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ADVANCED LIGHTNING LOCATION INTERFEROMETER

FINAL REPORT

to

Los Alamos National Laboratories

Ref: Subcontract #1813P0014-35

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New Mexico Institute of Mining and Technology
Geophysical Research Center
5/25/95

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ADVANCED LIGHTNING LOCATION INTERFEROMETER

Letter Subcontract # 1813P0014-35

Final Report

1. Introduction

In January, 1994, New Mexico Institute for Mining and Technology (NM Tech) was commissioned by Los Alamos National Laboratories (LANL) to develop a three-axis interferometric lightning mapping system to be used in determining the source of certain frequency-dispersed pulse pairs which had been detected by spaceborne sensors. The existing NM Tech VHF Lightning Interferometer was a two axis system operating at 274 MHz with 6 MHz bandwidth. The third axis was to be added to refine estimates of the elevation angle to distant RF sources in that band.

The system was to be initially deployed in support of an Air Force Technical Applications Center (AFTAC) effort planned for the Kennedy Space Center/Cape Canaveral AFS area in June-July of 1994. The project was, however, postponed until September of 1994. The interferometer was set up and operated at KSC near the Lightning Detection and Ranging (LDAR) central station. The initial setup was in two-axis configuration, and the third (vertical) axis was added at about mid-project. Though the storms were reduced in frequency and severity over what one would expect in mid-summer, several good data sets were obtained and delivered to AFTAC.

2. Project objectives

The original NM Tech VHF Lightning Interferometer (VLI) consisted of two orthogonal baselines arranged on a horizontal ground plane. Each long/short baseline combination can deliver a high-resolution estimate of the direction of arrival of a signal in the VHF range 271-277 MHz. The output of the VLI receivers determines the direction cosine to the emitter from each long/short baseline. One can envision the vector to the source as being the line of intersection of two cones, with each baseline defining the axis of one of the cones. Near the horizon, the cones intersect nearly tangentially, and the errors in elevation estimates increase drastically.

2.1 Solution to the low elevation angle accuracy problem

In order to reduce the elevation errors for determination of direction to distant sources, a third vertically-oriented baseline was to be added. Near the horizon, the vertical baseline will 'see' a source as lying on a shallow cone whose surface is nearly horizontal. This shallow cone will intersect the cones defined by the horizontal baselines at nearly right angles, thus minimizing elevation errors. Since we are determining the source position in two dimensions, having three independent parameters gives us an over-determined system and, therefore, flexibility in choosing the means of computing source direction. Using C.T. Rhodes' error analysis for interferometer systems, it appears that we can expect better than 2 degree accuracy on individual measurements of both azimuth and elevation for signals strong enough to drive the linear receivers into limiting.

The addition of the third baseline results in an increase of 50% in the data produced by the VLI system. The existing VLI system is running at maximum capacity, and so additional capability is necessary to accommodate the third baseline.

2.2 The vertical antenna array

The original NM Tech VLI employed vertically polarized antennas, making it preferable to employ vertically polarized antennas in the vertical baseline, as well, in order to minimize systematic differences in response between the vertical and horizontal baselines. However, in order for the antennas to be arranged vertically, their axes must coincide, and thereby a problem arises involving interaction of antennas with feed lines to the receiver. Several configurations were considered, including trap vertical dipoles, sleeve vertical dipoles (used on the horizontal system), multiple phased dipoles, discones, and biconics (dual cones). The biconics were considered the best choice from the standpoint of performance vs. cost, simplicity in correction for systematic errors, and lack of undesirable interactions as noted above.

For the vertical baseline receivers, an existing LANL system originally intended for a similar purpose will be employed. The LANL receiver system is functionally identical to the NM Tech VLI receiver systems, except that the LANL system has a 30 MHz Intermediate Frequency (IF), as opposed to the NM Tech 60 MHz IF. The IF discrepancy is transparent to the final computations of source direction.

The existing VLI system employs a horizontal ground plane. In addition to providing a locally benign environment for the propagation of electromagnetic waves, the ground plane significantly reduces multipath interference from ground reflections. Multipath signals distort signal phase measurements and compromise measurement accuracy, particularly for elevation. The vertical baseline does not have the advantage of a ground plane due to its height. A suitable ground plane scaled to the height of the horizontal array would be on the order of 500 feet in diameter--a decidedly impractical size. Preliminary phase distortion measurements were made at a LANL antenna range using biconic antennas. "Squinting" the antenna to distort the patterns to not include angles below the horizon was attempted without encouraging results. No drastic problems with ground reflections arose during initial tests, and so, in the interest of time, we ignored the ground reflection problem. The flat terrain of Florida is a more benign environment for electromagnetic waves than the mountains of northern New Mexico, but if multipath problems had arisen in Florida, we had the backup option of building a $.25 \lambda$ choke fence out of "chicken wire" around the vertical antenna array to attenuate reflections. This fence would consist of several concentric circles of woven wire fence spaced about 1.5', starting at a radius of several wavelengths from the vertical antenna. The drawback is that the fence takes up a great deal of room, and the actual radius (and performance) depends upon space constraints of the installation site. The fence real estate is less than that of a suitable ground plane, however. A radius approximately equal to the height of the antenna mast (about 20 feet) would be adequate. Siting the instrument on the top of a building would be more effective in reducing ground multipath reflections than resorting to the choke fence. This type of siting was chosen, in fact, in the September '94 Florida experiment.

2.3 Additional data items

Certain data items have been added to the original NM Tech system. We have included a GPS receiver and time decoder in the system. This gives us a clock synchronized to GPS, as well as time readouts to 1 μ sec accuracy. Digital TTL inputs are available for additional trigger event data, such as from a multi-channel receiver which is designed to detect wideband noise events.

2.4 The computational load and additional data

The addition of a third baseline increases the computation load and data throughput requirement by 50%. We have replaced the original PC-based Digital Signal Processor (DSP) with a card residing on the VME bus, a bus designed for high-speed data handling. The host is now a SUN IPC workstation. A DSP card containing two Texas Instruments TMS320C40 performs initial data selection and phase computations. The results of these computations are buffered into a large (32 Mbyte) memory on VME bus.

A VME bus to SUN S-bus converter allows the SUN access to the preprocessed data. A task running on the SUN will collate data into archival records and store them on 2.1 Gbyte disk. Data files will be limited to about 50 Mbytes and will change on 6 minute (.1 hour) boundaries. The shorter file length will facilitate post processing, as it is much easier to deal with 50 megabyte files than 500 megabyte files. As a data file is completed, its name will be added to a list. A separate task will sequentially archive files on the list to a tape medium such as DAT or Exabyte, then remove the files from the list and the disk. The 2.1 Gbyte disk should have room for 5 hours of data acquisition during periods of high activity. Extrapolating from prior experience with the two-baseline system indicates that we should expect a maximum of about 450 Mbytes/hour going to the disk. This amounts to 125 Kbytes/sec, well within the capabilities of an Exabyte or DAT tape archival system. Incorporating intermediate mass buffering as outlined above avoids latency problems often encountered in dealing with the Unix operating system in real-time.

Real-time displays in three available formats will be generated as the data are written to disk. The formats will be; 1) rectangular azimuth vs. elevation, 2) the polar overhead projection of az/el on the base of a unit hemisphere, and 3) the worm's-eye view as the discharge should appear from a lowly human viewpoint. The software for the generation of these displays exists on the old PC host and is portable to the SUN almost as-is; only the graphics commands need be changed. In addition, the fast and slow antenna data and a data acquisition log will be displayed.

2.5 Calibration

Though the system is inherently self-calibrating, certain systematic errors arising from the electromagnetic geometry of the area surrounding the antennas can cause errors in ambiguity resolution, and a correction table must be generated to minimize these errors. These errors show up as discontinuities in otherwise continuous lightning discharges when ambiguities in the high resolution long baseline measurement is not properly compensated for by the short baseline measurement. The discharges appear in the wrong place, in other words. In the past we have

used lightning itself to build up a correction table, but this is a time-consuming task. We have a test signal source, but a single-point measurement is not representative of the entire hemisphere. We have had reasonable success in flying the source around the site in a light aircraft, then invoking path and knowledge of the aircraft flight path to build the correction tables.

3-Axis VHF Lightning Interferometer
Data Acquisition System Block Diagram

2.6 Hardware upgrade summary

- The existing NM Tech VLI antennas, ground-plane, and receivers are used 'as-is'.
- A new vertical array of three biconic antennas has been added to improve elevation angle measurements near the horizon.
- A GPS receiver provides precise microsecond time tags to aid fusion with other data sources.
- The initial phase angle computations have been moved to a DSP residing on VME bus in order to accomodate a 50% increase in throughput resulting from addition of the third baseline.

- ◆ A SUN IPC host has been fitted with a large disk and now performs collation and archival of the processed data.
- ◆ A 32 Mbyte memory on VME bus and 2.1 Gbytes of disk provides massive buffering in order to circumvent Unix latency effects on SUN.
- Real-time displays will be generated by SUN as the data are written to disk.

2.7 Upgrade status

As of 1 March, 1995, all of the components and software were finally on hand. The VME crate and Sun IPC were successfully interfaced through the VME to S-bus converter. A problem on the Sonitech DSP card was rectified quickly by Sonitech, who also performed a no-cost upgrade to the board at that time. Software was generated for the DSP to access the digitizer board. This exercise turned up two minor layout problems with the digitizer, and one problem with programmable logic coding in the digitizer control circuitry. These problems were fixed and by 1 May all of the system components were communicating as originally designed. Now that the academic year has wound down, full effort can be directed to finishing the software and the three remaining digitizers. All the components for the digitizers are on hand, including the circuit cards, but components need to be inserted and the cards given a final checkout. Now, the basic software which was developed in 1994 (but which could not be debugged until all the hardware and support software was on hand) will be completed and debugged. We plan to have the full 3-axis interferometer system operational in time for the "lightning season" in the Socorro area (July - August).

2.7 Publications resulting from this work

NM Tech and KSC LDAR personnel are collaborating on a paper describing intercomparison of data sets simultaneously acquired by the NM Tech interferometer and the KSC LDAR systems:

Comparison of NM Tech VHF lightning interferometer and KSC LDAR observations, In progress.

An initial User's Manual for the upgraded interferometer has been drafted:

Gray, G., M. Landahl, ed., *3-Axis VHF Lightning Interferometer User's Manual*, 1995, NM Tech Geophysical Research Center: internal document.

A spinoff paper from the Florida field experiment has been submitted for inclusion in the AMS 27th Radar Meteorology Conference. The paper is accepted and in press:

Maier, L., C. Lennon., P. Krehbiel, M. Stanley, M. Robison, Comparison of lightning and radar observations from KSC LDAR and the NEXRAD radar systems, *Am. Met. Soc., Preprints: 27th Conference on Radar Meteorology*, Vail, CO, October, 1995.

3. CCAFS/KSC Field Deployment

The vertical baseline antenna array was fabricated at LANL, along with the associated receiver and phase demodulators. The vertical baseline was tested at NM Tech's Langmuir Lab in July-August of 1994. However, by late August NM Tech had still not taken delivery of certain critical system components, notably the analog to digital converter (ADC) cards. In addition, we were awaiting revised software for the Sun-VMEbus interface. Since the Florida field operation period was only one month (leaving little or no time for continued development should the components and software arrive), we decided to field the VLI in the standard two-axis configuration and independently acquire vertical baseline data with the intent of merging horizontal/vertical data sets at a later time for specific cases of interest.

The system was transported to KSC via truck, arriving late on 25 August. By 28 August the horizontal antenna baselines were set up and operating on the roof of building ??? at KSC. The remainder of the VLI receiver electronics and the VLI computers were housed in a rental office trailer sited outside Building ???. The trailer also served as the VLI operations center. (See Figure 2.) The system was declared operational on 31 August. Operations began on 1 September.

3.1 Data acquisition modes

Two modes of data acquisition were employed for the Florida effort. The normal, or real-time, mode employed the PC-based real-time data processing and display system in which data are written to disk then later transferred to a Sun computer for archival on 8mm data tape cartridges. The high-density mode added the capability of recording raw 1 microsecond digitized data on instrumentation tape, with a 9600' tape lasting about 15 minutes at 120 inches/second. Since instrumentation tape is quite expensive, the high-density mode was used very sparingly; primarily on request by AFTAC. Typically, only one hour on an active day was devoted to high-density mode. In normal mode, the data are thresholded on the basis of signal strength before being collated and recorded. This results in a data rate reduction of greater than 90% over raw recording in most cases. It is possible, however, that some interesting low-level events might be thresholded out.

All of the real-time data were transferred to Exabyte tapes and delivered to AFTAC. Copies were retained by NM Tech for later analysis. To date, no high-density data have been requested by AFTAC, though the machine has been reassembled and tested at NM Tech. NM Tech personnel have independently performed initial comparisons of the data with simultaneous LDAR data. Even without the presence of the vertical axis in the data set, the correspondence between LDAR and the NM Tech VLI are encouraging, considering the differences between the two measurement systems. The results of these comparisons will be summarized in a paper which is in progress.

3.2 Data Synopsis

The following table lists start and stop times for data recorded by the NM Tech VLI team during the Florida effort. TYPE = DISK implies normal data acquisition mode. HIGH SPEED TAPE # implies accelerated mode. The High Speed Tape number is the number for the day; e.g. HIGH SPEED TAPE #3 means that this was tape number 3 for the day. A strikethrough (e. g. ~~HIGH SPEED TAPE #...~~) indicates that the tape was erased and recycled (with the concurrence of AFTAC). The DAY is the Julian day starting at 1 January, 1994. All times are listed as Universal Time (Greenwich, or Zulu)

NM TECH VHF LIGHTNING INTERFEROMETER SEPTEMBER, 1994, KSC

SYNOPSIS OF DATA ACQUISITION ACTIVITIES

<u>DATE</u>	<u>DAY</u>	<u>TIME START</u>	<u>TIME STOP</u>	<u>TYPE</u>
9/1/94	244	20:28	21:28	DISK
9/2/94	245	18:02	19:36	DISK
		19:37	19:58	DISK
		21:00	22:10	DISK
9/3/94	246	18:06	20:17	DISK
		21:02	17:47	DISK
9/4/94	247	17:32	18:35	DISK
9/5/94	248	NO DATA COLLECTION		
9/6/94	249	NO DATA COLLECTION		
9/7/94	250	NO DATA COLLECTION		
9/8/94	251	16:57	17:03	DISK
		17:00	17:15	HIGH SPEED TAPE #1
		17:10	17:15	DISK
		17:18	17:33	HIGH SPEED TAPE #2
		17:18	17:52	HIGH SPEED TAPE #3
		17:36	17:52	DISK
		17:54	18:10	HIGH SPEED TAPE #4
		17:54	18:10	DISK
		18:16	19:13	DISK
		20:05	22:00	DISK
		22:25	22:42	DISK

9/9/94	252	18:00	18:02	HIGH SPEED TAPE #1
		18:03	18:15	DISK
		18:23	18:42	DISK
		18:30	18:44	HIGH SPEED TAPE #1
		18:47	19:03	HIGH SPEED TAPE #2
		19:07	19:25	HIGH SPEED TAPE #3
		19:27	19:42	HIGH SPEED TAPE #4
		19:45	19:49	HIGH SPEED TAPE #5
		22:21	23:00	DISK
				(SHUTTLE)
	22:22	22:34	HIGH SPEED TAPE #5 (SHUTTLE)	
9/10/94	253	18:29	18:47	DISK
		18:30	18:47	HIGH SPEED TAPE #1
		18:50	19:06	DISK
		18:50	19:06	HIGH SPEED TAPE #2
		19:09	19:25	DISK
		19:09	19:25	HIGH SPEED TAPE #3
9/11/94	254	NO DATA COLLECTION		
9/12/94	255	18:22	19:47	DISK
9/13/94	256	11:39	11:50	DISK
		12:00	12:15	DISK
		12:00	12:15	HIGH SPEED TAPE #1
		12:19	12:35	DISK
		12:19	12:35	HIGH SPEED TAPE #2
		12:38	12:54	DISK
		12:38	12:54	HIGH SPEED TAPE #3
		12:57	13:12	DISK
		12:57	13:12	HIGH SPEED TAPE #4
		13:17	13:32	HIGH SPEED TAPE #5
		13:21	13:32	DISK
		13:33	14:06	DISK
		15:01	15:34	DISK
		9/14/94	257	NO DATA COLLECTION
9/15/94	258	NO DATA COLLECTION		
9/16/94	259	13:00	13:45	DISK (AIRCRAFT TRACKING)

		18:14	19:26	DISK
9/17/94	260	18:25	19:25	DISK
		19:25	19:51	DISK
		20:05	20:19	HIGH SPEED TAPE #1
		20:13	20:19	DISK
		20:23	20:38	DISK
		20:23	20:38	HIGH SPEED TAPE #2
		20:45	21:01	DISK
		20:24	21:00	HIGH SPEED TAPE #3
9/18/94	261	NO DATA COLLECTION		
9/19/94	262	17:52	18:45	DISK
		18:30	18:45	HIGH SPEED TAPE #1
		18:49	19:41	DISK
		18:49	18:59	HIGH SPEED TAPE #2
		19:33	19:41	HIGH SPEED TAPE #2
		19:45	20:10	DISK
		19:45	20:00	HIGH SPEED TAPE #3
		21:31	22:30	DISK
9/20/94	263	20:01	22:34	DISK
		20:01	20:04	HIGH SPEED TAPE #1
		22:07	22:19	HIGH SPEED TAPE #1
		22:59	23:30	DISK
9/21/94	264	NO DATA COLLECTION		
9/22/94	265	20:40	20:46	HIGH SPEED TAPE (BLACKBEARD SUPPORT)
9/23/94	266	NO DATA COLLECTION		
9/24/94	267	20:00	20:21	DISK
		20:24	21:06	DISK
		20:50	21:06	HIGH SPEED TAPE #1
		21:08	21:24	DISK
		21:08	21:24	HIGH SPEED TAPE #2
		21:27	21:42	HIGH SPEED TAPE #3
		21:45	22:00	HIGH SPEED TAPE #4
		22:04	22:50	DISK
9/25/94	268	16:34	17:03	DISK

		17:15	18:10	DISK
		18:51	19:00	DISK
		19:00	19:15	HIGH SPEED TAPE #1
		19:18	19:34	HIGH SPEED TAPE #2
		19:36	19:52	HIGH SPEED TAPE #3
		19:55	20:02	HIGH SPEED TAPE #4
		20:02	20:35	DISK
		20:45	22:00	DISK
9/26/94	269	16:44	17:10	DISK
		17:11	17:14	DISK
		17:14	17:30	HIGH SPEED TAPE #1
		17:33	17:50	DISK
		18:15	19:00	DISK
		19:00	19:15	HIGH SPEED TAPE #2
		19:18	19:33	HIGH SPEED TAPE #3
		19:44	20:00	HIGH SPEED TAPE #4
		20:07	21:30	DISK
9/27/94	270	18:47	19:26	DISK

3.3 NM Tech KSC '94 Project Log transcription

The following is a transcript of the raw NM Tech data acquisition logbook for the ANLP Florida effort.

NM TECH VHF LIGHTNING INTERFEROMETER SEPTEMBER, 1994, KSC

PROJECT LOG

DAY 244, 9/01/94 LOCAL TIME

16:28 ANLP PROJECT BEGINS
WRITE TO DISK FOR START UP; A LITTLE ACTIVITY IN THE
DISTANCE IN THE SOUTH AND WEST
17:38 SHUT DOWN
E FIELD DATA E244_0.DAT NOT TRANSFERRED TO SUN
PHASE DATA P244_0.DAT NOT TRANSFERRED TO SUN

DAY 245, 9/02/94 LOCAL TIME

13:30 START UP WITH POWER PROBLEMS; BREAKER KEEPS TRIPPING
13:58 REPLACED BREAKER; POWER OK; SYSTEM START UP
14:02 RECORDING DATA TO DISK; A FEW LIGHTNING STRIKES TO THE SOUTH
14:10 HAIL
14:15 GAIN SET @ 6
14:18 FIRST DISCHARGE OF ANY SIGNIFICANCE TO THE SOUTH
14:20 DISCHARGE AND FIRST THUNDER
14:22 GAIN CHANGED TO 5 AFTER BIG DISCHARGE
14:24 RECORDING TO HIGH SPEED TAPE; FREQUENT DISCHARGES
14:27 GAIN TO 4
14:30 HIGH SPEED TAPE OFF
14:42 GAIN TO 5
14:45 GAIN TO 4
14:47-14:48 SPECTACULAR STRIKE
15:06 GAIN TO 5
15:08 GAIN TO 4

NOTE: OCCASIONAL SHORT INTERFERENCE BURSTS TO SSW

15:12 NEW ACTIVITY TO SOUTHWEST
15:31 GAIN TO 5; LIGHT ACTIVITY
15:36 DATA ACQUISITION OFF
E FIELD DATA E245_0.DAT NOT TRANSFERRED TO SUN

PHASE DATA P245_0.DAT NOT TRANSFERRED TO SUN
 15:37 RESTART
 15:42 INTERFERENCE
 15:47 LIGHT ACTIVITY
 15:58 SHUT DOWN DATA ACQUISITION
 16:22 TRANSFERRING E FIELD & PHASE DATA TO SUN
 16:48 TRANSFERRING COMPLETE
 16:48 SYSTEM RESTART
 17:00 WRITING TO DISK
 17:14 GAIN TO 7
 18:10 STOP DATA ACQUISITION
 18:13 HIGH SPEED TAPE OFF MACHINE AT 3442 FT.
 18:16 E245_1.DAT & P245_1.DAT TRANSFERRED TO SUN
 18:27 TRANSFER COMPLETE
 18:51 SHUT DOWN ALL EQUIPMENT

DAY 246, 9/3/94 LOCAL TIME

10:00 SWITCHED POWER SWITCHES ON TAPE DRIVES BECAUSE OF FAULTY SWITCH, LUBRICATED AND REPLACED IN OLD INTF DRIVE: NEEDS A SLIGHT TUG BEFORE TURNING ON TO ENSURE MECHANICAL FLIP FLOPS RESET, THEN NO PROBLEMS
 11:10 WEATHER BRIEFING: 1300 TO 1700 BEST WINDOW FOR STORMS; START LOOKING AT 1200; HIGH SPEED DATA FROM 1300-1400 UNTIL FURTHER NOTICE
 11:45 BROUGHT UP SYSTEM AND HAD TROUBLE WITH SYNC
 GAIN TO 7
 12:18:45 TIME SET
 14:06 RECORD TO DISK - LITTLE ACTIVITY
 14:16 GAIN TO 6
 14:36 FIRST THUNDER
 14:44 GAIN TO 5
 15:08 TAPE ON
 15:10 TAPE OFF; RESTART PC; NO SYNC; CHANNEL 3 IS BAD
 15:49 GAIN TO 6
 NOTE: FREQUENTLY THE INTERFERENCE FLAG SHOWS UP AT THE INITIAL EDGE OF A DISCHARGE; COULD THE ALGORITHM NEED TWEAKING?

 16:17 STAND DOWN TO TRANSFER DATA
 16:59 NEW TAPE LOADED
 17:02 RESTART AND CHANGE GAIN TO 5
 17:15 GAIN TO 4
 17:47 STOP RECORDING TO DISK
 17:50 SHUT DOWN ALL EQUIPMENT

DAY 247, 9/4/94 UNIVERSAL TIME

13:26 BRIEF SHOWER

17:32 START UP; WRITE TO DISK; GAIN @ 5

17:36 GAIN TO 7

NOTE: COLD FRONT PASSAGE AT 10:00 UNIVERSAL TIME THIS MORNING;
CONVECTION LARGELY SHUT DOWN

18:35 SHUT DOWN COLLECTION

DAY 248, 9/5/94 DOWN DAY

DAY 249, 9/6/94 UNIVERSAL TIME

14:10 WEATHER BRIEFING: COLD FRONT ON SAT. BROUGHT IN COOLER,
DRYER AIR; STABILITY INDEX 5.5; LITTLE OR NO CHANCE OF STRONG
CONVECTIVE ACTIVITY UNTIL THURSDAY EXCEPT FOR CHANCE OF
THUNDERSTORM BUILDUP WEST OF ORLANDO ON SEA BREEZE
BOUNDARY

DAY 250, 9/7/94 DOWN DAY UNIVERSAL TIME

ASSEMBLED BASIC PARTS FOR VERTICAL BASELINE; WILL NEED
ROUGHLY 200' OF ROPE TO ANCHOR PLATFORM; RENAMED FORCE CPU-40
"VULTURE" AND WAS ABLE TO USE IT ON THE TRAILER SUB-NET

14:19 START UP BUT NOT RECORDING TO DISK; GAIN @ 4

14:48 SYSTEM SHUT DOWN

DAY 251, 9/8/94 UNIVERSAL TIME

SYNCED TO GOES

RAIN IN THE VICINITY OF KSC/CCAFS; EARLY BUILDUP

14:00 NO ELECTRICAL ACTIVITY AS OF 10:00 AM LOCAL

14:23 THUNDER

14:45 WEATHER BRIEFING: COLLECTION INITIALLY SCHEDULED FOR 11:30 TO
12:30 LOCAL TIME (15:30-16:30 UT), THIS WAS MODIFIED AT 11:00

LOCAL TO 13:00-14:00 LOCAL (17:00-18:00 UT)

15:20 GPS STILL NOT SYNCING. PICKED OFF IPFS FROM GOES RECEIVER
(AFTAC); NOW SETTING CLOCK ON LEADING _EDGE_ OF 100MS IPFS
PULSE

15:28 LENNON CALLED, LDAR TRIGGER IS ON CABLE

15:15 THUNDER

16:57 WRITE TO DISK; LIGHT ACTIVITY; GAIN @ 4

17:00 START DATA COLLECTION WITH HIGH DENSITY TAPE #1

17:02 GAIN TO 6
 17:03 LOST REALTIME DISPLAY; TAPE LOOKS OK; DATA TO DISK OFF
 17:10 REALTIME BACK ON LINE; DATA TO DISK
 17:15:47 END OF TAPE #1
 17:18 NEW TAPE #2
 17:30 BAD SECTION OF TAPE 1 MIN.
 17:33 END TAPE #2
 17:36 NEW TAPE #3
 17:46 20 SECONDS OF BAD TAPE
 17:52:16 END OF TAPE #3
 17:54:40 NEW TAPE #4
 18:05 GAIN TO 5
 18:10 END OF TAPE #4 AND END OF HIGH DENSITY COLLECTION
 18:16 DATA TO DISK
 18:42 GAIN TO 6
 19:13 SHUT DOWN; DISK FULL; TRANSFER DATA TO SUN
 20:05 SYSTEM UP AND DATA TO DISK
 20:55 DATA TO DISK
 20:55 GAIN TO 5
 21:05 GAIN TO 4; BIG DISCHARGE
 21:25 GAIN TO 5; ACTIVITY INCREASING
 21:37 GAIN TO 4
 21:42 E_009 GOOD OVERHEAD DATA; GAIN TO 5
 22:00 DISK FULL; TRANSFERRING DATA TO SUN
 22:25 WRITING TO DISK
 22:42 SYSTEM SHUT DOWN; REWIND TAPES
 22:50 INTERFERING SIGNAL -NOT TOO STRONG- BUT CONSISTENT, PULSATING
 AT 1-2HZ; NOTICED ON I/Q MONITOR SCOPE(S)
 00:43 TAPE 1-4 REWIND AND LABEL COMPLETE

DAY 252, 9/9/94 UNIVERSAL TIME

GPS UP

12:40 CLOCK SYNCED
 WEATHER BRIEFING: 90%-100% CHANCE OF LIGHTNING TODAY;
 PROBABLY SEA BREEZE WILL NOT MOVE CONVERGENCE INLAND TODAY;
 PEAK ACTIVITY 1300-1700 LOCAL TIME; DATA COLLECTION SET FOR
 1400-1500 LOCAL TIME (1800-1900 Z).
 SYSTEM CAME UP WITH NO SYNC PROBLEMS; MOST CHASSIS' ON ALL
 NIGHT EXCEPT TAPE
 16:50 GAIN TO 7; DISTANT ACTIVITY S-SW
 17:05 GAIN TO 6
 18:00 RECORD TO HIGH DENSITY TAPE #1
 18:02 STOP DATA AT 1128'; START HIGH DENSITY TAPE AT 18:30 PER PHONE CALL
 FROM CAPT.LONG

18:03 RECORD TO DISK; GAIN @ 6
 18:15 STOP RECORDING TO CLEAN DISK FOR DATA COLLECTION WITHOUT
 INTERRUPTION
 18:23 RECORD TO DISK; GAIN @6
 18:25 THUNDER
 18:27 GAIN TO 5
 18:30 RECORD TO TAPE #1 STARTING @ 1220'
 18:32 STRONG CG DISCHARGE
 18:36 GAIN TO 4 AFTER STRONG CG DISCHARGE
 18:40 STOP AND RESTART SYSTEM BECAUSE OF ERRORS (20 SECONDS OFF)
 18:42 NOT RECORDING TO DISK
 18:44 END OF TAPE #1
 18:47 BEGIN TAPE #2
 18:48 GAIN TO 5
 19:03 8870' TAPE STOPPED; RESTART
 19:03 END OF TAPE #2
 19:07 START TAPE #3
 19:09 A FEW SECONDS OF ERRORS
 19:25 END OF TAPE #3
 19:27 START TAPE #4
 19:42 END OF TAPE #4
 19:45 START TAPE #5
 19:49 END TAPE #5 AT 2160'
 21:30 WAITING FOR SHUTTLE LAUNCH. . . AT 3 MIN. AND HOLDING FOR
 DEBRIS CLOUD

NOTE: LDAR TRIGGER IS INSERTED INTO ON SHORT BASELINE LSB

21:39 GAIN TO 7
 22:21 WRITE TO DISK; GAIN AT 5
 22:22 TAPE #5 AT 2190' WITH STS 64/DISCOVERY SPACE SHUTTLE LAUNCH
 22:34 END OF TAPE #5
 23:00 SHUT DOWN; LEAVING SITE ~

DAY 253, 9/10/94 UNIVERSAL TIME

18:25 GAIN TO 6
 18:29 WRITE TO DISK
 18:30 WRITE TO HIGH DENSITY TAPE #1
 18:34 ONE MINUTE OF DISK ERRORS - RESET CLOCK
 18:38 ATOP RECORDING TO RESET CLOCK
 18:39 RECORD TO DISK AND TAPE #1 BACK ON LINE
 18:44 GAIN TO 7
 18:47 END OF TAPE #1
 18:50 START TAPE #2; VERY LIGHT ACTIVITY TO THE FAR SOUTH

19:06 END OF TAPE #2
19:09 START TAPE #3
NOTE: CLOCK RESET AT 18:34 WAS 10 MINUTES FAST - FAULTY THUMBWHEEL
SETTING
19:25 END OF TAPE #3; SYSTEM SHUT DOWN
20:19 BEGIN REWINDING TAPES
21:31 COMPLETE REWINDING TAPES

DAY 254, 9/11/94 UNIVERSAL TIME

15:00 HOUSEKEEPING
20:00 LOST GPS LOCK - CODE (DISCIPLINED OSC OK)

DAY 255, 9/12/94 UNIVERSAL TIME

NOTE: GPS STILL NOT LOCKED; SWITCHED CLOCK TO HP/MHZ
18:22 WRITING TO DISK; GAIN TO 6
19:47 END OF DATA ACQUISITION
NOTE: AT THE REQUEST OF AFTAC; THE HIGH DENSITY RECORDING (HDR) WAS
NOT USED

DAY 256, 9/13/94 UNIVERSAL TIME

NOTE: GPS NOT LOCKED; SYNCING CLOCK TO GOES EAST 06:30 LOCAL TIME
11:10 SYSTEM WARMED UP & FUNCTIONING; GAIN TO 6
11:39 WRITING TO DISK
11:50 NO SYSTEM SYNC - DISK OFF
12:00 SYSTEM SYNC - WRITING TO DISK; START TAPE #1
12:15 END OF TAPE #1
12:19 START TAPE #2; GAIN TO 5
12:20 GAIN TO 6
12:23 RESTART PC SOFTWARE
12:35 END TAPE #2
12:38 START TAPE #3
12:46 INTERFERENCE SOURCE SSE
12:51 HEAVY INTERFERENCE
12:54 END TAPE #3
12:57 START TAPE #4; ACTIVITY INCREASING
12:58 GAIN TO 5
13:12 END OF TAPE #4
13:17 START TAPE #5
13:21 RECORD TO DISK OFF FOR 9 MINUTES
13:32 END OF TAPE #5
13:33 GAIN TO 6

13:44 GAIN TO 5
14:06 END WRITING TO DISK; REWINDING TAPES; END OF TAPE SENSOR NOT WORKING
15:01 WRITING TO DISK; ACTIVE STORM TO THE SOUTH
15:34 END OF DATA COLLECTION; RESUME REWINDING TAPES
17:26 SYSTEM SHUT DOWN

DAY 257, 9/14/94 DOWN DAY
NOTE: PUT UP VERTICAL ANTENNA

DAY 258, 9/15/94 DOWN DAY
NO DATA COLLECTION

DAY 259, 9/16/94 UNIVERSAL TIME

11:17 START UP SYSTEM; COLD NOT COMPLETELY OPERATIONAL
11:59 SYSTEM OPERATIONAL; GAIN @ 4
12:46 GAIN TO 6
12:52 GAIN TO 5
13:00 WRITE TO DISK
13:06 AIRCRAFT TRACKING IN VIEW
13:26 AIRCRAFT SIGNAL IS OUT OF RANGE
13:45 STOP WRITING TO DISK
16:48 GAIN TO 6
18:14 WRITING TO DISK; GAIN @ 5
19:26 STOP RECORDING DATA TO DISK; TRANSFERRING FILES TO SUN

DAY 260, 9/17/94 UNIVERSAL TIME

GOES BEFORE 19:51
GPS AFTER 19:51
NOTE: PULSER ON NORTH OF ARRAY - 150'
17:35 START UP SYSTEM; GETTING READY FOR DATA COLLECTION
18:24 SYSTEM RUNNING PROPERLY
18:25 RECORDING TO DISK; MODERATE ACTIVITY; GAIN @ 6
19:25 CLEARED DISK (CORRUPTED FILES)
19:25 START RECORDING TO DISK; GAIN TO 6
19:51 GPS BACK ON LINE (COLD SOLDER JOINT ON BOARD?)
20:05 START TAPE #1
20:07 DSP NOT SYNCING PROPERLY
20:13 WRITE TO DISK
20:19 END OF TAPE #1

20:20 REBOOT SYSTEM
20:23 TAPE #2; WRITE TO DISK
20:32 SYSTEM TROUBLE
20:34 SYSTEM WORKING - CONSIDERABLE INTERFERENCE
20:38 END OF TAPE #2
20:45 START TAPE #3
21:00 END OF TAPE #3
21:01 END RECORDING TO DISK; REWINDING TAPES
22:03 REWINDING COMPLETE

DAY 261, 9/18/94 DOWN DAY

GPS UP; PROBLEM WAS COLD-SOLDERED JOINT ON CARD.
NO SIGNIFICANT WEATHER; DOWN DAY
NO DATA COLLECTION

DAY 262, 9/19/94 UNIVERSAL TIME

GPS UP 28 DEGREES 32.303'
80 DEGREES 38.618'

14:30 CLOCK SYNCED TO GPS

NOTE: CLOCK MAY BE FALSE TRIGGERING ON 1MHZ DISCIPLINED OSCILLATOR
FROM GPS; WILL USE STABILIZED HP OSCILLATOR FOR REMAINDER OF
PROGRAM

14:40 WEATHER BRIEFING: 80% CHANCE THUNDERSTORMS IN AFTERNOON;
HIGH DENSITY RECORDING (HDR) SCHEDULED FOR 1500 LOCAL TIME
(1900Z); TERMINATE OAS CALL FROM CAPT. LONG; BLACKBEARD
PASSAGES AT 20:23 AND 22:12 UNIVERSAL TIME (UT)

16:35 SYSTEM START UP; NOT COMPLETELY ON LINE

17:52 GAIN TO 5; WRITING TO DISK

18:30 GAIN TO 4

18:30 START TAPE #1; VERY ACTIVE; THUNDER AND RAIN

NOTE: 4/5 SINE A/D CONVERTER APPEARS DAMAGED

18:45 END OF TAPE #1

18:46 4/5 SINE A/D CONVERTER REPLACED

18:49 START TAPE #2

18:59 STOP TAPE PER CAPT. LONG; RESUME HIGH SPEED COLLECTION WHEN
CAPT. LONG CALLS BACK

19:33 RESUME DATA COLLECTION TAPE #2

19:41 END OF TAPE #2

19:45 START TAPE #3

19:58 GAIN TO 5

20:00 END OF TAPE #3

20:10 END OF DATA COLLECTION TO DISK; REWINDING TAPES

21:31 DATA TO DISK; REWINDING TAPES COMPLETE
21:35 GAIN TO 6
22:30 END OF DATA COLLECTION TO DISK

DAY 263, 9/20/94 UNIVERSAL TIME

GPS UP

14:30 WEATHER BRIEFING: FRONT AREA CLOUDS WILL REDUCE HEATING
EXPECT LESS ACTIVITY THAN YESTERDAY; PEAK ACTIVITY 2-4 PM
LOCAL TIME; 90% CHANCE TRW; WED. - 80% CHANCE CAPE/KSC;
THURS. - 60% CHANCE CAPE/KSC; RECORD AT DISCRETION DURING
SIGNIFICANT LIGHTNING
14:41 CLOCK SET TO GPS PULSE
17:13 SYSTEM WARMED UP AND FUNCTIONING; GAIN @ 6
20:01 WRITING TO HIGH SPEED TAPE #1; GAIN @ 6; WRITING TO DISK
20:04 HIGH SPEED TAPE #1 OFF
20:08 GAIN TO 7
21:21 GAIN TO 5; SOME LOCAL ACTIVITY
21:51 GAIN TO 6
22:07 WRITING TO TAPE #1; ACTIVITY TO THE SOUTHWEST; THUNDER AND
RAIN
22:19 END OF TAPE #1; GAIN TO 5
22:34 END WRITING TO DISK
22:35 REWIND TAPE #1; TRANSFERRING DATA TO SUN
22:59 SYSTEM ON LINE RECORDING DATA TO DISK; LIGHT ACTIVITY
OVERHEAD AND TO THE WEST
23:30 LITTLE LIGHTNING ACTIVITY - TORRENTIAL RAIN AT TRAILER

NOTE: IT SEEMS AS IF A.C. DIRECTLY BLOWING ON THE HIGH SPEED TAPE
RECORDER WILL AFFECT PERFORMANCE; AFTER A.C. IS TURNED OFF WE
HAVE NO PROBLEMS WITH THE SYSTEM KEEPING IN SYNC

DAY 264, 9/21/94 UNIVERSAL TIME

GPS UP

14:08 SET CLOCK - GPS PULSE
16:58 SYSTEM WARMED UP AND READY TO TAKE DATA; NO ACTIVITY
17:30 ADJUSTED DC OFFSETS FOR HORIZONTAL BASELINES
21:00 OPERATIONS FOR DAY CALLED OFF; NO ACTIVITY

DAY 265, 9/22/94 UNIVERSAL TIME

GPS UP

13:55 SET CLOCK - GPS PULSE

14:10 WEATHER BRIEFING: DOWN DAY; 20% - 30% CHANCE OF TRW; NEXT
OPPORTUNITY PROBABLY SUNDAY; CAPT. LONG WILL NOT COLLECT
DATA TAPES UNTIL TUESDAY
20:43 3 MINUTES BLACKBEARD SUPPORT DATA ON HDR; END TAPE AT 1770'
20:50 SYSTEM SHUT DOWN

DAY 266, 9/23/94 UNIVERSAL TIME

GPS UP

14:15 WEATHER BRIEFING: DOWN DAY; 20% CHANCE OF RAIN/LIGHTNING IN
THE PM; 30% CHANCE TOMORROW; 30% SUNDAY; INCREASING
PROBABILITY OF ACTIVITY WITH APPROACHING FRONT MONDAY
16:30 GPS LOST LOCK

DAY 267, 9/24/94 UNIVERSAL TIME

GPS UP

12:45 GPS BACK IN SYNC; GPS LOG SHOWS THAT IT WAS OUT OF LOCK FOR
ONLY 30 MINUTES LAST NIGHT
19:33 CLOCK SET USING GPS; GAIN TO 6; VB CLOCK SET; WEATHER
DEVELOPING TO SOUTHWEST; EXPECTING HDR COLLECTION BETWEEN
2100 AND 2200 UT
20:00 WRITING TO DISK; PULSER IS ON
20:03 VB SYSTEM ACTIVE; TRIGGER LEVEL 1.4V
20:04 PULSER OFF
20:13 INSULATOR ON SLOW ANTENNA CLEANED
20:14 VB SYSTEM RE-ACTIVATED; TRIGGER LEVEL 1.6V; LDAR TRIGGER
ABSENT AGAIN
20:21 STOP RECORDING TO CHANGE HIGH SPEED TAPE
20:24 RECORDING TO DISK; TAPE MOUNTED AND READY
20:39 GAIN TO 5; VB TRIGGER TO 1.75V
20:50 START RECORDING TO HIGH SPEED TAPE #1
20:51 OVERHEAD ACTIVITY
20:53 GAIN TO 4; VERY ACTIVE
21:06 END OF TAPE #1
21:08 START TAPE #2
21:19 VB TRIGGER TO 1.89
21:24 END OF TAPE #2; STOP RECORDING TO DISK
21:27 START TAPE #3
21:31 TRACK 24 LIGHT ON
21:34 TRACK 24 LIGHT OFF
21:34 VB TRIGGER TO 1.80V
21:39 VB TRIGGER TO 1.71B
21:42 END OF TAPE #3; GAIN TO 5
21:45 START TAPE #4

21:47 GAIN TO 4
21:58 GAIN TO 5
22:00 END OF TAPE #4
22:04 WRITING TO DISK
22:16 GAIN TO 4
22:50 DATA ACQUISITION ENDS
22:55 REWIND TAPES AND TRANSFER DATA FILES TO THE SUN
COMMENTS: STARTING AT 20:45 A VERY ACTIVE STORM PASSED NEARLY
OVERHEAD; PEAK ACTIVITY WAS BETWEEN 2100 AND 2124 UT;
GRADUALLY SUBSIDING TO END OF COLLECTION PERIOD AT 2200 UT

DAY 268, 9/25/94 UNIVERSAL TIME

GPS UP

14:45 CLOCK AND VB SET USING GPS
15:05 DISTANT STORMS AND LOCAL DRIZZLE; SYSTEM SYNCED
15:11 GAIN TO 5; VB TRIGGER TO 1.60V
16:05 GAIN TO 6; ACTIVITY MOVED OFFSHORE TO SOUTHEAST
16:34 WRITING TO DISK; GAIN TO 6; VB SYSTEM ACTIVATED & TRIGGER SET
TO 1.60V; FREQUENT THUNDER
17:03 DISK RECORDING OFF
17:15 WRITING TO DISK
17:22 GAIN TO 5; VB TRIGGER TO 1.75V (34 TRIGGERS)
17:25 GAIN TO 4
17:39 GAIN TO 3; ACTIVITY VERY CLOSE, DIRECTLY OVERHEAD
17:42 RESET VB SYSTEM CLOCK
17:46 GAIN TO 4
17:55 CLOSE STRIKE SYSTEM DOWN FOR 2 SECONDS AND WE LOSE SYNC
17:56 BACK ON LINE AND IN SYNC; RECORDING TO DISK
18:10 DOWN TO TRANSFER DATA TO THE SUN
18:51 WRITING TO DISK; GAIN TO 6
19:00 RECORDING TO HIGH SPEED TAPE #1; STOP RECORDING TO DISK; VB
TO 1.6V
19:08 GAIN TO 7
19:15 END OF TAPE #1
19:18 START TAPE #2
19:34 END OF TAPE #2
19:36 START TAPE #3
19:52 END OF TAPE #3
19:55 START OF TAPE #4
20:01 GAIN TO 6
20:02 RECORDING TO DISK; HIGH DENSITY TAPE OFF
20:35 RECORDING OFF; REWINDING TAPE; VB TO 1.75V
20:45 RECORDING TO DISK; TAPE 4 OFF LINE FOR REUSE ANOTHER TAPE #4
MOUNTED

22:00 NO WEATHER; SHUTTING DOWN; REWINDING AND ARCHIVING

DAY 269, 9/26/94 UNIVERSAL TIME

GPS UP

12:56 SET SYSTEM CLOCKS USING GPS; VB TRIGGER 1.60V; GAIN @ 6
16:00 ALIGNING GAIN/OFFSET FOR HORIZONTAL BASELINE CHANNELS; A
GREAT DEAL OF INTERFERENCE TODAY
16:44 RECORDING TO DISK; GAIN TO 6; VB TRIGGER 1.6V; THUNDER
16:48 GAIN TO 5; VB TRIGGER 1.75V; SERIOUS THUNDER; SLOW ANTENNA IS
LOOKING TOO SLOW
17:04 GAIN TO 4
17:10 SYNC LOST AFTER LIGHTNING STRIKE; LOST 3 SECONDS
17:11:30 SYSTEM BACK ON LINE; RECORDING TO DISK
17:14 START HIGH SPEED TAPE #1; VERY ACTIVE STORM
17:16 GAIN TO 3; STRIKES OVERHEAD
17:23 GAIN TO 4; MANY STRIKES CLOSE TO ANTENNA
17:30 END OF TAPE #1
17:33 WRITING TO DISK ONLY; STORM MOVING EAST
17:50 STOP WRITING TO DISK
18:15 WRITING TO DISK; GAIN TO 6
19:00 RECORDING TO HIGH SPEED TAPE #2; NOT RECORDING TO DISK
19:06 GAIN TO 5
19:15 END OF TAPE #2
19:18 START TAPE #3
19:22 GAIN TO 6
19:30 GAIN TO 5
19:33 END OF TAPE #3; SYNC LOSS
19:44 START TAPE #4
19:45 GAIN TO 4
19:52 GAIN TO 5
19:59 GAIN TO 6
20:00 END OF TAPE #4; ALL DATA COLLECTION TERMINATED
20:07 DATA ACQUISITION RESUMES; RECORDING TO DISK

DAY 270, 9/27/94 UNIVERSAL TIME

GPS UP

12:30 POSSIBLE OPERATION BETWEEN 1000 AND 1300 LOCAL (1400 - 1700 Z)
13:40 CAPT. LONG CONFIRMS 1000 - 1300 LOCAL COLLECTION WINDOW;
MEETING AT AFTAC TOMORROW 10:30 LOCAL TIME
17:00 GAIN TO 7; NO ACTIVITY
17:05 KEEP 8TH, 9TH, AND 10TH TAPES
18:47 THUNDER; WRITING TO DISK; GAIN TO 6

18:57 GAIN TO 5; VB TRIGGER TO 1.60V
19:03 GAIN TO 4; VB TRIGGER TO 1.25V
19:26 STOP WRITING TO DISK

END OF PROJECT DATA COLLECTION OPERATIONS

DAY 271, 9/28/94 LOCAL TIME

10:30 WRAPUP/DEBRIEFING MEETING AT AFTAC;

END OF DOCUMENT