X-551-62-198

NASA TM X-55357

RADAR TRACKING SHIP PERFORMANCE DURING MA-8

PREPARED BY

MANNED SPACE FLIGHT SUPPORT DIVISION

OCTOBER 30, 1962

GODDARD SPACE FLIGHT CENTER

GREENBELT, MD.

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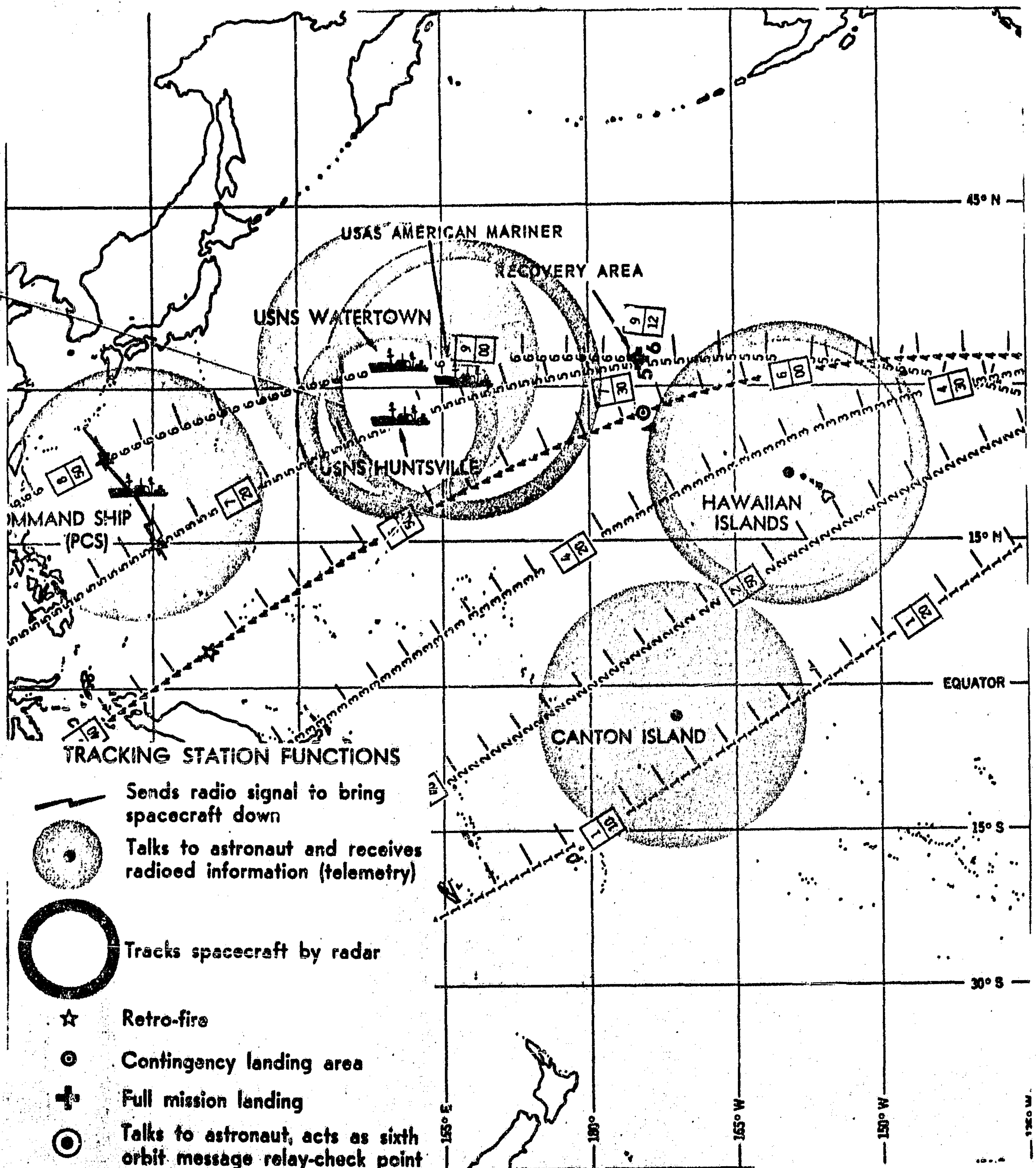


FIGURE 1

LOCATION OF TRACKING SHIPS DURING MA-8

The purpose of this report is to present the results of support provided by the USAS American Mariner (DAMP ship), USNS Watertown, and the USNS Huntsville for the Mercury MA-8 mission. The reader will be led through a discourse on the background of ship selection, preparation for support, and the actual results of the support.

MA-8 was planned by NASA/Manned Spacecraft Center as a test of astronaut and spacecraft performance beyond the original three orbit mission concept. To allow sufficient time for a daylight recovery, a Pacific Ocean landing was necessary. Further factors influencing mission planning required that the primary recovery area for the intended six orbit mission be located at the intersection of the fifth and sixth orbits, approximately 300 miles NE of Midway Island. This presented the Mercury Tracking Range with new problems for ground support in communications and tracking. Experience gained from MA-7 showed that telemetry readouts of capsule attitude might not give the reliability needed for landing point prediction. Radar data would be needed at the Goddard computers to define the reentry trajectory in the event of non-nominal retrofire. Since no island tracking station existed in the reentry corridor, a tracking ship was the only solution which would meet the launch date.

SHIP SELECTION

Informal discussion concerning tracking ships' support was carried on between NASA/GSFC, NASA/MSC, and DOD Mercury representatives. Ship capability and availability were considered. On June 5, NASA/MSC confirmed the requirement for tracking ship support and requested the PMR ship USNS Range Tracker in a message to DOD/Representative to Project Mercury. This requirement was acknowledged by DOD, but it was pointed out that the Range Tracker was currently committed to Joint Task Force-8. Estimates of JFT-8 release date and NASA/GSFC estimates of the time required to qualify the shipboard systems for integration into the Mercury Network indicated that the ship would be available. The JTF-8 scheduled release date, however, was later extended into conflict with the Mercury schedule. DOD then proposed the use of the two S-band trackers, USNS Watertown and USNS Huntsville, in lieu of the Range Tracker. On August 8 NASA/MSC adopted DOD's alternate proposal.

NASA/GSFC was given the responsibility of evaluating the ships and determining their readiness for mission support. On August 15, a meeting was held at Pacific Missile Range between representatives of PMR, NASA/MSC, and NASA/GSFC. The discussion covered the capability of shipboard instrumentation and modifications which would be necessary to meet NASA requirements. These requirements were as follows:

The ship would:

1. Send radar tracking data in near-real-time to the Goddard computers for landing point computation.
2. Track and record the telemetry signal and use the pedestal readouts as an acquisition aid.
3. Provide telemetry readouts visually recorded for the information of flight controller (s).
4. Provide UHF air-to-ground voice communications between the capsule and flight controller (s).
5. Provide primary and backup HF point-to-point communications for radar data transmission and mission control.

(A list is given in appendices 1 and 2 of the major components in the shipboard systems and modifications which were made to meet the above requirements).

A NASA/GSFC team visited the ships and gathered equipment specifications. At a meeting of the Manned Space Flight Support Division at Goddard, a tentative test plan was devised. Obviously, considering the time required for system modification and sailing to the on-site position only an abbreviated evaluation could be done. Proven Mercury testing procedures were changed to suit the special requirements of the equipment and brief time available. Mercury Detailed Systems Test documents, where applicable, provided standards for equipment calibration and alignment.

Further investigation indicated that equipment specifications were the only evidence of the probable accuracy of the radar data. A NASA instrumented aircraft was sent to PMR to determine system accuracy and give tracking experience on a Mercury beacon. As soon as equipment modifications were ready for testing, PMR and NASA/GSFC began a cooperative test program of dockside and sea trials.

A brief synopses of test results are given below:

August 25 - September 6

Numerous discrepancies were found and corrected.

1. insufficient test equipment on board.
2. 15 minute timing error noted in HTV time standard.
3. Biases of 2400 yards in range, 2 degrees in azimuth, 1 degree in elevation were noted in the WAT radar.
4. HTV radar was inoperative, HTV and WAT AGAVES were inoperative, Mark 19 gyro compass on HTV was inoperative.
5. Telemetry standby antenna (single helix) mounting broke and was replaced.

6. WAT radar become inoperative.

September 6, 8, 11

HTV and WAT remained dockside with the NASA aircraft flying various patterns to simulate angular rates to be encountered while tracking a Mercury capsule. A land based FPS-16 also tracked the aircraft as a standard of comparison. The following results were determined:

SHIP	COORDINATE	BIAS	STANDARD DEVIATION (1 SIGMA)
HTV	S/R	190	±20 yards
	AZ	-.52	±.07 degrees
	EL	.25	±.05 degrees
WAT	S/R	130	±30 yards
	AZ	.3	±.03 degrees
	EL	.15	±.05 degrees

(Note: Test results given are a composite of several days testing and are intended to give only an idea of magnitude)

September 7, 11, 12

Sea trials were run with a land based VERLORT radar tracking a beacon on the ship to get an estimate of ship's position. However, the uncertainty in ship's position (due to multipathing and system biases in the land based VERLORT) made it impossible to interpret the results to better than one degree. The tests only indicated that the stable platforms were functioning.

The ships had to leave for their on-site position no later than September 13. No further tests were possible to seek further system improvement*. Indeed PMR stated specifications for the data systems indicated that these specifications were actually equalled. NASA/GSFC advised the Manned Spacecraft Center of the test results and advised that confidence in repeatibility was extremely low. NASA/MSC made the decision to use the ships for telemetry and communications purposes with radar data to be taken for evaluation.

DAMP SHIP REQUESTED

On September 14, NASA/MSC presented DOD Range Management the requirement for the DAMP ship. The ship was released from its assigment with JTF-8 and placed under the command of PMR officially on September 29. Its only requirement was to attempt to acquire and track the Mercury capsule C-band beacon and transmit radar data in near-real-time to be processed by the

* The test descriptions do not give due credit to the PMR and NASA people who worked long and hard to ready the ships for their sailing date. In several instances, people worked twice as much overtime as they could be paid. Many thanks.

Goddard computers. In anticipation of its suppport of MA-8, the DAMP ship had left Hawaii on September 18 for its on-site position. Tests were run the afternoon of the 18th with the NASA instrumented aircraft to determine the feasibility of beacon interrogation using the two FPQ-4 mono-pulse radars to supply the required coded pulse separation. The test indicated that the beacon could be successfully interrogated. On September 19 the aircraft rendezvoused again with the DAMP ship. During this test the telemetry tracker and UHF communications were also checked. All systems performed satisfactorily. These tests indicated that the DAMP ship was capable of supporting the Mercury MA-8 mission. (Appendices 1 and 2 contain a list of equipment on-board and modifications which were necessary).

ESTABLISHMENT OF COMMUNICATIONS AND DATA LINES

Original plans for data lines assumed that PMR-Navy circuits were available for sending data from the Huntsville and Watertown to the PMR computers for reformating and retransmission to Goddard. The computer at Point Mugu was the primary data link and the one at Point Arguello was backup. However, investigation by PMR indicated that their lines were inadequate to the task without a large investment in new equipment. Goddard communications experts looked into the matter and advised that reliable communication could be established with switching at Honolulu, Goddard, and the Pt. Arguello Mercury Station. The plan would utilize existing Mercury lines between Hawaii and Goddard, and Pt. Arguello and Goddard. Using this scheme the data would be routed from the ships to Goddard in the ship format, sent to the PMR computers for reformating, then sent back to the Goddard computers. Since this was probably a one time operation the expense of providing equipment for a more optimum system was not justified. Radio communication between Hawaii and the ships (WAT and HTV) would be handled by both ships copying Hawaii transmission and the Huntsville transmitting to Hawaii through the Watertown. Each ship had alternate data routing to Hawaii. Data lines tests and CADFISS checks (the lines included the California computers) were scheduled daily from September 14 to October 2. At first, tests gave poor results since all shipboard radio equipment was in use and when frequency changes were necessary, communications had to be broken. The Watertown and Huntsville put into Wake Island five days before mission day for additional transmitters, receivers, and operators. The scheduled tests on October 1, 2 and 3 showed greatly improved reliability. Pre-launch CADFISS tests on October 3 showed excellent data transmission reliability at that time of day.

Data from the DAMP ship was to be transmitted to Hawaii where it would be patched into the Mercury Communications Network at Honolulu Telephone Company. Reformating of DAMP ship data would be performed at Goddard. Pre-mission testing of voice and data lines between the DAMP ship and GSFC was attempted with unsatisfactory results. The lack of good voice and teletype communications can be attributed to the fact that there was insufficient time to engineer a reliable system.

TRAINING OF PERSONNEL IN MERCURY PROCEDURES

The work which was necessary to bring the *Huntsville* and *Watertown* to a state of readiness allowed little time for formal training in Mercury procedures. Personnel of both ships were briefed on their function in Project Mercury. NASA/GSFC representatives worked closely with the shipboard people during the aircraft tests, explaining acquisition and tracking techniques used when tracking the Mercury capsule. Special emphasis was placed upon the upcoming radar slew and data flow tests (CADFISS), network simulations, countdown procedures, and mission time network operations.

Due to the short time involved it was felt that the Standard Operating Procedures on-board the DAMP ship must suffice in meeting Mercury support requirements

MISSION SUPPORT

The *Huntsville* supported the mission from the position of 27°13.5'N and 159°28'E. The ship was to provide radar track and telemetry information on orbit five. A secondary role was to provide backup tracking for the Watertown on orbit six. The Watertown supported the mission from 31°N and 159°E. Its function was to provide radar track on reentry, UHF ship to capsule voice communications, and record and display telemetry information for Flight Controller use.

During orbit five the Huntsville acquired radar and telemetry track at horizon crossing. Approximately six minutes of data was taken and recorded. UHF communication between the ship and capsule was satisfactory. Signal levels appeared to be nominal. The ship reported in a post pass report that personnel and instrumentation performed as well as could be expected.

It is unfortunate the Watertown was unable to display its full capability due to a complete power failure. This occurred at its acquisition time on the fifth orbit. The cause was found to be an overloaded generator. Power was restored within 95 seconds by switching to a alternate generator. The acquisition aid (AGAVE) and telemetry receiver were the only systems returned to operational status. These systems produced over five minutes of data. This was of value to the Flight Controller although it was uncorrelated with timing information. Mission planning included a test of simultaneous radar track between the HTV and WAT. This was not possible due to the power failure.

The AGAVE antenna is located on the deck of the WAT and HTV, totally obstructed by the bridge in the aft direction. The forward structure blocks its view at elevations below forty degrees. The WAT had a low elevation angle for orbit five and the heading was changed from 130 to zero degrees to allow the AGAVE antenna to track off the starboard side. The maneuver was practiced a number of times and worked very well during the fifth pass. The elevation angle during orbit six was high enough to eliminate the necessity for the WAT to maneuver. The HTV performed a similar maneuver on the sixth orbit which was at low elevation for it.

The Watertown's acquisition aid system made contact with the capsule initially at one degree elevation angle. It tracked through the point of nearest approach and lost signal at blackout. Telemetry blackout apparently occurred at ten degrees elevation angle. A total of five minutes of telemetry data was produced. The radar first acquired the target in automatic track momentarily at four degrees above the horizon. It reacquired at forty-five degrees elevation angle and tracked through the point of nearest approach. The signal was lost at sixteen degrees elevation. It was discovered immediately after the pass that the raddr had been operated in the wrong range interval causing a 410,000 yard error in range.

The Huntsville was also successful in tracking the reentry pass with the acquisition aid system. It recorded telemetry information but was unable to accomplish a radar track.

There was a lack of confidence in communications reliability between the WAT and HTV, and Hawaii during the premission time. However, launch day communications held up extremely well.

The DAMP ship arrived at the assigned on-site position (165°30'E, 31°40'N) on October 1. This location was selected by NASA/MSC to allow radar coverage on both orbit five and six. The location of the FPQ-4 radars on the aft portion of the ship made it necessary that the ship be positioned with her stern pointing toward the orbit during the pass. To insure a horizon-to-horizon track, the ship went through a turning maneuver described below:

> On orbit five the ship remained on a base course of 17° speed full ahead for 100 seconds after capsule horizon time. It then turned port to a heading of 300° and remained on course for the duration of the pass. On orbit six the ship maintained a heading of 128° for 90 seconds after capsule horizon time then turned starboard and maintained a heading of 225° for the duration of the pass.

The operations plan for the DAMP ship designated radar #1 (TR-1) as the primary data source. Radar #2 (TR-2) was to be slaved to radar #1. The primary acquisition source was to be the analogue designation computer, using acquisition messages from GSFC as inputs. Backup acqusition would be the acquisition aid after elevation lock on at 15°. A time list of events during the mission follows: ("A" time refers to the time at 1° elevation. All times are approximations).

ORBIT 5

TR-2 was slaved to TR-1 in analogue mode.

A-3	TM contact
A+1	Acquisition aid locked on in azimuth
A+5	Weak beacon returns seen by TR-1
A+60	TR-1 locked on target
A+75	Beacon faded into noise, dropped track
A+120	Acquisition aid locked on in elevation
A+140	Reacquired from acquisition aid
A+190	TR-1 dropped track
A+240	TM L.O.S.

Telemetry contact was maintained from horizon-to-horizon. Eleven radar data points were obtained for orbit five.

ORBIT 6

TR-2 slaved to TR-1 in analogue mode.

A-3	TM contact
A+2	Acquisition aid locked on in azimuth

A+10	Weak beacon returns were seen by TR-1
A+120	Acquisition aid locked on in elevation
A+125	TR-1 and TR-2 slaved to acquisition aid
A+170	TR-1 locked on to target, TR-2 remained slaved to acquisition aid
A+230	TM blackout, TR-2 slaved to TR-1, dropped track

Telemetry contact was maintained from horizon-to-TM blackout. Six radar data points were obtained for orbit six.

Communications between GSFC and the DAMP ship during the mission varied from poor to non-existent. All TTY messages from liftoff until shortly before splash were badly garbled.

DAMP ship acquisition messages were obtained by voice from the PMR voice communications network in Hawaii. All eleven data points on orbit five and four of the six data points on orbit six, transmitted by the DAMP ship were received by GSFC on mission day.

DATA ANALYSIS

The Mercury real-time programs were to receive reentry data for landing point prediction. It was decided that data taken on the fifth orbit would be evaluated "off-line" to give an idea of what might be expected on orbit six.. After a look at this data it was thought best to take a closer look at the reentry data before it was used "on-line". The data was not needed since retro-fire was perfectly normal. It is fortunate that it was since post flight evaluation of the data showed that it was of little value. The following is a summary of the data quality:

The data as collected by the three ships is shown on plots 3-1, 3-2, 3-3, 3-4. The data which was expected is shown on 3-11, 3-12, 3-13, 3-14. The residuals, or observed minus computed, are shown on plots 3-5, 3-6, 3-7, 3-8, 3-9, 3-10. The graphs are all plotted to the same scale, with the measurement (range, azimuth, elevation) or the residual plotted versus Greenwich Mean Time. The scaling is not uniform for range on 3-9 due to large bias.

Table 1 reflects the apparent errors on the data. The best estimate of the orbit is compared to the data. An R.M.S. value is computed from the residuals and the biased deviation in the data is approximated. The second step is to fit the equations of motion to the ships' data without regard to the determined orbit. This is roughly equivalent to adding the bias to the standard of comparison rather than removing the bias from the observations. The standard deviation is identified as the unbiased deviation. Guaymas, Mexico data taken shortly after the Huntsville amd DAMP ship on the fifth orbit is shown for comparison.

ORBIT	SHIP	NO. OF DATA POINTS	RANGE R.M.S. (YDS)	RANGE STD. DEV. (YDS)	AZIMUTH R.M.S. (DEG)	AZIMUTH STD. DEV. (DEG)	ELEVATION R.M.S. (DEG)	ELEVATION STD. DEV. (DEG)
5	HTV	49	±3022	±1900	±2.5	±.27	±.24	(a)
5	DAMP	11	±1860	±485	±3.5	±1.2	±.2	(a)
6	WAT	12	397,030(b)	±2700	±2.3	±.1	±1.5	±.47
6	DAMP	6	10,160(b)	±250	2.6(b)	±.08	1.8(b)	±.09

(a) Standard Deviation is not defined since STD. DEV. exceeds R.M.S.

(b) Bias only

ORBIT	SHIP	NO. OF DATA POINTS	RANGE R.M.S. (YDS)	RANGE STD. DEV. (YDS)	AZIMUTH R.M.S. (DEG)	AZIMUTH STD. DEV. (DEG)	ELEVATION R.M.S. (DEG)	ELEVATION STD. DEV. (DEG)
5	*Guaymas, Mexico	38	±455.5	±44.8	±.16	±.125	±.17	±.08

* Data was taken by a VERLORT radar tracking at a maximum elevation of 9.8 degrees.

TABLE 1

HUNTSVILLE DATA (3-1) Looks smooth after point of closest approach, but azimuth and range appear biased. The inclination of the orbital plane is skewed 1.4 degrees (33.9 degrees) by the data. The computed perigee heighth is 2.3 miles too low. Twenty-one measurements, principally azimuth and elevation, were rejected as being spurious.

DAMP SHIP (Orbit 5) Data is definitely biased in azimuth in the last eight observations. The first three and next six azimuth measurements are biased from each other by nearly three degrees. The first three fit the orbit much better than the last eight. The last two azimuth measurements were assumed to be unusable. Perigee is defined 20.6 miles too high and the orbit inclination is given as 33.24 degrees.

WATERTOWN Data is heavily biased in range and extremely rough in the angles (3-9). It was not analyzed any further.

DAMP SHIP (Reentry) The orbital plane is fairly well defined, but the height of the capsule was defined as being five miles too low. Noise in the data does not allow good convergence with only six data points.

SUMMARY

The errors noted are not broken down as to probable cause. However, it is obvious that ships' position is a serious cause of error in the real-time computing of orbits. In the analysis of the data other large biases are found to be present and the adjusting for ships' position or motion is not feasible. The Huntsville data does show some reduction in bias when the position is moved. However, it is felt that this ship was probably not out of position by 90 miles. The reader is left to his own devices in assuming the specific cause of the errors.

EPILOGUE

The Range Tracker tracked the Mercury capsule on its second orbit. The ship was at dockside at Johnston's Island and pitch and roll was not a problem. A brief analysis is included in appendix 4.

APPENDIX I

The equipment used in support of MA-8 are as follows:

I. USNS Watertown and USNS Huntsville

1. Telementry System

2 each	Nems-Clark receiver, Model 1412
2 each	Nems-Clark receiver, Model 1432
1 each	Nems-Clark preamplifier, Model PR-203
8 each	Data Control Systems discriminators Model GFD-3
2 each	CEC magnetic tape recorders, Model 2500
1 each	ITT Oscilloscope, 17 inch, Model 1735D
2 each	Brush six channel pen recorders

2. HF (High Frequency) Transmitting and Receiving Equipment covering the 2 to 30 MC Frequency Spectrum is as follows:

2 each	Collins KWT-6 Transceiver, 500 W Peak
2 each	Collins 310F-6E/204F-1 Exciter/Amplifier Transmitter, 2.5 KW Output
2 each	Collins 50E6 Receiver
5 each	Collins 51J4 Receiver

3. UHF (Ultra High Frequency) Transmitting and Receiving Equipment covering the 200 to 400 MC Frequency Spectrum is as follows:

2 each	AN/GRC-27 Transceiver

4. Teletype and associated equipments: (60 wpm Capability)

- 2 each — TT-48A/UG Teletypewriters
- 2 each — AN/FGC-25 Teletypewriters, including:
  - TD or Transmitter Distributor (2 Each)
  - Reperforators (2 Each)
- 2 each — Tone Keyers
  AN/URA-8B Frequency Shift Converter
  Comparator Groups

5. Antenna Systems supporting the Communications Equipment:

- 2 — Long Wire Antennas
- 1 each — Discone HF Antenna
- 1 each — 11 MC Yagii Antenna
- 1 each — 15 MC Yagii Antenna

6. Miscellaneous Communications Equipment:

- 1 each — Magnecord Recordor/Reproducer for recording all voice transmissions
- 1 each — 44-MC Interoffice System
- 1 each — 1 MC Paging and Addressing System
- 1 each — KY-123 Beacon Keyer
- 1 each — Stromberg Carlson Two-Way Interphone System

7. Radar, S-Band, AN/SPQ-8

8. PMR/GUQ-4, Dual Timing System

II. USAS American Mariner

1. Two AN/FPQ-4, C-Band radars.
2. Cubic Acquisition aid.
3. Nems-Clark 1432 telemetry receiver.
4. Random access solid-state digital computer (RADAP-C).
5. Disignation and stabilization analog computer with Mark 19, MOD-3, gyro compass.
6. Ampex FR-100 14 track magnetic recorder.
7. CEC 14 track ascillograph
8. Communications equipment as follows:
   a. 1 each HF transmitter, 1 KW
   b. 1 each HF transmitter, 3 KW
   c. 1 each HF transmitter, 10 KW
   d. 7 each HF receiver
   e. 1 each UHF receiver, AN/GRC-27

APPENDIX II

The modifications of equipment used in support of MA-8 are as follows:

I. USNS *Watertown* and USNS *Huntsville*

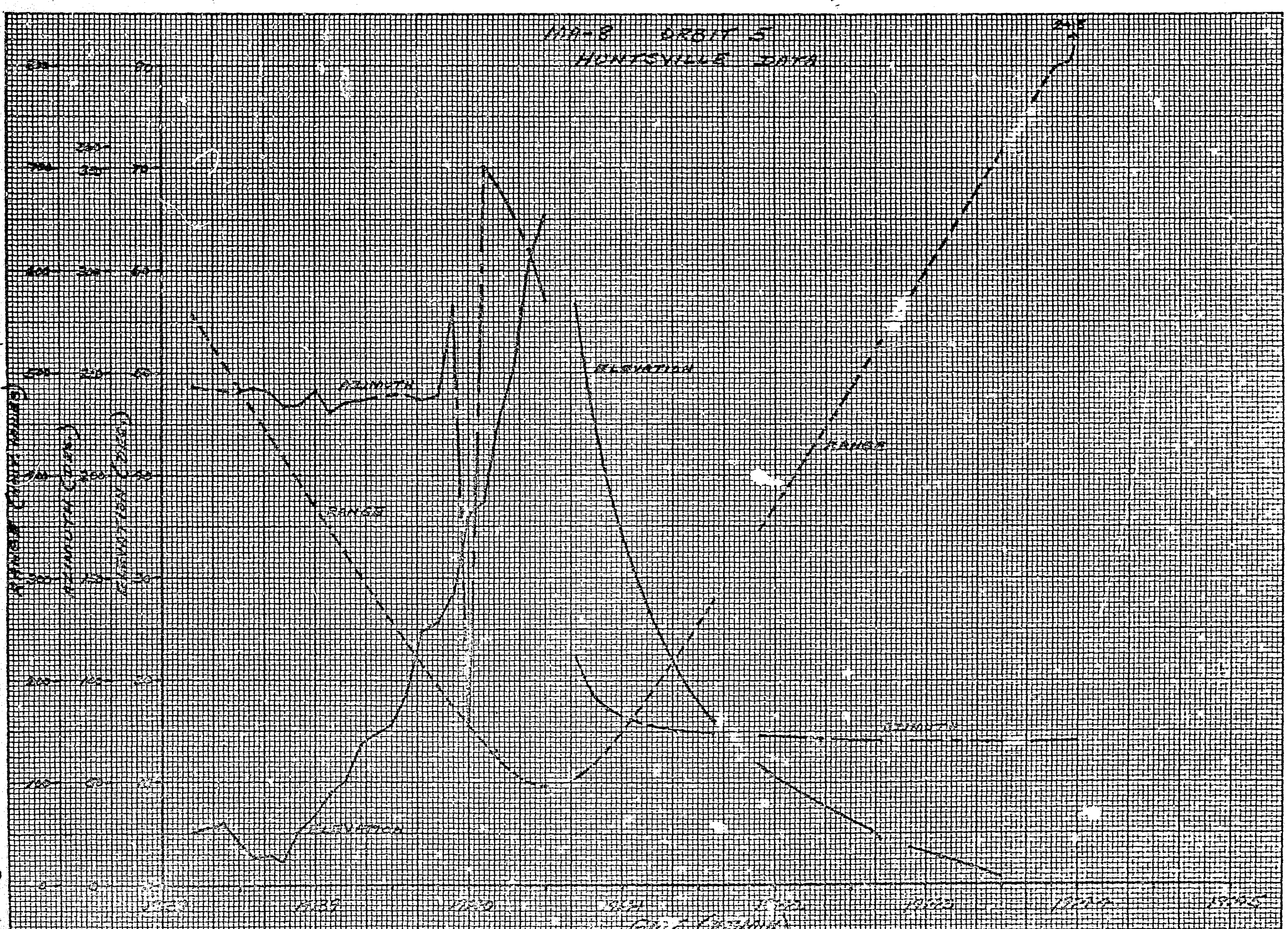
1. Moved AN/GRC 27 from the transmitter room to the electronic work shop. Reason was to shorten the antenna cable run to the high gain Doppler antenna. This antenna to be used with the primary UHF system.
2. Installed Nems Clark HI-PASS filter in the Single Helix antenna line. Reason to reduce interference from ship board transmissions.
3. Fabricate and install converter to produce one pulse every six seconds. Reason, installed to feed Datex and sample Radar data one time every six seconds.
4. Install FCC-3 TTY carrier equipment. Purpose is to mux tty trafic to hono.
5. Install 4 ea Limpanders, used to provide superior quality voice and TTY circuits.
6. Provide the capability to record WWV and capsule communications on the Magnecord tape recorder

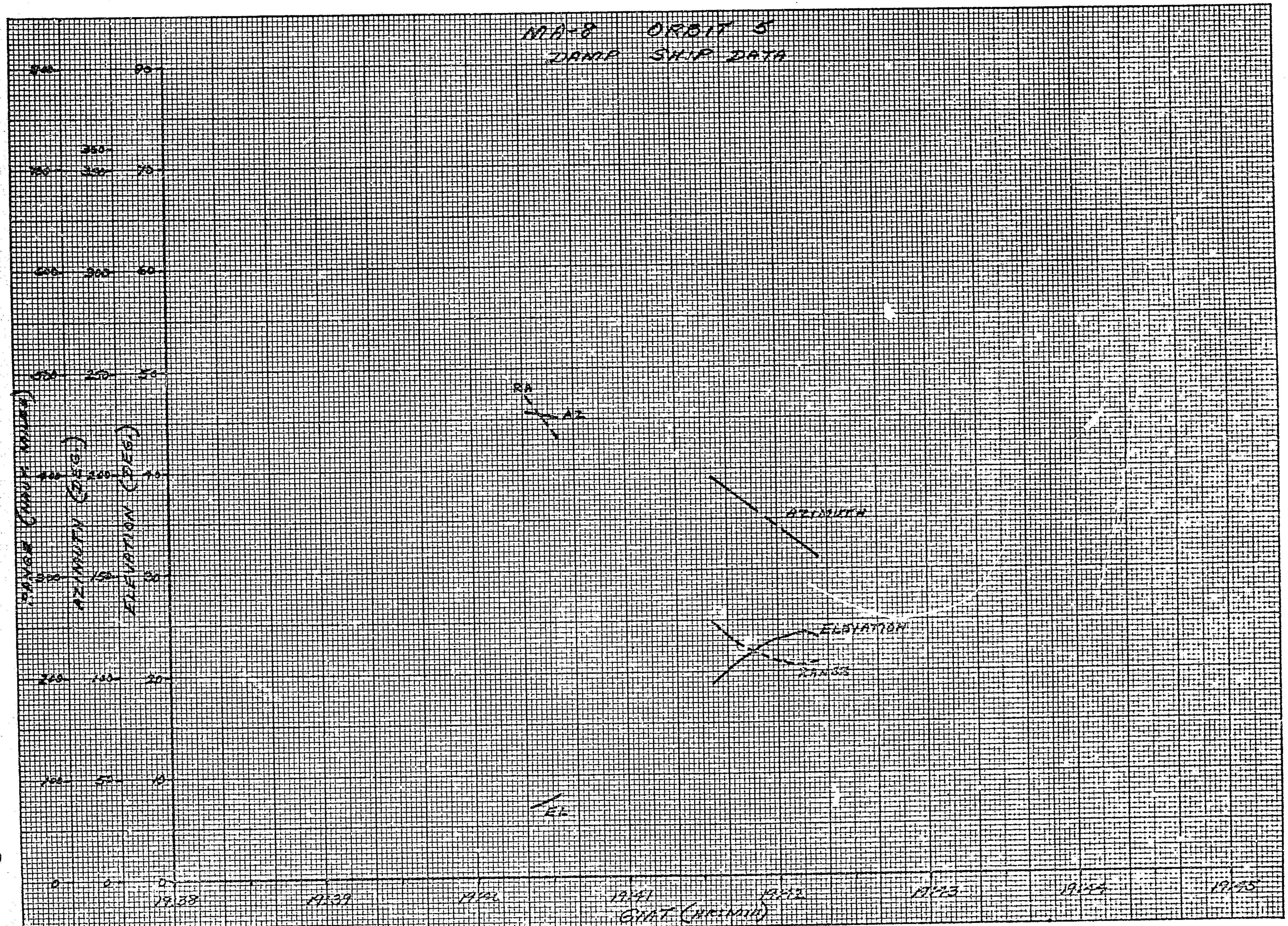
7. Provide squelching between the primary and secondary AN/GRC 27. Squelches both receivers when either transmitter is keyed.
8. Install three circuits with switching and monitoring equipment at the flight controlers desk.
9. Install two circuits to the M&O desk.
10. Installed a new high gain omni directional antenna on the aft starboard kingpost. Antenna will be used with the secondary UHF transmitter.
11. Removed the squelch circuit from the AGAVE system. Provides a lower tracking threshold.
12. Installed 15 IPS compensation networks in the playvack amplifiers of the TM tape recorders.
13. Installed two 25 KC reference oscillators in the model 101B mixing amplifiers. Required for reference on tape.
14. Installed new TTY machine next to the Datex equipment Purpose is rapid transmission of radar data as it is punched on the radar datex.
15. Installed NASA signaling equipment.
16. Installed new TTY patch panel to handle the new TTY machine and the FCC-3 carrier equipment.
17. Provide the capability to record the M & O loop on the TM tape recorders.

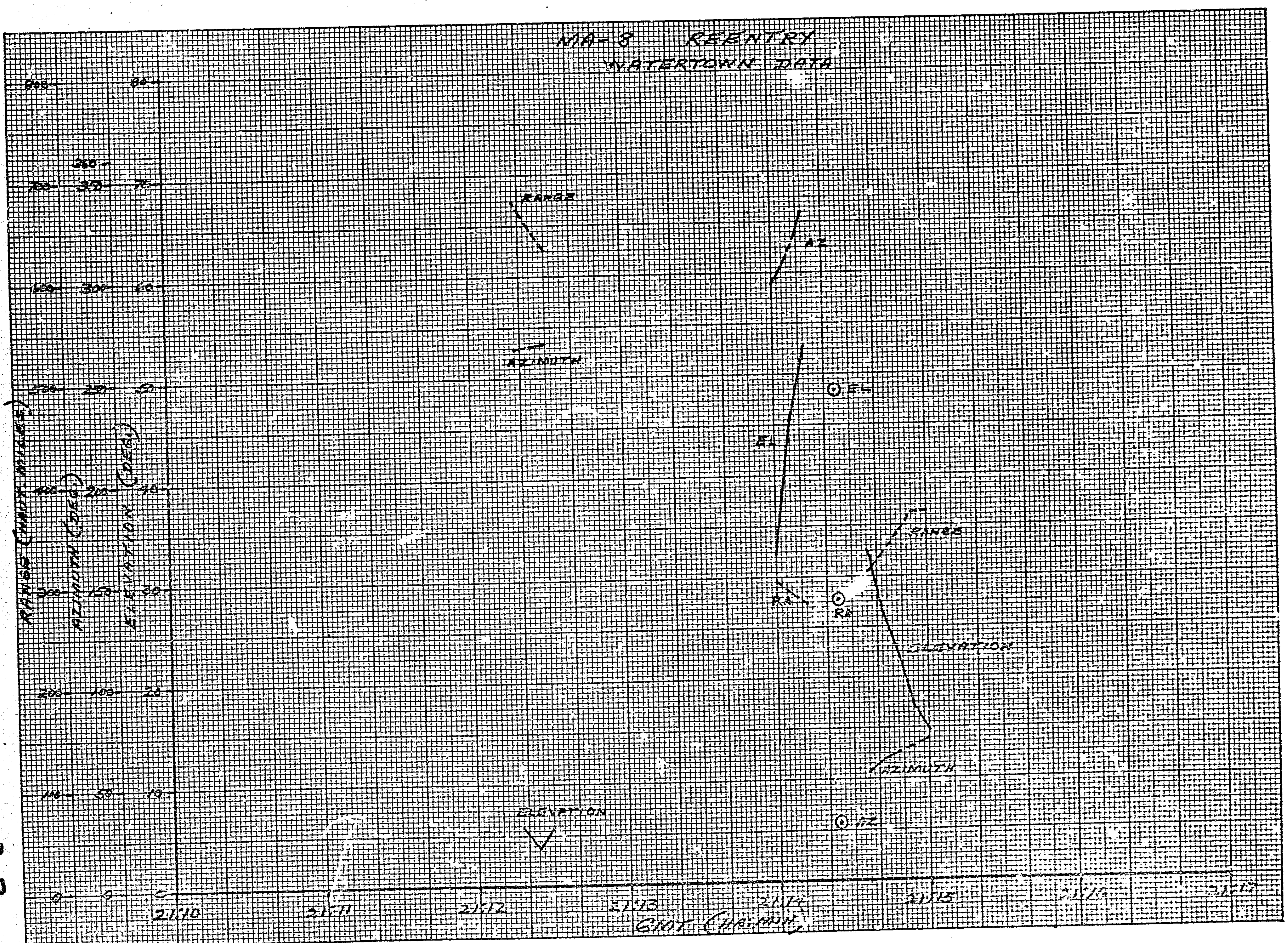
II. USAS American Mariner

1. The AN/FPQ-4 radars were interconnected to provide coded pulse operation. A delay line was installed to delay the second radar transmitter pulse six microseconds from the first pulse.
2. The acquisition aid was modified by the installation of a wide band correlation detector and voltage controlled oscillator. The RF assemble was tuned for optimum performance on 226.2 MCS. A ground screen was installed on the boresight tower to reduce elevation multipath.
3. The RADAP Agena-Ranger program was modified to punch continuous data with integer time tags.

APPENDIX 3


MA-8 ORBIT 5
HUNTSVILLE DATA
AZIMUTH
RANGE
ELEVATION


MA-8 ORBIT 5
DAMP SHIP DATA
RANGE (NAUT. MILES)
AZIMUTH (DEG.)
ELEVATION (DEG.)
RA
AZ
AZIMUTH
ELEVATION
RANGE
EL
19:38
19:39
19:41
GMT (HR:MIN)


MA-8 REENTRY
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AZIMUTH (DEG.)
ELEVATION (DEG.)
GMT (HR:MIN)
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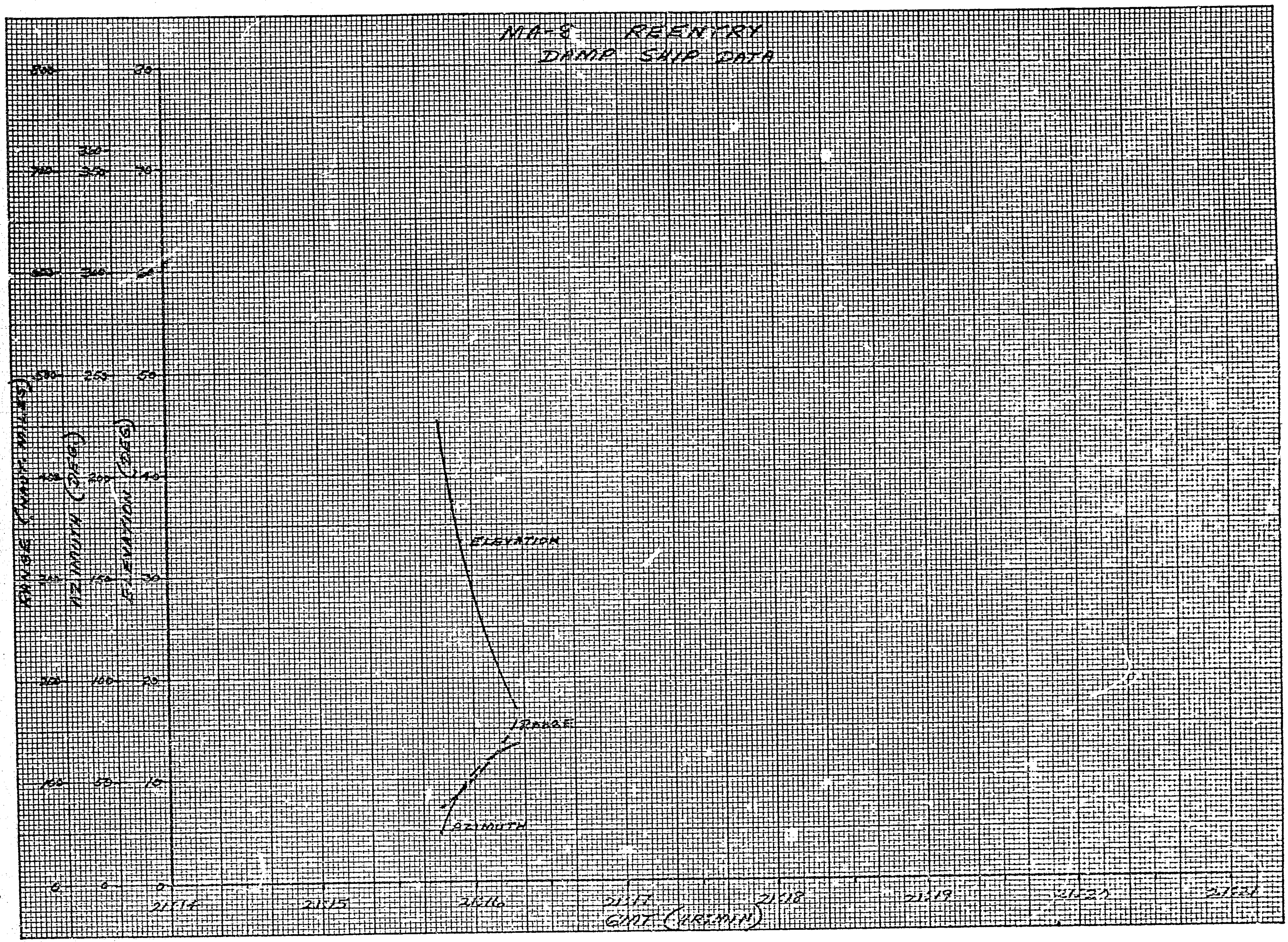
RANGE
AZIMUTH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AZIMUTH (DEG)
ELEVATION (DEG)
ELEVATION
RANGE
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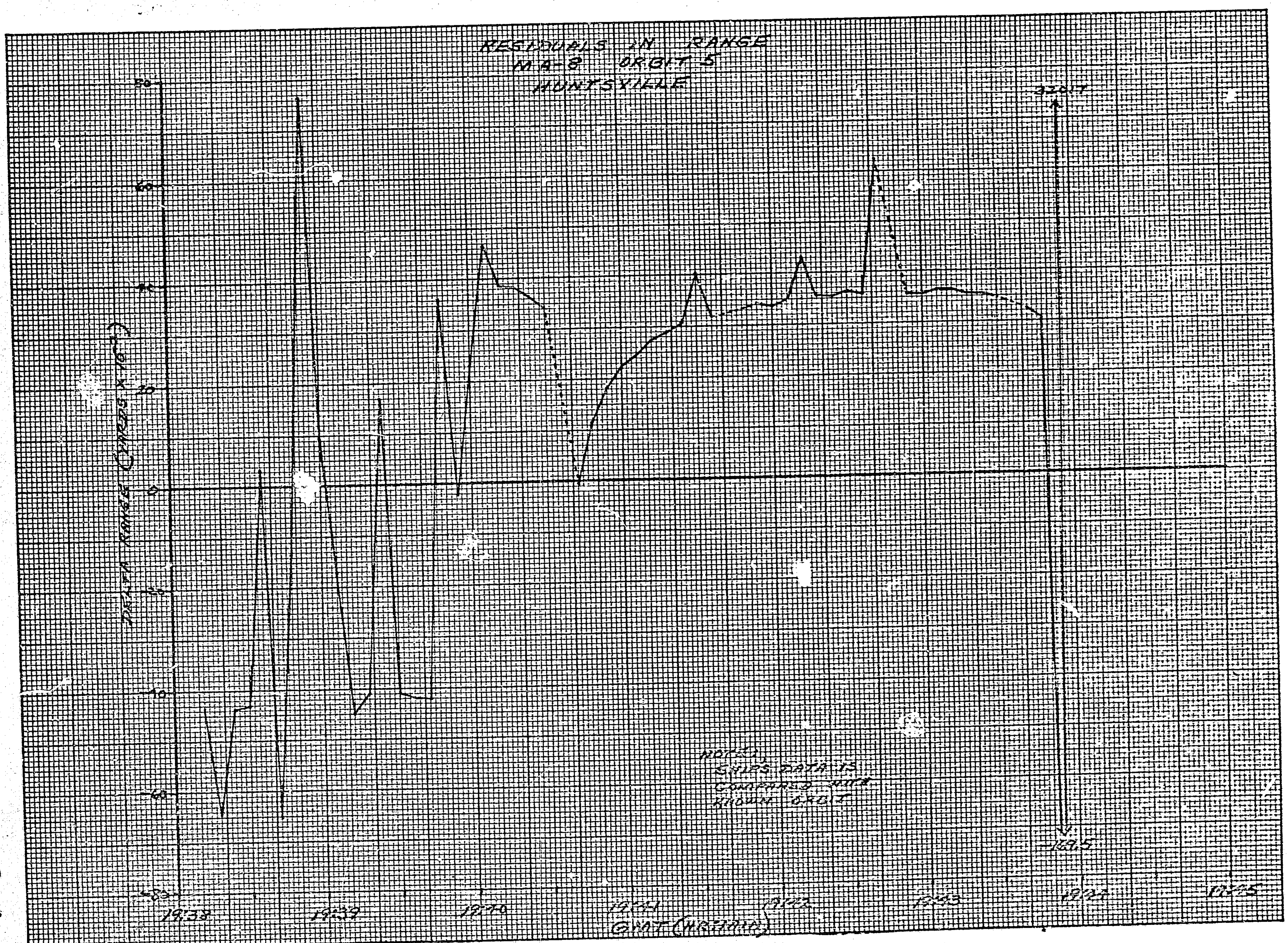
GMT (HR:MIN)


RESIDUALS IN RANGE
MA-8 ORBIT 5
HUNTSVILLE
DELTA RANGE (YARDS x 10^2)
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60
40
20
0
-20
-40
-60
-80
1938
1939
1940
1941
1942
1943
1944
1945
GMT (HR MIN)
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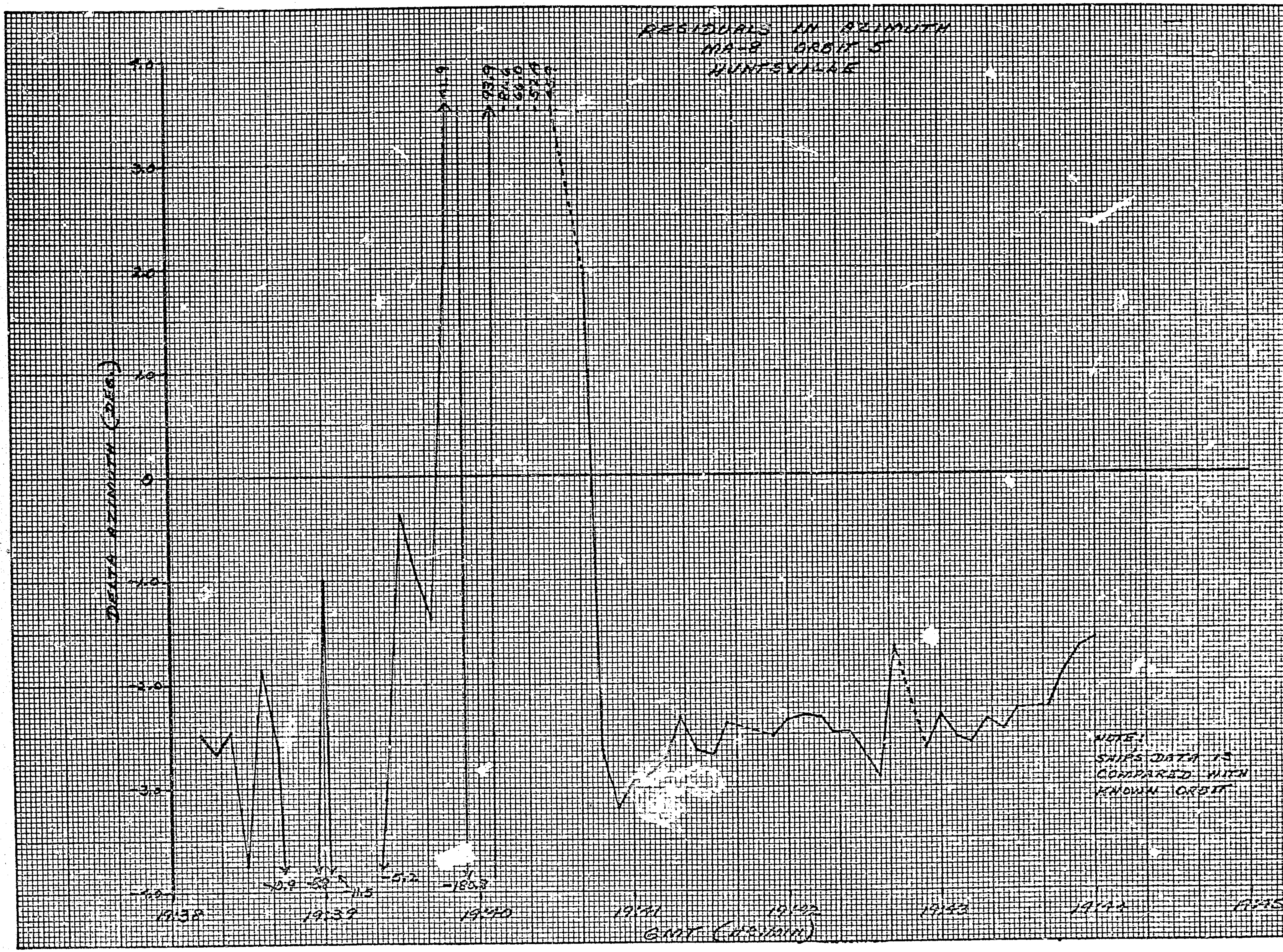
NOTE:
SHIPS DATA IS
COMPARED WITH
KNOWN ORBIT



RESIDUALS IN AZIMUTH
MA-8 ORBIT 5
HUNTSVILLE
DELTA AZIMUTH (DEG.)
GMT (HR:MIN)
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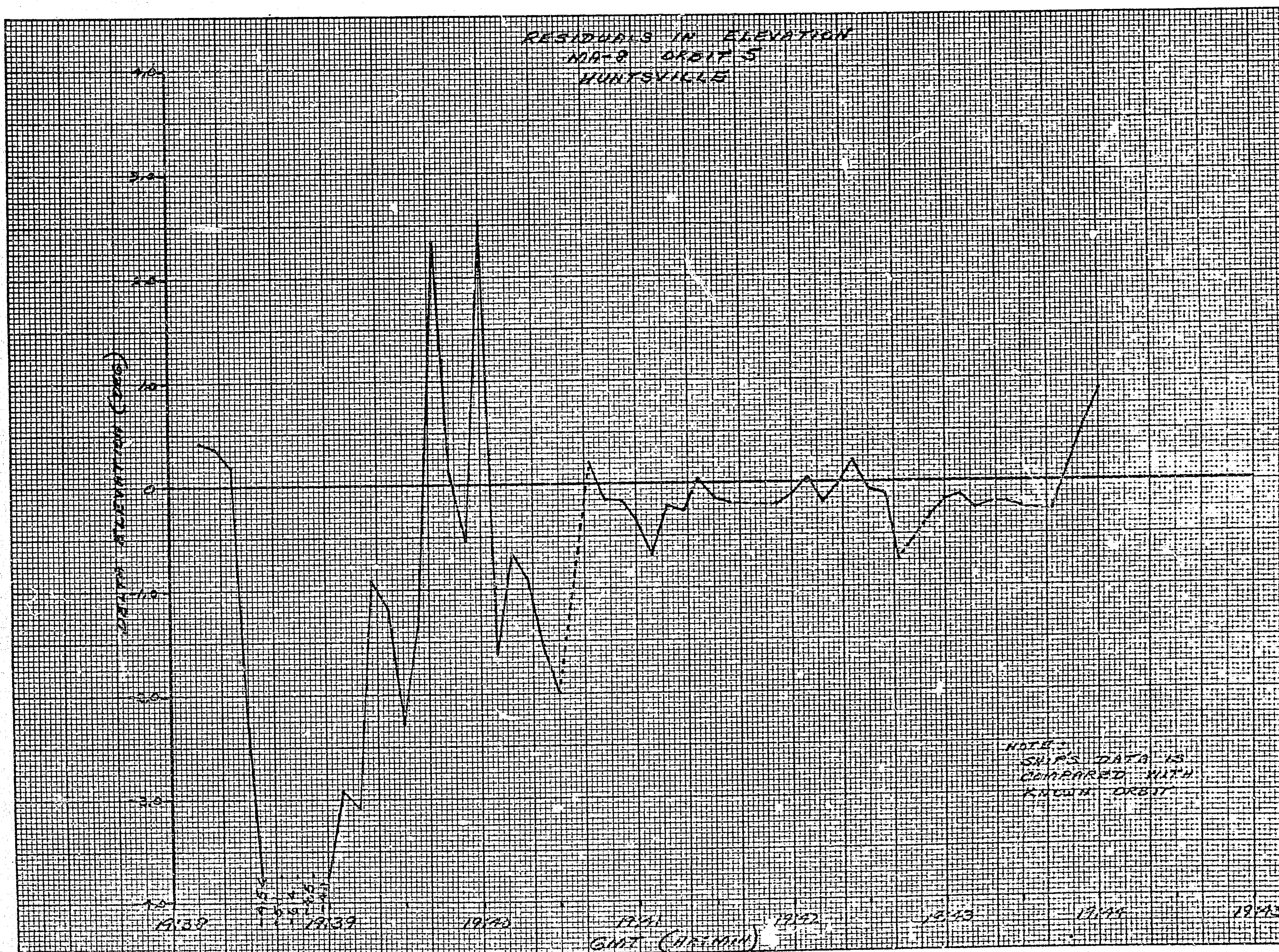
19:45
NOTE:
SHIPS DATA IS
COMPARED WITH
KNOWN ORBIT


RESIDUALS IN ELEVATION
MA-8 ORBIT 5
HUNTSVILLE
NOTE:
SHIPS DATA IS
COMPARED WITH
KNOWN ORBIT
GMT (HR:MIN)
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19:39
19:40
19:41
19:42
19:43
19:44
19:45
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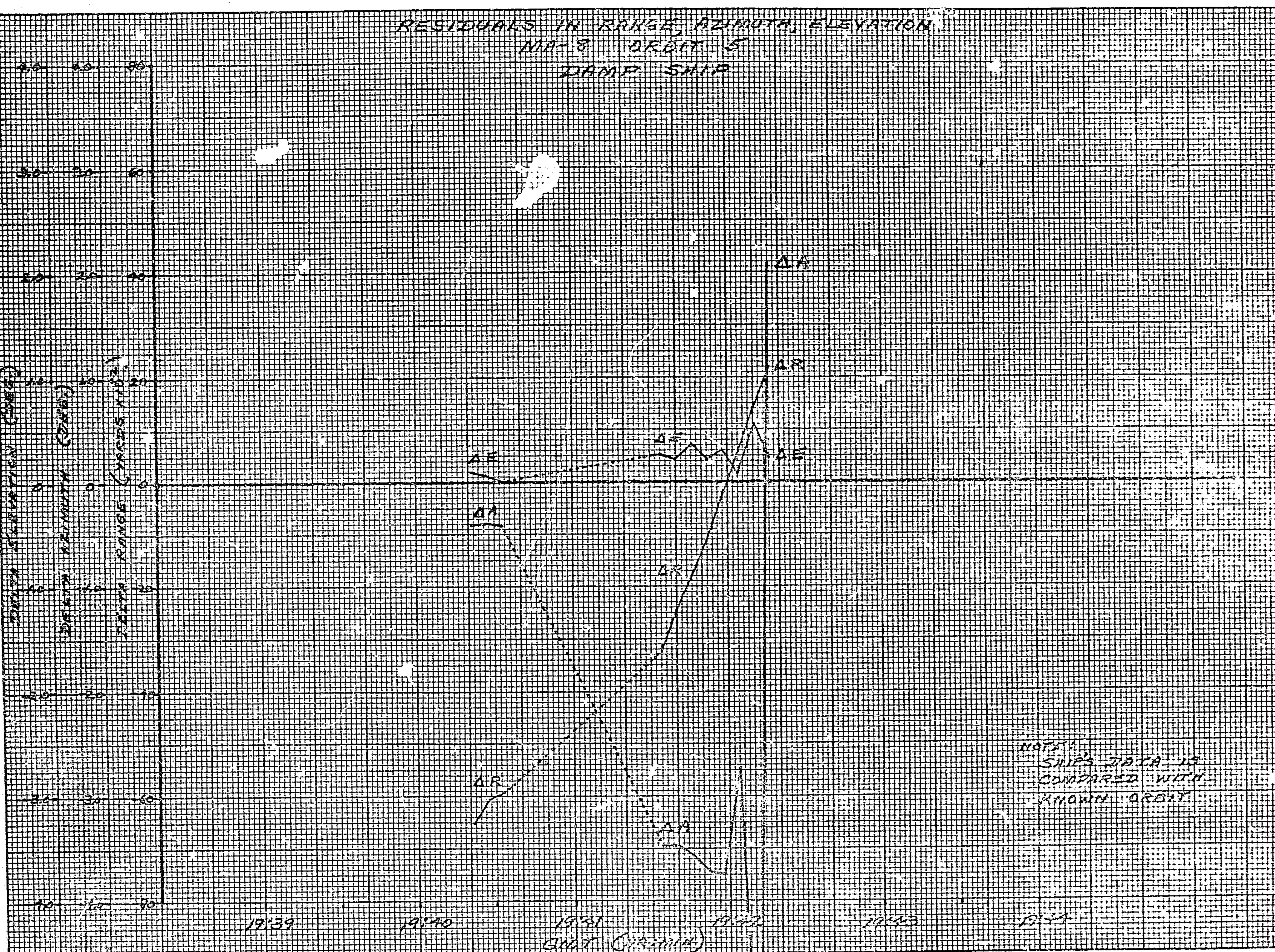
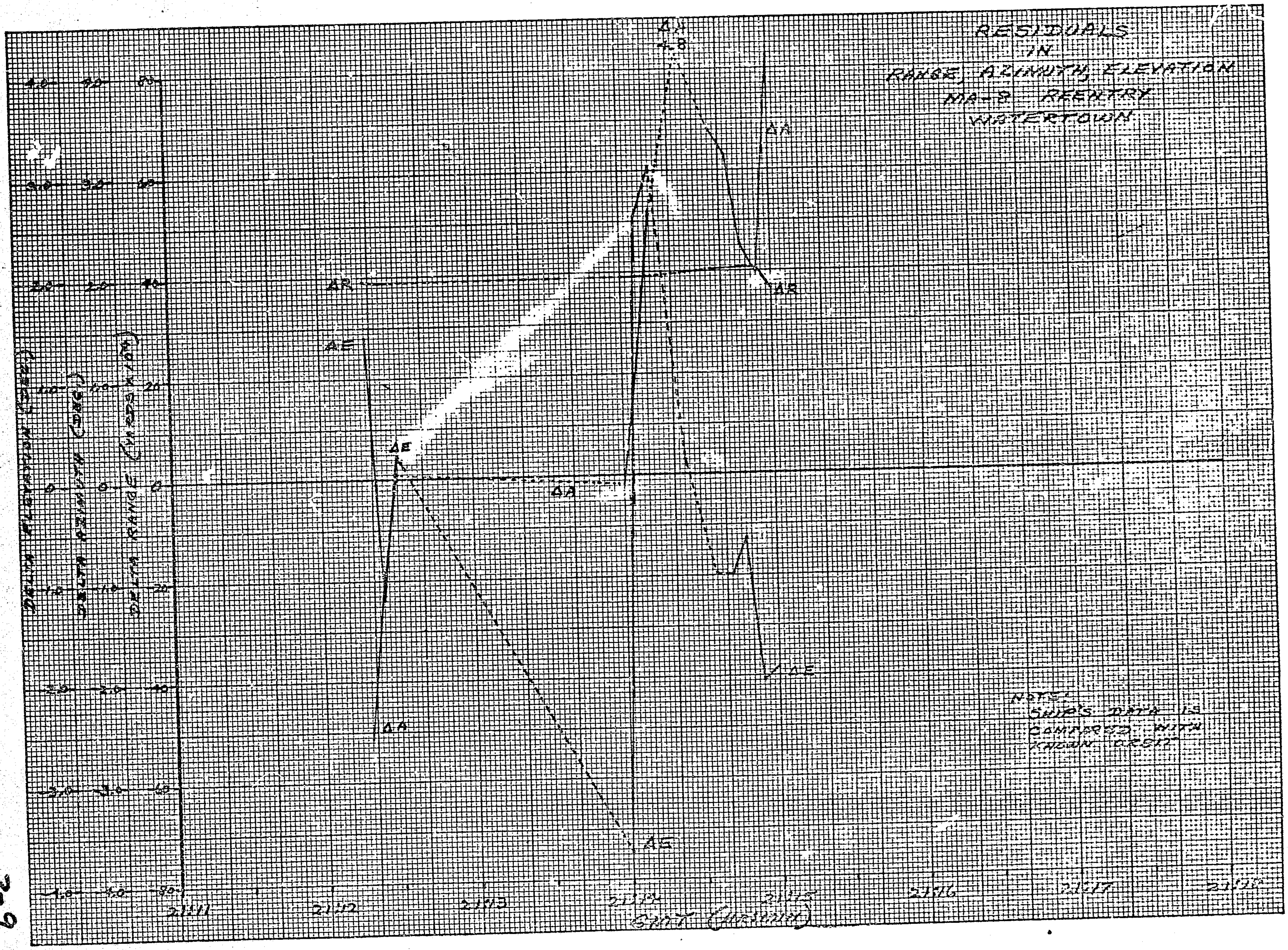
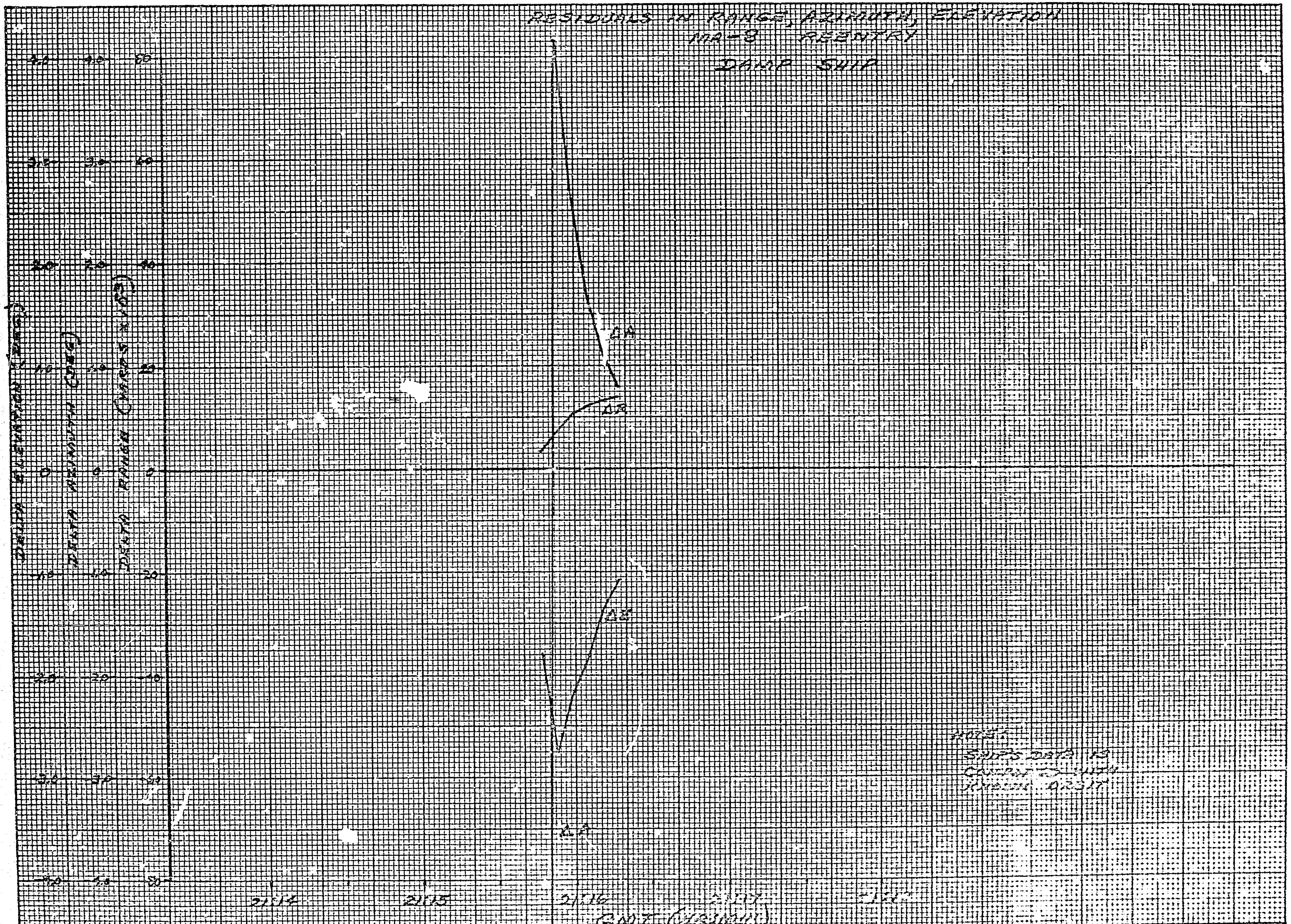
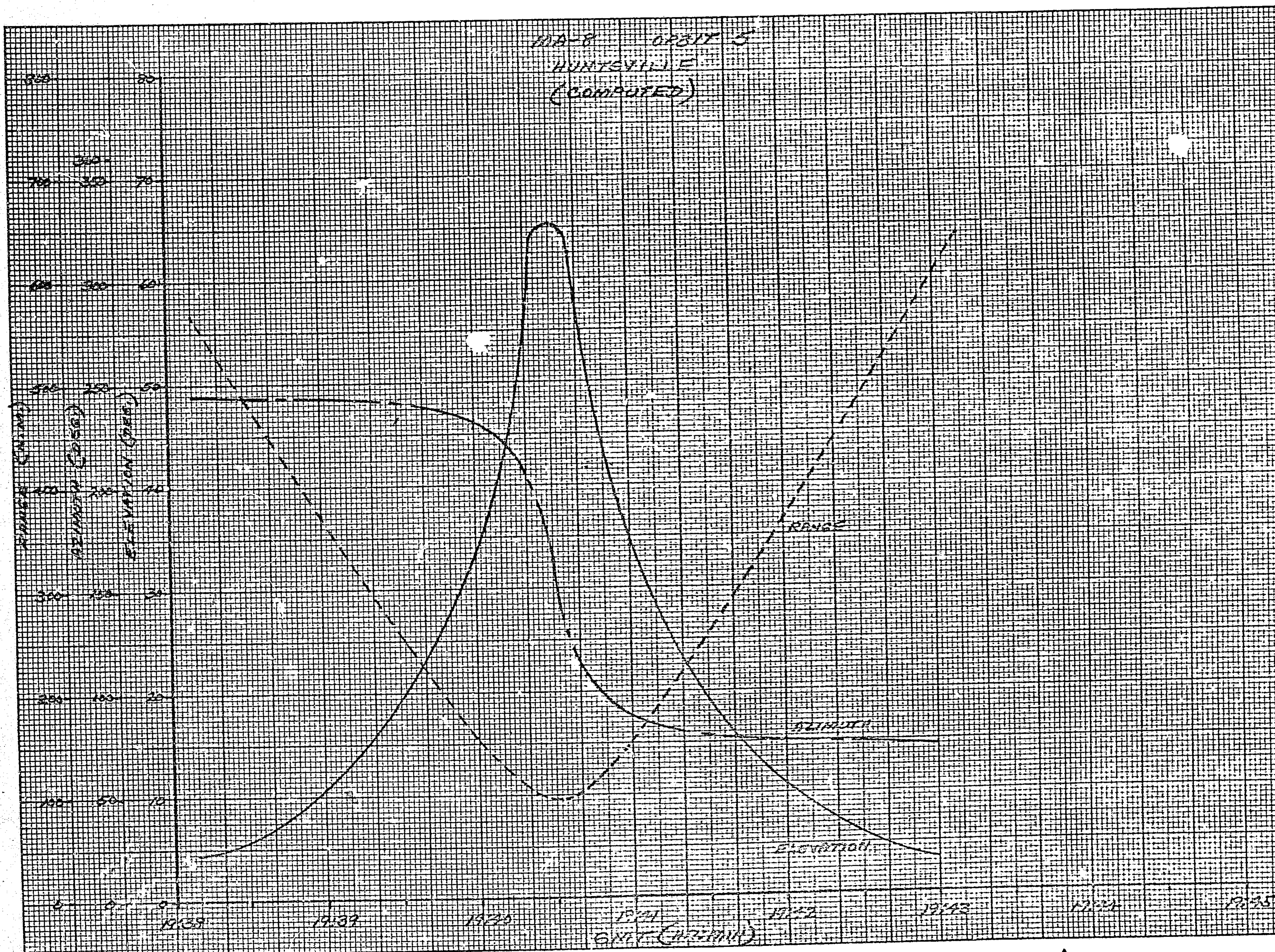
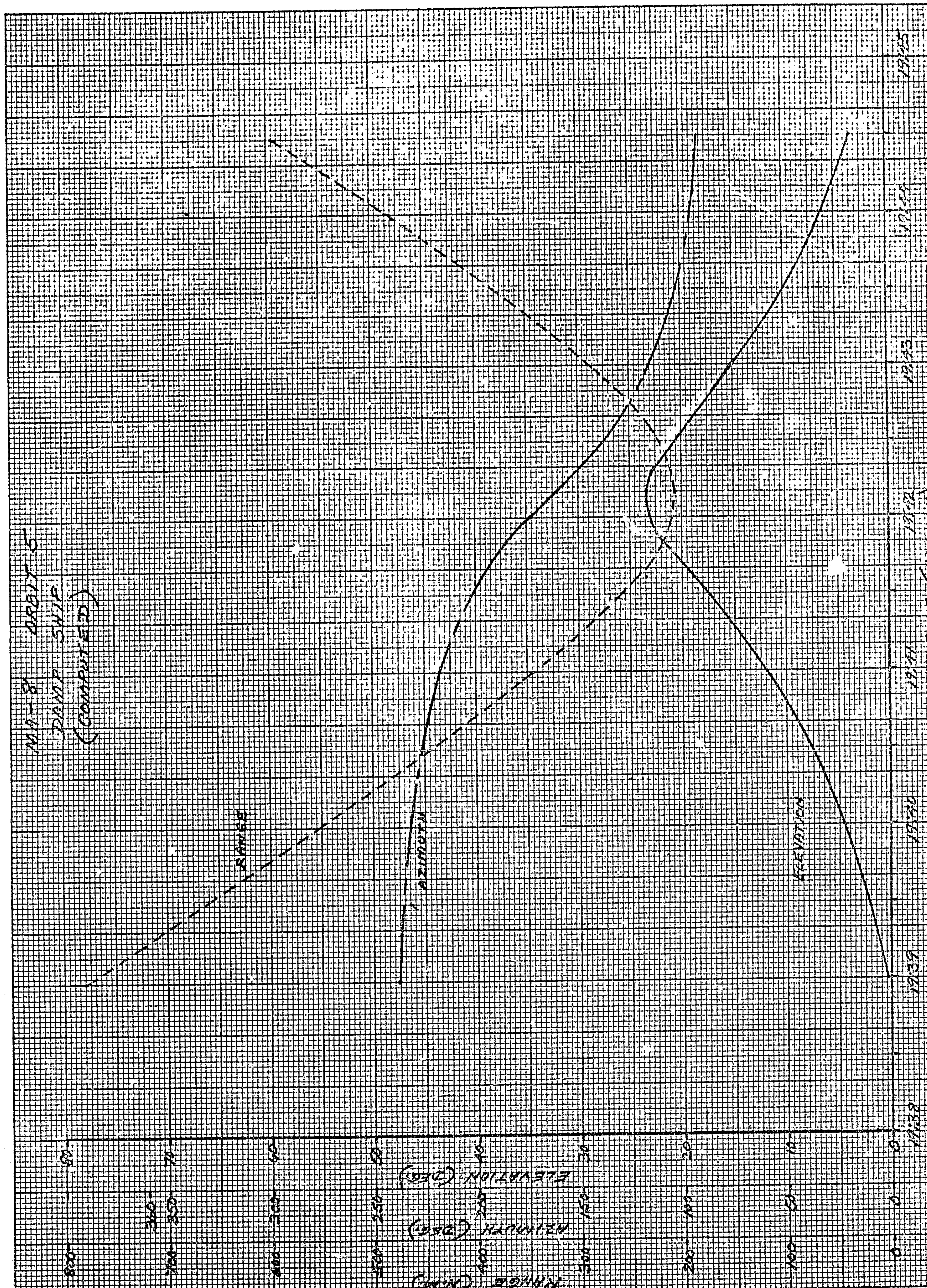
3.0
2.0
1.0
0
-1.0
-2.0
-3.0
-4.0

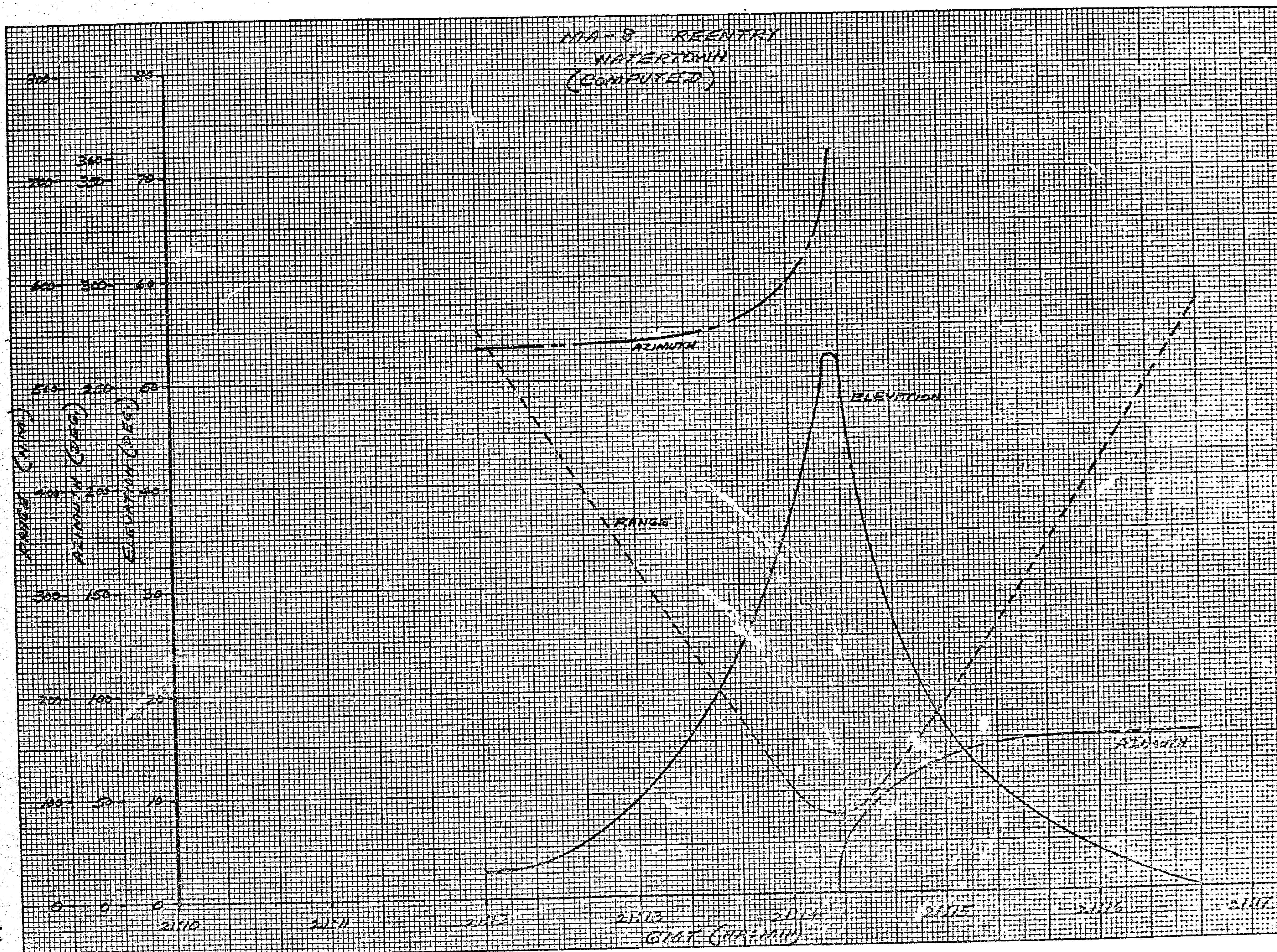

RESIDUALS IN RANGE, AZIMUTH, ELEVATION
MA-8 ORBIT 5
DAMP SHIP
DELTA ELEVATION (DEG.)
DELTA AZIMUTH (DEG.)
DELTA RANGE (YARDS X10²)
ΔA
ΔR
ΔE
NOTE:
SHIP'S DATA IS
COMPARED WITH
KNOWN ORBIT
19:39
19:40
19:41
19:42
19:43
19:44
GMT (HR:MIN)
-6.6

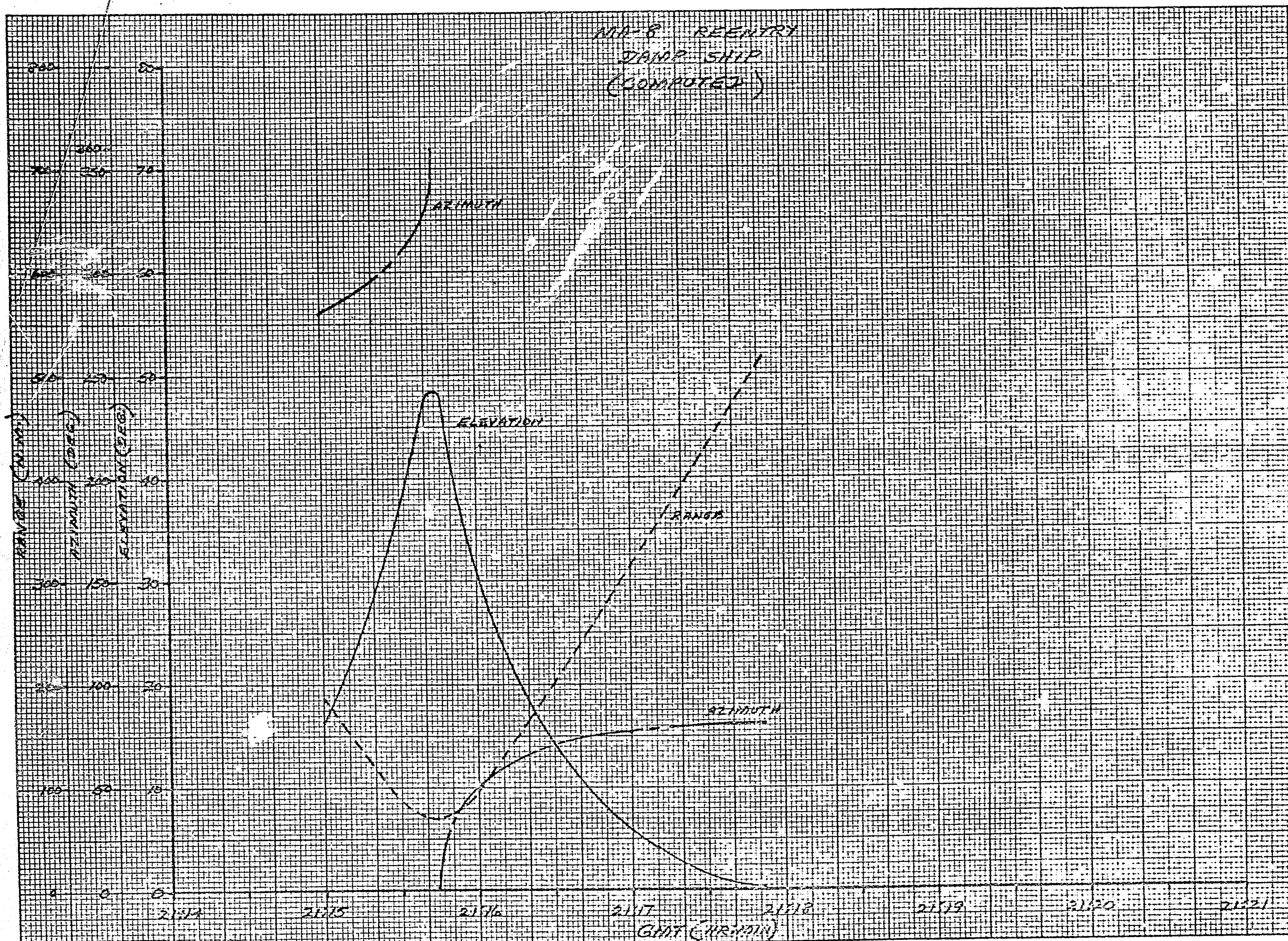

RESIDUALS
IN
RANGE, AZIMUTH, ELEVATION
MA-8 REENTRY
WATERTOWN
DELTA ELEVATION (DEG)
DELTA AZIMUTH (DEG)
DELTA RANGE
4.0
3.0
2.0
1.0
0
-1.0
-2.0
-3.0
-4.0
80
60
40
20
-20
-40
-60
-80
2:11
2:12
2:13
2:14
2:15
2:16
2:17
2:18
ΔA
4.8
ΔR
ΔE
NOTE:
SHIP'S DATA IS
COMPARED WITH
KNOWN ORBIT


RESIDUALS IN RANGE, AZIMUTH, ELEVATION
MA-8 REENTRY
DAMP SHIP
DELTA ELEVATION (DEG)
DELTA AZIMUTH (DEG)
DELTA RANGE (YARDS x 10³)
ΔA
ΔR
ΔE
NOTE:
21:14
21:15
21:16
GMT (HR:MIN)


MA-8 ORBIT 5
HUNTSVILLE
(COMPUTED)
RANGE (N.MI.)
AZIMUTH (DEG.)
ELEVATION (DEG.)
RANGE
AZIMUTH
ELEVATION
GMT (HR:MIN)


MA-8 ORBIT 5
DAMP SHIP
(COMPUTED)
RANGE
AZIMUTH
ELEVATION
ELEVATION (DEG)
AZIMUTH (DEG)
RANGE (N.M.)
GMT (HR:MIN)
19:38
19:39
19:40
19:41
19:42
19:43
19:44
19:45


MA-8 REENTRY
WATERTOWN
(COMPUTED)
RANGE (N.M.)
AZIMUTH (DEG.)
ELEVATION (DEG.)
AZIMUTH
ELEVATION
RANGE
GMT (HR:MIN)
2110
2111
2112
2113
2114
2115
2116
2117

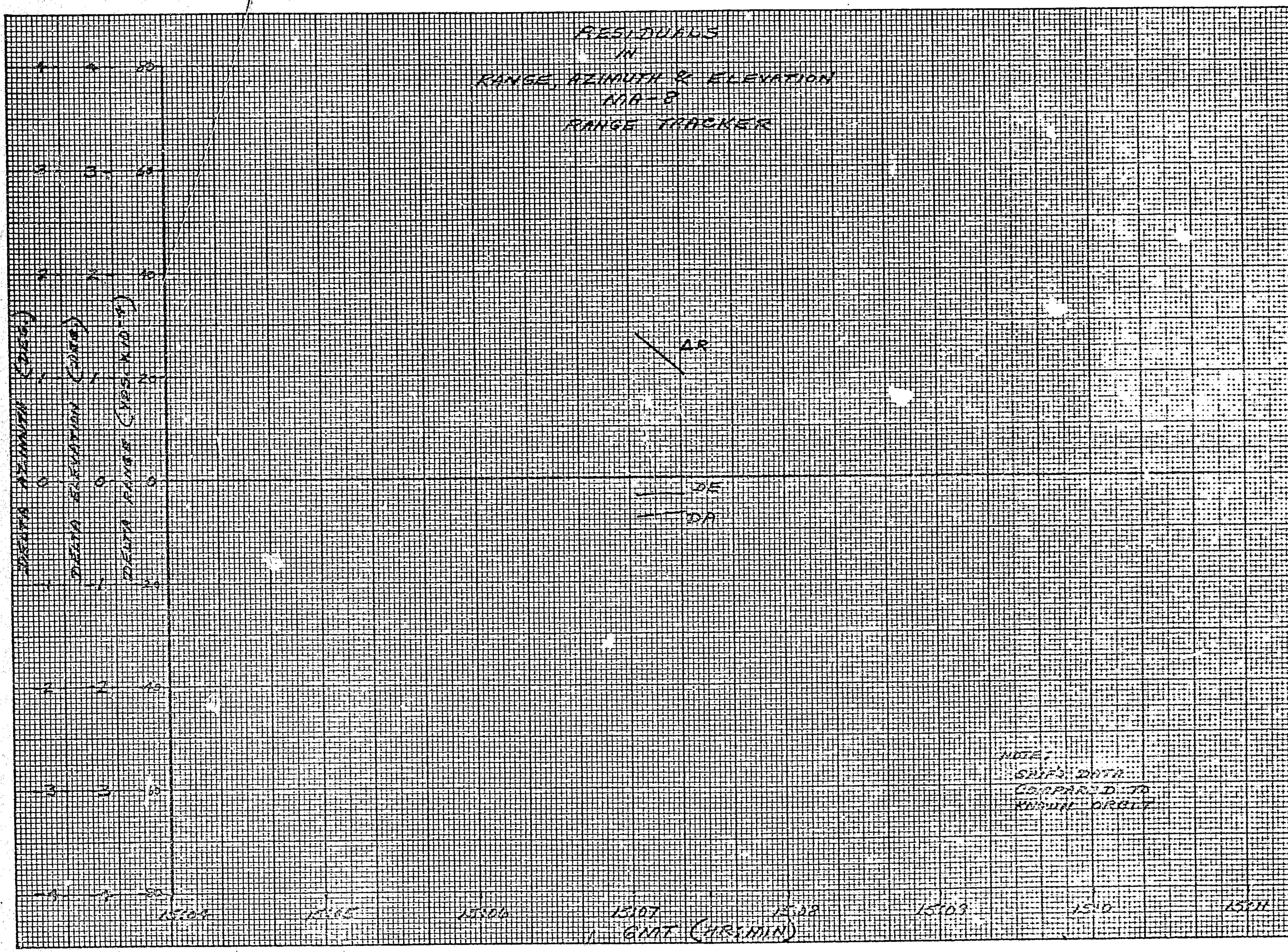

MA-8 REENTRY
DAMP SHIP
(COMPUTED)
AZIMUTH
ELEVATION
RANGE
AZIMUTH
RANGE (N.M.)
AZIMUTH (DEG)
ELEVATION (DEG)
GMT (HR:MIN)
2114
2115
2116
2117
2118
2119
2120
2121

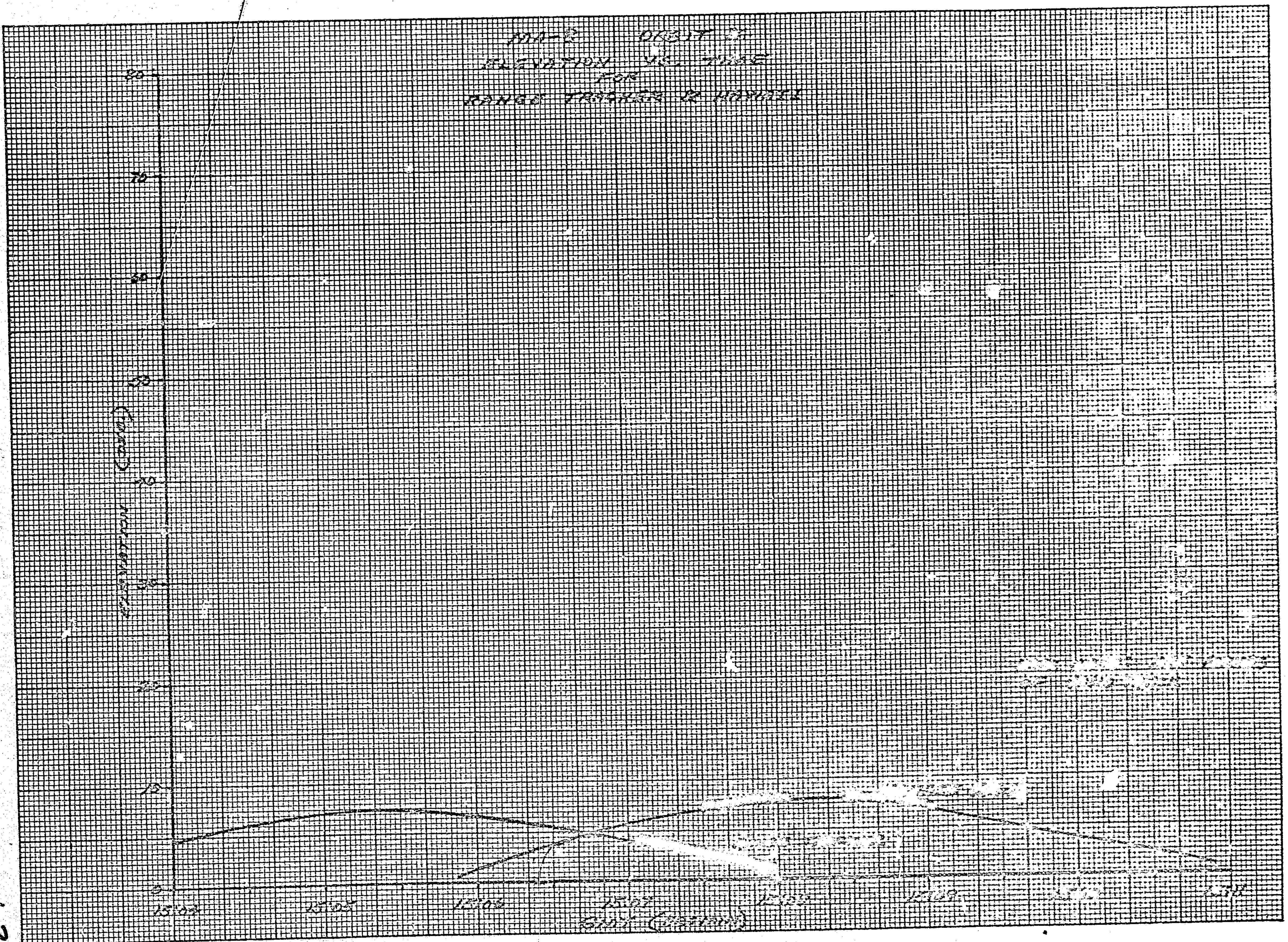
APPENDIX 4

SUMMARY OF THE QUALITY OF THE RANGE TRACKER DATA

The USNS Range Tracker tracked the Mercury MA-8 capsule on its second orbit. The data could not be used in real-time but beacon interrogation was allowed so that data from the ship could be evaluated. The ship was resting at dockside at Johnston's Island with a nearly constant pitch and roll. Ship's position was surveyed and was known as well as the location of the island is known. The FPS-16 acquired late on the second orbit and did not track at all on the third orbit. An AGAVE was used to track the telemetry signal and as an acquisition aid. The ship's superstructure obscured the higher elevation angles on third orbit and the radar was never able to acquire.

The angle data looked very good. The residuals, observed minus computed, are plotted on 4-2. The data was taken at a 10 per second rate and the noise was less than a mil on both angles. However, slant range was biased as much 140 miles. It is possible that the Range Tracker was tracking Hawaii's beacon (see plot 4-3).


RESIDUALS
IN
RANGE, AZIMUTH & ELEVATION
MA-8
RANGE TRACKER
ΔR
ΔE
ΔA
NOTE:
SHIP'S DATA
COMPARED TO
KNOWN ORBIT
15:07
15:08
15:09
15:10
15:11
GMT (HRS:MIN)


MA-2 ORBIT
ELEVATION VS. TIME
FOR
RANGE TRACKER @ HAWAII
ELEVATION (DEG)
80
70
60