final data reduction and expect to have five-meter-accuracy site coordinates by next spring.

I think we have established, as Figure 3 indicates, that USB Doppler data can provide geodetic information with accuracies comparable to those produced by laser ranging.

PROBLEM: DETERMINE GEODETIC PARAMETERS OF STDN USB SITES TO FIVE-METER ACCURACY FOR APOLLO AND SKYLAB PROGRAMS

SOLUTION: ALL STDN USB STATIONS TRACK MARINER-9 IN DEEP SPACE IN THREE-WAY DOPPLER MODE; USE THIS DOPPLER DATA TO DETERMINE GEODETIC PARAMETERS

RESULTS: PRELIMINARY RESULTS PROVIDE GEODETIC PARAMETERS WITH AN UNCERTAINTY OF 15 METERS FOR USE IN APOLLO-16

PRELIMINARY RESULTS AGREE TO WITHIN TEN-METERS OF THE GSFC 1971 GEODETIC SET

FIVE-METER ACCURACY ANTICIPATED BY SPRING 1973

NEW TECHNOLOGY:

ESTABLISH THAT USB DOPPLER DATA PROVIDES GEODETIC RESULTS WITH ACCURACIES COMPARABLE TO LASER RANGING DATA

Figure 3. Mariner-Mars 1971, unified S-band tracking and calibration experiment.