



**JOINT STARS DATA ANALYSIS
OF "THE BATTLE OF KHAFJI"
FINAL REPORT**

8 May 97

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CDRL ITEM A002

19980130 118

31010

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1. AGENCY USE ONLY (Leave blank)	2. REPORT DATE 8 May 97	3. REPORT TYPE AND DATES COVERED Final	
4. TITLE AND SUBTITLE Joint Stars Data Analysis The Battle of Khafji Scientific and Final Report		5. FUNDING NUMBERS	
6. AUTHOR(S)		7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) Northrop Grumman Corporation, Surveillance & battle Management Systems, Electronics & Systems Integration Division, 2000 W. NASA Blvd, Melbourne FL 32902 Harris Information Division (HSD), 150 Wickham Road, Melbourne FL 32902	
8. PERFORMING ORGANIZATION REPORT NUMBER P.O. 0277-6011311		9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES) Air Force Studies and Analyses Agency, 1570 AF Pentagon, Washington DC 20330 AFMC/RL, 26 Electronic Parkway, Rome NY 13441	
10. SPONSORING/MONITORING AGENCY REPORT NUMBER 31010		11. SUPPLEMENTARY NOTES	
12a. DISTRIBUTION AVAILABILITY STATEMENT No Limitations		12b. DISTRIBUTION CODE	
13. ABSTRACT (Maximum 200 words) This report details analysis results of JSTARS datafiles from 25 January to 3 February 1991. Lines of Communication in use by Iraqi vehicles on those dates are geographically specified on a map. Probable identification of specific maneuver units, intent, and the relative impact of air interdiction attacks is detailed. Preparations of other defensive actions is revealed. Tactics resorted to on subsequent days in response to air attacks are identified. Overall, the magnitude of Iraqi activity revealed indicates the failed attempt at Khafji from 29 to 31 Jan 1991 was planned to be a major ground effort. The analysis provides a historical example of the military worth of Intelligence Surveillance and Reconnaissance (ISR). Methodology for follow-on analysis is outlined.			
14. SUBJECT TERMS JSTARS, Khafji, Operation DESERT STORM, ISR, Information Superiority, Air Interdiction, Halting Phase, Asymmetric Attacks, Battlefield Dominance, Global Attack, Precision Engagement			15. NUMBER OF PAGES
17. SECURITY CLASSIFICATION OF REPORT UNCLASSIFIED			16. PRICE CODE
18. SECURITY CLASSIFICATION OF THIS PAGE UNCLASSIFIED	19. SECURITY CLASSIFICATION OF ABSTRACT UNCLASSIFIED	20. LIMITATION OF ABSTRACT UL	

**Joint STARS Data Analysis
Technical Interchange Meeting
(TIM) # 2 8 May 1997**

Battle of Khafji

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- When considering the Battle of Khafji, two quotes come to mind.
- *“The Air Force Has Never Decided A War” (Saddam Hussein)*
- *“The Battle of Khafji did validate the idea that air power could be used to defeat the enemy army before it closed with our own ground forces” (Gen. Chuck Horner)*
- This study analyzes the Joint STARS Moving Target Indicator (MTI) data from Desert Storm and quantifies the movements of the Iraqi forces during the time period of 25 January 1991 to 3 February 1991. The results of this examination are remarkable. The combination of wide area coverage and all weather surveillance offers a unique record of the actions surrounding the Battle of Khafji, primarily through the characterization of the operational maneuvers of four Iraqi divisions (1st and 5th Mechanized, 3rd and (possibly) 6th Armored). This study reveals the primary and secondary lines of communications utilized by the Iraqi invading forces as well as their disruption by Airpower, the development of alternative routes, and ultimately the denial of operational maneuver. Another discovery from the MTI data was the preparation of defensive positions, both along the border from the “elbow to the heel” as well as the artillery positions in central Kuwait, north of Al Wafra. These artillery positions, whose flanks were guarded by the defensive positions to the west were intended to provide of kill zone that retreating Iraqi forces would draw Coalition ground troops to after initiating contact and withdrawing.

Agenda

- **Review of Khafji Study**
- **Summary of Results**
- **Data Analysis**
- **Follow-on Study Concepts**

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- **The purpose of this presentation is to review the study objectives and describe the progress that was made, identify the discoveries that arose from the review of the MTI data and to characterize the data that has been generated from this effort. Some discussion will be presented on the challenges presented in analyzing the EMD Joint STARS data, data collected a full six years before scheduled IOC. As is often the case in small studies, opportunities have been identified that could extend the knowledge generated thusfar. After reviewing the results of this analysis a brief discussion of potential follow-on activities is presented.**
- **This study was conducted by Northrop Grumman Surveillance & Battle Management Systems (SBMS) Division, Melbourne, Florida under subcontract to Harris Corporation Information Systems Division, also of Melbourne Florida for the Air Force Studies and Analyses Agency. The only contract deliverable is the final report.**

Joint STARS Data Analysis

Review of Study

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- In the conduct of this analysis a great deal of information was discovered concerning the Iraqi actions during the 25 January 1991 to 3 February 1991 timeperiod. The appearance of extensive coherent movement, or *lines of communication* provide a vast database on operational and tactical Iraqi maneuvers - ranging from extensive transportation networks, preparation of defensive positions, operational deployments from cantonments, and tactical attack formations. Additionally, review of Joint STARS MTI data reveals the effect of Coalition Airpower including road closures, alternative route usage, and the disruption of Iraqi columns. The lack of persistence in Joint STARS coverage coupled with limited objective data on specific aircraft employment makes the quantitative assessment of airpower necessarily subjective. This notwithstanding, clear evidence of the overall effects are seen in halted columns, closed roads and the overall ineffectiveness of the Iraqi operational maneuver.
- The remainder of this report describes the extensive line of communication database that has been created and the implications of this patterns in the context of the Persian Gulf War. The analytic process developed to derive the quantitative metrics is described and potential follow-on topics are also discussed.

Study Objectives

- **Identification of Convoy Movement**
- **Characterization of Convoy Movement**
- **Correlation to Air Attacks**
- **Trend/Behavior Analysis**
- **Theater Battle Arena Support**

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- **This analysis centers on the Joint STARS Moving Target Indicator (MTI) data collected from 25 January to 3 February 1991, and more specifically that subset of data frames that covered the requisite geographic areas. MTI data records a variety of data associated with a moving object (or target). The information provided is quite powerful but there are limitations associated with this technology. Other aspects of radar detections include background noise or clutter, radar returns from weather and other random events associated with the probabilistic nature of the radar detection phenomena. Hence the data collected by Joint STARS does not directly translate into a complete picture of the battlefield, it requires filtering or processing to arrive at the information required in this contract.**
- **Joint STARS data from Desert Storm did not contain Doppler Radial Velocity and Cross Range Error Estimate (as well as a few other data fields). Missing this data transforms the convoy analysis from a tracking problem to the analysis of non-correlated 'dots' spaced irregularly in time. Conventional pattern matching technologies were applied and a technique was developed that estimates vehicle count, inter-vehicular spacing and velocity from the raw MTI data. The first step in this process is to inspect the raw MTI data and to isolate concentrations of MTI reports along lines of communication. From this database significant operational**

Specific Tasking

- **“Provide analysis support to review available Joint STARS MTI data/reports and assist in the development of a synopsis of battle activity for the Khafji action conducted 25 Jan - 3 Feb 91”**
- **STATUS:**
 - **Database Designed, 100% Populated**
 - **Identification of 560 Lines of Communication Provides Unprecedented Assessment of Enemy Activity**

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- **The review and analysis of the Joint STARS MTI data results in a remarkable database that characterizes Iraqi movement throughout the KTO. In all 560 distinct observations of coherent movement were identified covering approximately seven different areas of activity. Details of the observations and specifics of the database design are presented later in the presentation.**
- **The isolation of lines of communications and their associated MTI data reports shows the location of both the major axes of movement as well as the construction of defensive blocking positions and artillery firing positions which, when considered from an operational standpoint, reveal the intentions of the Iraqi maneuver prior to their action. What is fascinating about the Joint STARS MTI data is that the operational use of only a single aircraft at a time limited the areas that the radar could cover. In the historical context of late January 1991 the onset of Scud attacks on Saudi Arabia and Israel it is understandable that the priority for KTO coverage by the Joint STARS aircraft was (roughly) only 40%. As a result continuous, persistent surveillance occurred only rarely, resulting to some extent in a fragmentation of the data and the large number of observed coherent movements.**

Specific Tasking

- **“Provide, per information available, quantitative analysis and comment as to target indicators being wheeled or tracked vehicles, location, speed, and direction of travel. As matching Air Force mission reports are available (per time frame of MTI) analysis comments shall be provided as to targeting, destruction, delay/diversion, and/or other military significant target activity”**
- **STATUS:**
 - **Target Indication of Tracked or Wheeled Inactive**
 - **Methodology Developed to Discern Vehicle Count, Speed and Direction**
 - **Have Identified Data Sources For Correlation to Air Attack**
 - **Found Evidence of Preparation of Defensive Positions**

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- **The 1991 EMD Joint STARS data collection did not capture all the data specified for the production aircraft. The wheeled/track indicator was not active, thus to determine that attribute of an MTI report would require alternative sources of data such as overhead imagery of access to field inspection reports. Without Doppler Radial Velocity and Cross Range Error Estimate (CRE) the determination of ‘location, speed, and direction of travel’ of MTI targets offered the greatest challenge. Missing the kinematic track data, the estimation of the MTI target dynamics required the use of pattern matching techniques to calculate velocity and position. This process has been developed and tested on limited data but the combination of the manual nature of the process, the extensive number of observations, and the limited schedule of the contact prohibited the processing of the line of communication database.**
- **Without the MTI target dynamics it is still possible to learn a great deal from the Joint STARS MTI data. Clear evidence of defensive position preparation, interdiction and disruption of lines of communication offer subjective assessment of the impact of airpower on the movement of Iraqi forces. Even given the computed metrics, the correlation to Air Force (and Marine, RAF, etc.) sorties requires access to additional data sources. Review of various mission reports provide insight into air activity but the dynamic nature of the battlefield often found aircraft diverted to different targets or other deviations from the original ATO. It is recommended that the E-3C AWACS Air Track data be reviewed and correlated with Joint STARS MTI data to provide the best characterization of airpower.**

Specific Tasks (Cont.)

- **“Comment on any military trend data and target response activity noted within the specified ten day period of available data”**
- **STATUS:**
 - **Large Set of Lines of Communication Identified, Analysis Across Database Provides Trend Data**
 - **Evidence of Air Attacks**
 - **Target Response Activities Identified Include: Alternative Road Use; Halted Advances; Disrupted Lines of Communication**
 - **New Insight Into Iraqi Operational Maneuvers**

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- **Much has been written about the Battle of Khafji, beginning with the 1993 GWAPS and more recently Gordan and Trainor’s “The General’s War” (1995) The review of the lines of communication maps and their consideration over a period of time offers new insight into the battlefield that has not been addressed in open literature.**
- **To comment on the military trends observed and the target responses one needs to consider the lines of communication over time. Along the Basra highway alternate, parallel roadways are often seen used in place of main routes, evidence of road closure due to air strikes. Towards the south main arteries feeding Al Wafra are clearly observed one day and later in the timeperiod these same road segments are severed. Further, isolated cases of Joint STARS coverage of actual air interdiction has been catalogued.**
- **Probably the most interesting trend data is the combination of defensive blocking positions observed around OP-6 (at the “Elbow”) and the artillery emplacements seen from north of Al Wafra to the coast. The combination of these two formations, in hindsight, reveal the operational intentions of the Iraqis.**

Summary of Progress

- **All Ten Days MTI Data Has Been Screened For Lines of Communication And Entered Into Database**
- **Methodology To Compute Quantitative Convoy Metrics Has Been Developed But Process Proved Too Time-Consuming For The Study Schedule**
 - **Compiled Mathematica 3.0 Has Been Installed. Should Provide Significant Throughput Gains.**
- **Correlation To Air Attacks Is Currently Subjective, Seek Quantitative Data On Air**
 - **AWACS Air Track Data**

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- The analysis of the requisite ten day period has yielded an extensive database of observed movements. This data has been processed into a number of data products integrated into a database. The central element is, of course, the Joint STARS MTI data that contains coherent lines of communication. This information has been augmented by cartographic data, graphic files of JSX displays, and to some extent, various mission reports and logs from the various participating military units. The combination of this information in a chronological database provides the analyst a substantial database for analysis of the events surrounding the Battle of Khafji.
- The computation of quantitative metrics (vehicle count, velocity and inter-vehicular spacing) was not completed for this study. The missing data elements from the EMD Joint STARS mandated the development of alternative processes to perform the tracking function. While we were successful in the analytic approach, time did not permit the processing of the extensive database of observed lines of communication.
- The correlation of changes in movement doctrine to the presence of airpower can only be done at a subjective level. The missing quantitative metrics combined with the lack of detailed sortie data requires that the assessment of airpower be based on observed changes in the lines of communication. Here, the effects of airpower are clearly evident but the quantification is less definitive.

Joint STARS Data Analysis

Summary of Results

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- Over the ten day period from 25 January to 3 February 1991 the Joint STARS EMD aircraft logged over 100 hours of operational mission time, collecting a total of 3332 frames of MTI data. Of this, 1059 frames (31.8%) covered the area south of Kuwait City to the Saudi Arabian Border. While it is these 'looks' that are of the most interest, the other areas covered included the Basra Highway and the region between the Wadi al-Batin and Observation Post 6 (OP-6, located at the "Elbow"). Regardless of the persistence or the frequency of looks, by noting the accumulation of concentrations of MTI reports along lines of communication we are able to identify the movement patterns that Iraq employed in their attempted invasion of Saudi Arabia.
- The following section will first summarize the overall data collected and characterize the general trends that have been observed and then will proceed to a daily summary of Joint STARS MTI data. Again, it is important to note that the sensor can only collect data where it is directed and the operational decision was made to only employ one E-8A at a time. Further, the priorities of the sensor employment was debated to the highest levels and the resulting emphasis on Scud Hunting and the protection of the maneuvering VII and XVIII Corps significantly reduced the amount of data collected in the MARCENT area.

Summary of Results

- **Flight Summary**
- **MTI Data Issues**
- **Lines of Communication**

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- **The first step in understanding Joint STARS data collection is to consider the mission times. Subjective reports note that with the onset of the Air War, the Iraqis quickly stopped maneuvering during the day, not realizing that the Joint STARS to observe their movements at night, through the weather, at considerable distance.**
- **The next factor in the nature of the Joint STARS MTI data is the immature state of onboard data collection during 1991. Fully six years prior to scheduled IOC, the E-8A aircraft proved quite reliable, with a 85% mission capable rate. Fortunately, if problems occurred in one aircraft the second was available, thus full missions were conducted for every day during the time period (the entire war in fact). However, the software was truly engineering development code and in order to promote system reliability, certain features of the software were deactivated. This section will describe the impact of the missing data.**
- **The final section analyzes the observed lines of communication. This extensive database provides a unique record of the events surrounding the Battle of Khafji and the Gulf War in general. The magnitude of the forces deployed and their utter failure to advance itself is subjective evidence of the effects of airpower. Other features of the data will be discussed including observations of the preparation of defensive positions that, if recognized at the time would have given remarkable insight to the Iraqi intentions.**

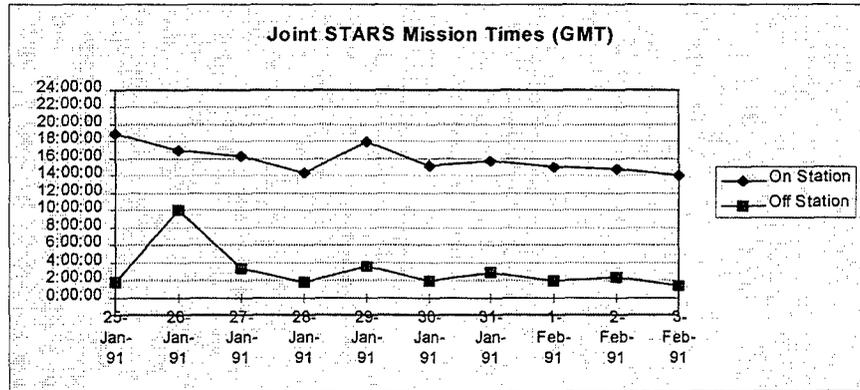
Flight Summary

- **Two Joint STARS EMD Aircraft (T1 and T2) Arrived In Theater Mid January 1991, First Operational Flight 17 January**
- **One Aircraft Was Operated Each Night, Mission Times (25 January to 3 February) Averaged 11 Hours**
- **As a Result of Limited Resources, Sensor Coverage Is Not Continuous (24 Hour)**
- **Historical Context is Important. SCUD Launches Occurred at the Time And Joint STARS Aircraft Primary Tasking Was SCUD Hunting, Not Khafji**

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- **The arrival of the two EMD Joint STARS aircraft to Saudi Arabia 11 January 1991 did not bring with them high expectations. Although the history of the Joint STARS program can be traced to the mid-1970's the actual system was in 1991 in a rather early stage of development. The Joint STARS Program Office was stood up in May of 1983 and the E-8 designation was assigned in September of 1985. The first fully configured E-8A aircraft flight took place in December of 1988. The complexity of the system warranted operational environmental test for risk mitigation and one of the first such tests ("Early Look") took place in February 1990. In the fall of 1990 Joint STARS participated in the Army Operational Field Demonstration (OFD) "Operation Deep Strike", to troubleshoot and fine-tune the software. The success of the E-8A at the OFD paved the way for the assignment of the EMD aircraft to the Persian Gulf War.**
- **After deploying to Saudi Arabia in mid-January the two Joint STARS aircraft flew 49 missions in 49 days, achieving a remarkable 85% operational readiness rate. Caution dictated the use of only one aircraft at time and missions were only flown during darkness. Still, the flights averaged in excess of ten hours in duration and provide a remarkable insight in the actions the the Kuwait Theater of Operations (KTO).**

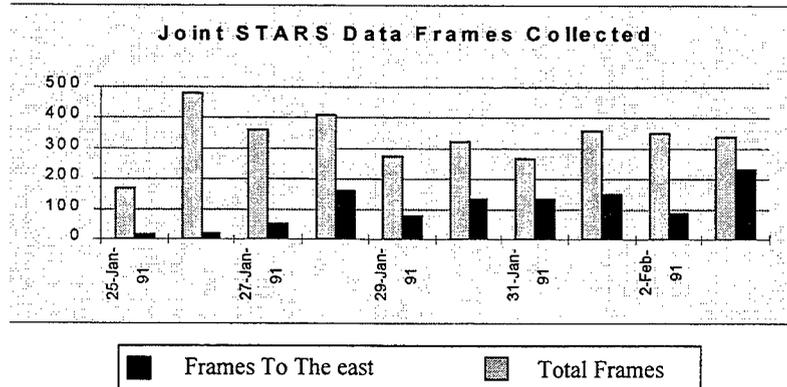
Operational Overview



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- In terms of data collection this does not have a large impact on the characterization of Iraqi movements because with the onslaught of the Coalition Air Campaign (0300 17 January 1991) daytime movement by Iraqi forces ceased. For reference local time is GMT +3 with dawn occurring at 0340Z and dusk at 1440Z.

Operational Data Frames

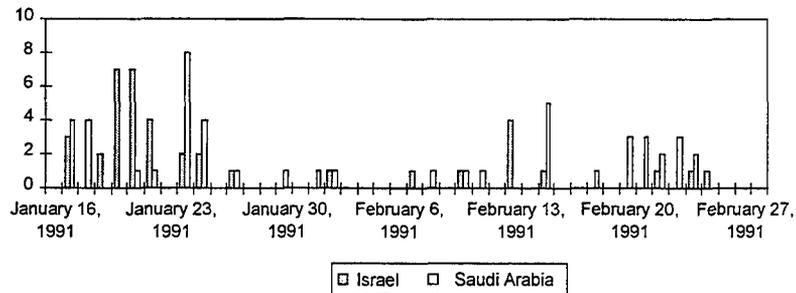


This is a Subjective Assessment of the Location of the Joint STARS GRCA. Historical Records Reflect CINC-directed Joint STARS Employment Was Split Approximately 60% "Scud-Hunting" and 40% To the east.

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- In an attempt to characterize the distribution of data collected in the requisite timeperiod data frames were reviewed and catalogued in terms of their coverage. At the time of battle, Coalition forces were conducting the 'Hail Mary' maneuver and were vulnerable to attack, especially along the Wadi al-Batin. Further, electronic deception was employed near Khafji to mask the movement of the VII and XVIII Corps west. Consider then the Scud missile launches from near the Tri-Border area and one begins to understand the assignment of the Joint STARS radar to areas other than southern Kuwait.
- A historical perspective is warranted. By the 25th day of January 1991, Iraq had been subjected to nine days of crippling of coalition air attacks on their air defense and command hierarchies. The Scud launches began January 16 had inflicted some damage but the restraint of Israel kept the Coalition intact. In one of the more heinous acts of the war, Iraq began pumping millions of barrels of Kuwaiti oil into the Gulf. After occupying Kuwait since 2 August 1990 the Coalition unleashed Operation Desert Storm January 17 at 3 a.m. Baghdad time. Phase I was intended to establish air superiority, destroy Iraq's strategic capability, and disrupt command and control. In all 750 attack missions are flown during the first part of the day. Eight days later, Coalition forces had completed 14,750 attack sorties and the Iraqi forces were at a critical juncture.

Scud Launches During Desert Storm



SOURCE: US Air Force as referenced in *Airpower in the Gulf*, James P. Coyne, Air Force Association, 1992, p.56.

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- Scud launches at both Israel and Saudi Arabia began on January 16 and caused some damage but Israel heeded US warnings of not militarily responding and the Coalition held firm. The effect of these attacks with missiles capable of carrying weapons of mass destruction had a significant effect on Coalition operations in general and Joint STARS mission tasking in particular. Of the 3332 data frames collected over the ten-day period, 31.8% (1059) were dedicated to the Battle of Khafji.
- Blinded by the assault on their air defense and command hierarchy, Iraqis desperately needed to initiate contact with the coalition ground forces in order to learn their disposition. A plan had been developed that, if successful, could inflict significant casualties on the American forces and follow north Viet Nam's technique of bringing the war home.

MTI Data Overview

- **Review of MTI Data Over Time Reveals Concentrated Patterns of Movement Along Limited Number of Lines of Communication**
- **Identification of Individual Vehicles And Associated Dynamics (Speed and Direction) Complicated By the Immature Status of the EMD Sensor System in 1991**
 - **Doppler Radial Velocity, Cross Range Error Estimate (CRE), Wheeled/Tracked Indicator Inactive, High Clutter, WX**

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- **The main thrust of this study contract is to quantify Iraqi convoy movement during the specified time period. The first step in the identification of convoy movement is the isolation of coherent patterns of MTI data. This step was performed using Northrop Grumman's Joint STARS Data Exploitation Workstation (JSX). By displaying multiple frames of data simultaneously, accumulations of MTI 'dots' reveal road usage or lines of communication. Current Joint STARS data and exploitation software allow the use of tracking algorithms that automatically quantify vehicular traffic patterns.**
- **Unfortunately, the EMD Joint STARS aircraft in 1991 did not collect the necessary data required for such algorithms, in particular Doppler Radial Velocity, Cross Range Error Estimate (CRE), and the Wheeled or Tracked indicator. Early in the analysis lines of communication data was evaluated with the tracking algorithms and they do not perform with a sufficient degree of accuracy to automatically compute the quantitative metrics required in the contract. An alternative approach was developed that used pattern matching technologies to estimate vehicle dynamics. This process, while successful, does not lend itself to automation and the time-consuming nature of the process prohibited completion of the metric computations.**
- **From the line of communication database alone the sequencing of Iraqi movements reveal a remarkable synopsis of operational maneuver. Isolated cases of actual air interdiction has been observed and catalogued, as well as the use of alternative routing due to road closure from previous air strikes.**

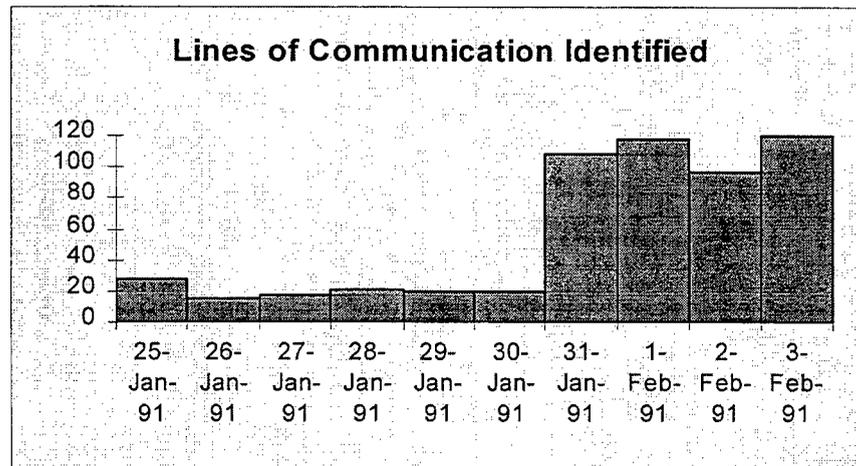
Lines of Communication Database

- **Over the 10 Day Period 560 Distinct Lines of Communication Have Been Identified**
- **Apparent Movements Map Closely to Historical Accounts**
- **Computation of Metrics From Line of Communication Data is a 4-Step Process**
 - **Filter MTI Data Within Threshold Distance to LOC**
 - **Project MTI Report Onto LOC (Capture CRE Estimate)**
 - **Transform MTI Report From {x, y, t} to {d, t}, where d is distance along LOC**
 - **Fit Transformed MTI Report to Linear Feature in Hough Space, Allowing the Estimate of Vehicle Dynamics (Capture Doppler Radial Velocity)**

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- **The database that has been prepared by this study isolates 560 instances of coherent Iraqi movements, mostly on known roadways but often movement is seen parallel of main arteries as well as numerous instances of tactical maneuver off-road. Plotting these lines of communication on maps with the overlay of the current perception of the Iraqi operational plan reveals a close tracking of events to the Joint STARS MTI data. Of significant note is the lack of discussion in literature of the probing of the region near and to the east of the Wadi al-Batin.**
- **In order to arrive at the quantitative metrics (vehicle count, inter-vehicular spacing, and velocity) to further define these lines of communication, a four step analytic process has been developed. This process will be further defined in the Data Analysis section but a general introduction will provide the reader with an understanding of the importance of certain aspects of the data collected. After visually inspecting the MTI data and extracting apparently coherent movements that data is first filtered to consider MTI reports within a threshold distance to the roadway. Taking the radar error ellipse parameters into account this data is then projected onto the roadway or line of communication (in the case of off-road movements). Taking an arbitrary start point calculate the distance down the road that the MTI report is projected to and now the data is defined in terms of distance and time. Data in this format can be processed using linear feature analysis to determine vehicle count, spacing and velocity.**

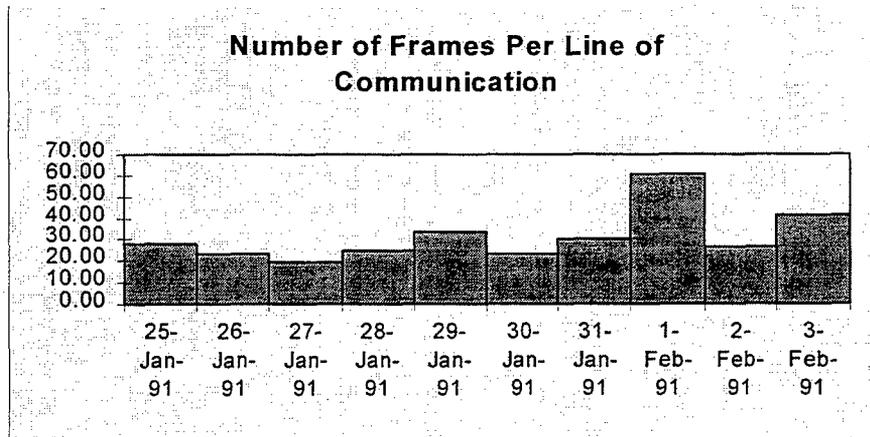
Lines of Communication (LOC) Database



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- When considering the overall number of lines of communication a couple of subtle factors need to be taken into account. First and foremost is the tasking of the Joint STARS radar: Where and for how long was it tasked to look? The initial days of the Battle of Khafji (prior to 31 January 1991) had little coverage of the region south of Kuwait City where numerous tactical movements were later observed. To the north and west the lines of communication were actually small in number. The Basra-Al Jahra highway in the north and the pipeline road to the west dominate observations.
- The effect of airpower clearly effected movement doctrine in that survivability dictated an overall dispersion of movements. Quantifying that phenomena has been hindered by the lack of definitive Coalition sortie data and the difficulty in processing the MTI data. However a subjective assessment of lines of communication count and dispersion supports the premise that airpower forced Iraqis to modify their movement doctrine.

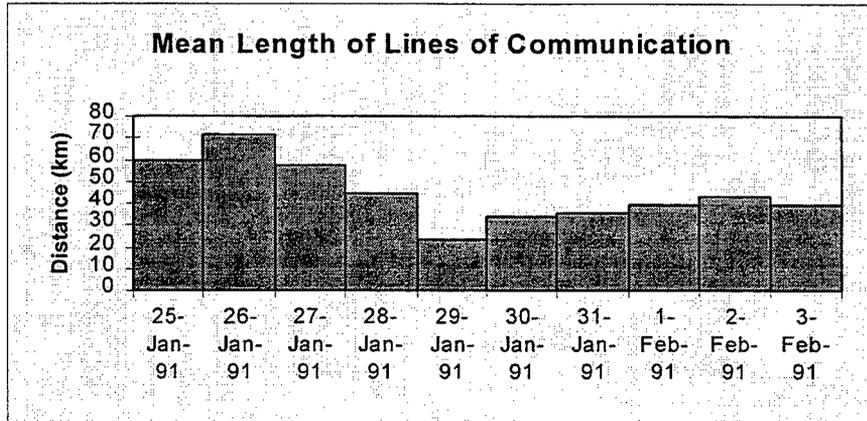
Lines of Communication Database



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- The number of frames of data used to characterize a line of communication can be roughly translated into time of coverage with each frame taking roughly 40 seconds. Of note is the greater persistence observed on 1 February. historically, the Joint STARS aircraft was a full 6 years away from introduction into the armed forces and as a result the Concept of Operation (CONOPS) was not in place. It is a credit to the military leadership that flexibility was employed and tactical employment of the new Joint STARS was experimented .
- “Over a four day period of the Battle of Khafji, almost all F-15E night sorties (100 out of 104 sorties flown) and a significant number of F-16 night sorties (40 out of 142 sorties flown) were either controlled by Joint STARS or directed against Joint STARS-developed targets. Joint STARS redirected fully half of these sorties against moving targets in the KTO”
- Source: “The Battle of Khafji: An Overview and Preliminary Analysis”, James Titus, Air University, Maxwell AFB, 1996, p. 20.

Lines of Communication Database



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- The representation of the mean length of lines of communication is meant only to help give the audience a sense of the area covered, not necessarily the length of individual convoys. The technique used to collect the line of communication data involves displaying multiple frames of MTI targets and to observe the concentrations amongst roads or pathways. As the data is accumulated over time the result of this is multiple reports on individual vehicles that are moving. This metric is presented to show that coherent movements were observed that were on the average 30-40 km in length.

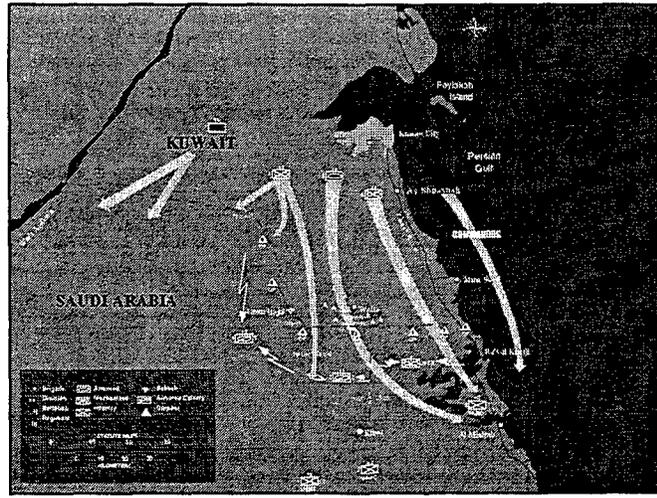
Lines of Communication Summary

- **Observed Movement Dominated By Kill Box AG6, Basra Highway Area north of Al Jahra/Kuwait City**
 - Sensor Collects Data Where It Is Pointed
- **Next Area of Concentrated Data Is Kill Box AG5, Kuwait City and south 30 nm**
- **Coast Road Data Shows a Great Deal of Noise:**
 - Weather, Returns Off Water, etc.
- **Excellent Data on Preparation of Defensive Positions:**
 - Artillery Positions south of Emir's Farm to the Coast
 - Blocking Positions at "Elbow", Between Al Manaqish and Al Minisha Oil Fields
- **Clear Evidence of Iraqi Probe of Region Between Elbow and Wadi al-Batin**

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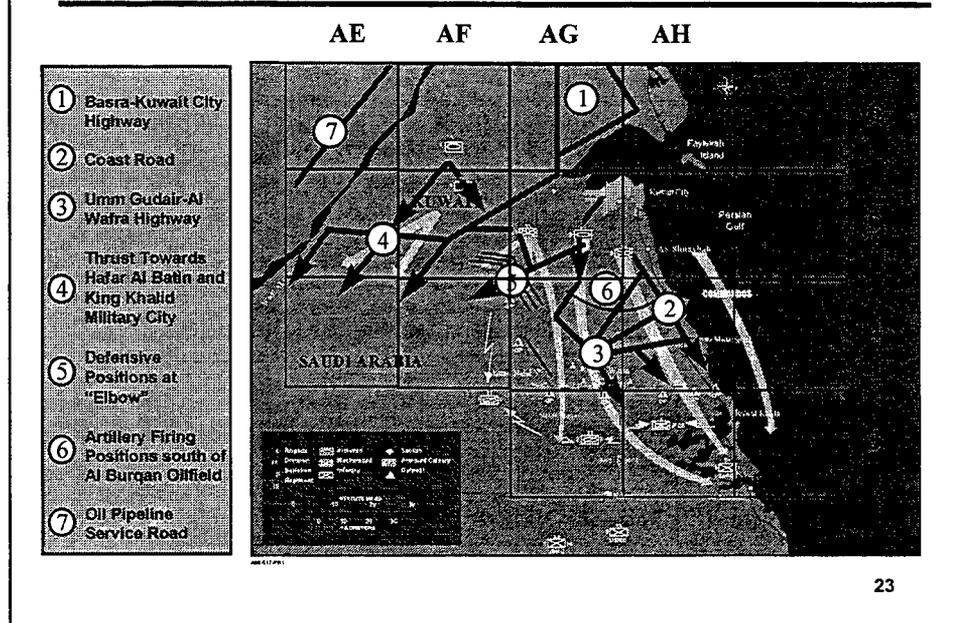
- A geographic plot of where the Joint STARS radar was tasked to look reveals a concentration on the Basra-Al Jahra Highway and the road south from Kuwait City to the Al Jaber Airbase. These numbers are considering only those areas relevant to the Battle of Khafji, that is, when Joint STARS was tracking targets within the borders of Kuwait. It is important to note that operationally the aircraft was tasked to spend 60% of its time 'Scud Hunting' in the Tri-Border on western Iraq regions and only 40% in the KTO.
- Retrospective analysis of events and decisions are delicate matters that cannot hope to capture the dynamics of the past, especially in the context of war. Considering the sequence of events surrounding the last week in January 1991, especially the military and political effects of Iraqi Scud launches at Saudi and Israeli cities, it is understandable that the Coalition was slow to discern Iraqi intentions. Additionally, the strategic direction of concentrating on the Republican Guard units to the west led Coalition commanders to suspect that the action in and around Al-Khafji was a diversion from a larger thrust down the Wadi al-Batin. Attacking there, "the Iraqis could catch the American XVIII Corps on the move, overrun King Khalid Military City, the Saudi military base south of Hafar al-Batin at the head of the Wadi, and deal a blow to the arriving VII Corps." (Gordan and Trainor)

Operational Overview



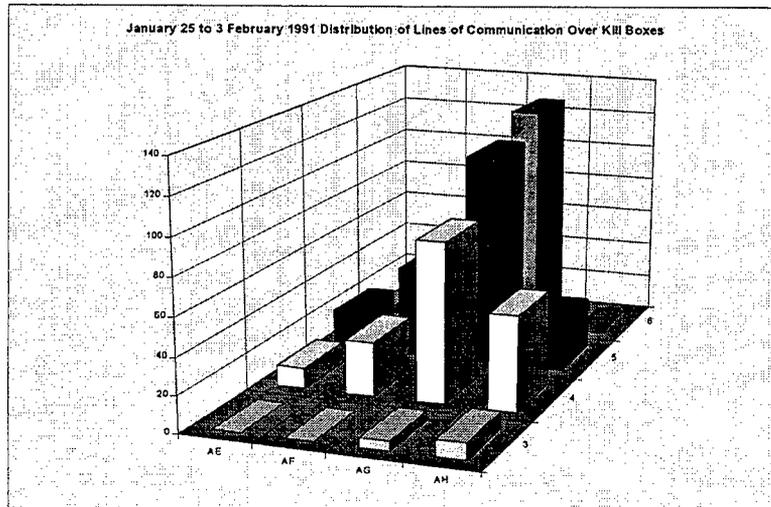
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Summary of Areas of Activity



- This map presents a stylized representation of the Joint STARS observed coherent movements of Iraqi forces in Kuwait from 25 January to 3 February 1991. Overlaid on the diagram is the cartographic labels referred to as the 'kill boxes'. Actual observations of movement are characterized in much greater detail in subsequent maps but this diagram serves to sort the data in categories that support the preparation of a battle summary.
- Label 1 shows the considerable coverage of the Basra-Al Jahra highway, including feeder roads. Numerous instances of closed roads and the development of alternative roadways were observed in the data.
- Label 2 is the Coast Road which suffered to some degree by returns off the water but significant movement is observed including a 15 mile convoy that apparently was interdicted on 31 January.
- Label 3 centers on the Al Wafra oilfields and includes an observed air attack on a 10 mile convoy.
- Label 4 centers on the southwesterly thrust east of the Wadi al-Batin. Could this be a fourth division not previously considered?
- Label 5 focuses on the defensive positions observed at the "Elbow" north of OP-6 and the movements through these lines of probing forces.
- Label 6 reveals the artillery positions put in place, preparing the 'kill zone' for later in the operational plan.
- Label 7 is the traffic flow down the pipeline service road. This was not studied.

Overall LOC Distribution



24

- Plotting the occurrences of observed Lines of Communication reveals the dominance of the central kill boxes AG-4, -5, and -6, representing the Basra-Al Jahra highway and the main arteries south of Kuwait City. Operationally, 3rd Armor Division was located in the region south (and west) of Kuwait City. AH-4, which is the Coast Road north of Al Khafji contains a significant number of coherent movements. Again, this metrics are influenced in part by the lack of persistence and the overall times that the sensor was directed in that particular area.
- The next section reviews each days coverage and summarizes the observations.

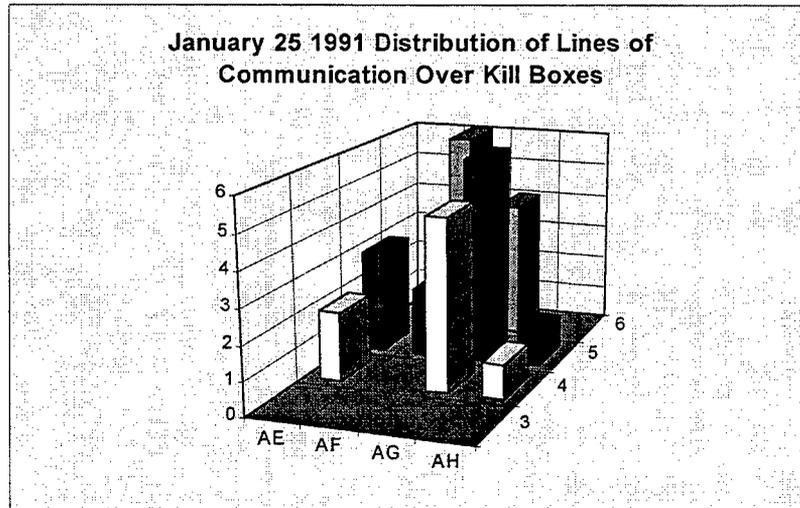
Summary of January 25 Data

- **Coverage Primarily to the west and Basra Highway**
 - western Coverage Shows Iraqi Incursion into Saudi Arabia Between “Elbow” and Wadi al-Batin
 - Coherent Traffic Flow on Basra Highway, Including Alternative Road Use
- **Clear Movement From Iraqi Units west of Ali Al Salem Airbase**
 - Supporting Incursion west of “Elbow”
- **Limited Looks to Khafji Area**
 - 20 Minutes Starting at 19:38:51Z
 - 50 Minutes Starting at 23:51:53Z
 - Defensive Positions at “Elbow” and “Heel”
 - Coherent Movements south

25

- The first day of coverage centered on the Basra-Al Jahra highway and the region west or the “Elbow”. Alternative road use is observed on the Basra highway indicating either excessive traffic or disruption due to air attack. Significant traffic flow is also observed adjacent to and east of the Wadi al-Batin. This corresponds to historical accounts of Iraqi probing of Coalition lines without achieving contact. As the action develops the extent of these probes extends thirty miles into Saudi Arabian territory. Additionally, clear movement is observed out of the area west of Ali Al Salem Airbase, the operational diagrams depict this unit as an unknown but analysis of the Iraqi positions on G-Day indicate that this may be the 6th Armor Division.
- In terms of Khafji, or areas south of Kuwait City, coverage is limited to two looks of 20 and 50 minutes which reveal movements south as well as the preparation of defensive blocking positions (three closely spaced parallel berms) at the Elbow as well as indication of a single defensive berm located at the “Heel”.

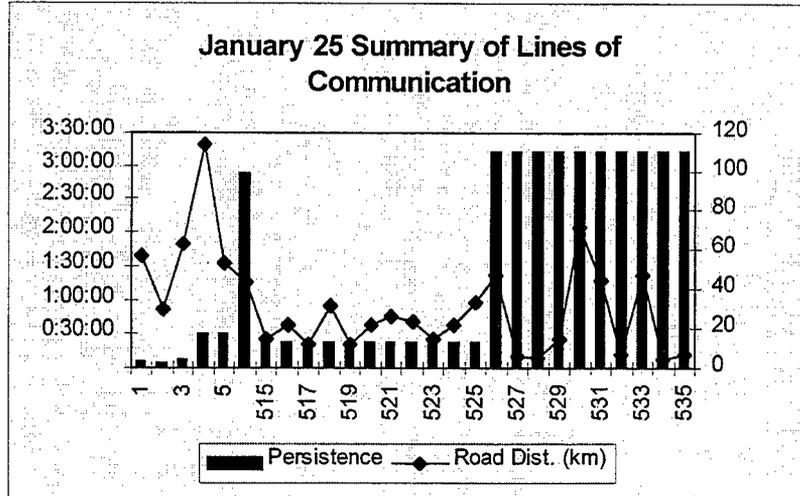
January 25 LOC Distribution



26

- This graph shows the dominance of the northern sectors as compared to the coastal areas (AH-3 and AH-4). Of note is the observations of activity near and directly east of the Wadi al-Batin (AE-4 and AE-5). Recall that AE-4 is entirely within Saudi Arabian territory.

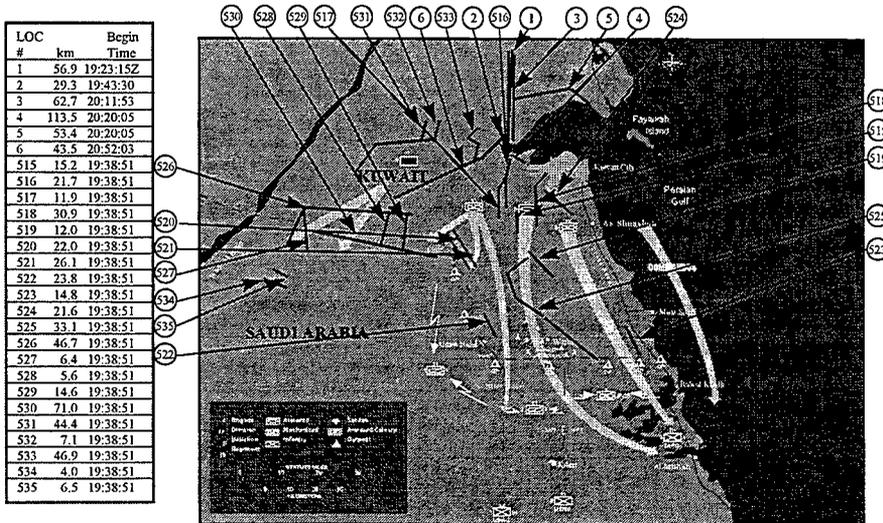
January 25 Lines of Communication



27

- This chart presents both the geographic length of the observed lines of communication as well as the time of coverage. Cross referencing the numeric identifier of the line of communication with the map plot shows the geographic location and, indirectly, the concentration of the Joint STARS radar in the northern and western regions.

January 25 Lines of Communication



28

- The coverage of Kuwait on 25 January sees a number of movements with operational implications for the Battle of Al Khafji that began early on the evening of 29 January. The incursion into Saudi territory just east of the Wadi al-Batin, combined with the apparent defensive fortifications being prepared at the "Elbow" provide valuable insight into Iraqi intentions for the operation that were about to begin. Movements south are seen from the area associated with the 3rd Armor Division and in the vicinity of Al Wafra.
- Coherent movement from west of the Ali Al Salem Airbase in support of the probes to the west give evidence of the fourth division activity not mentioned in current literature on the battle.

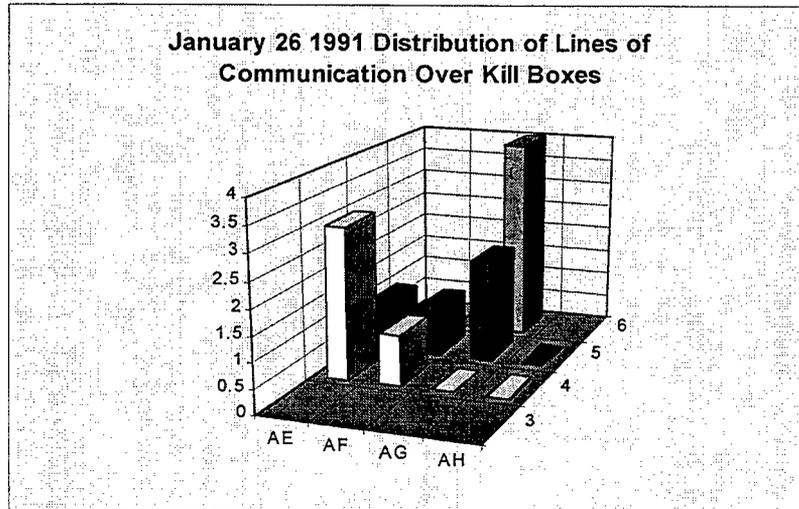
Summary of January 26 Data

- **Coverage Again to the west and Basra Highway**
 - **Iraqi Incursion Into Saudi Arabia Between “Elbow” and Wadi al-Batin Supported By Movement Along Al Jahra Highway**
 - **Coherent Traffic Flow on Basra highway, Including Alternative Road Use**
- **Clear Movement From Iraqi Units west of Ali Al Salem Airbase**
 - **Whereas 25 January Saw Activity Heading southwest, Here Movement is southeast to the Road to Al Jahra (Kuwait City)**
 - **Supporting Incursion west of “Elbow”**
- **Observation of Coherent Movement Between western Probe and Defensive Positions at “Elbow”**
- **No Looks to Khafji Area**

29

- **On the 26th of January Joint STARS coverage is exclusively to the north and west. As in the data from the 25th, movements are observed in support of the western probes along the Wadi al-Batin. No looks to the southern area of Kuwait.**

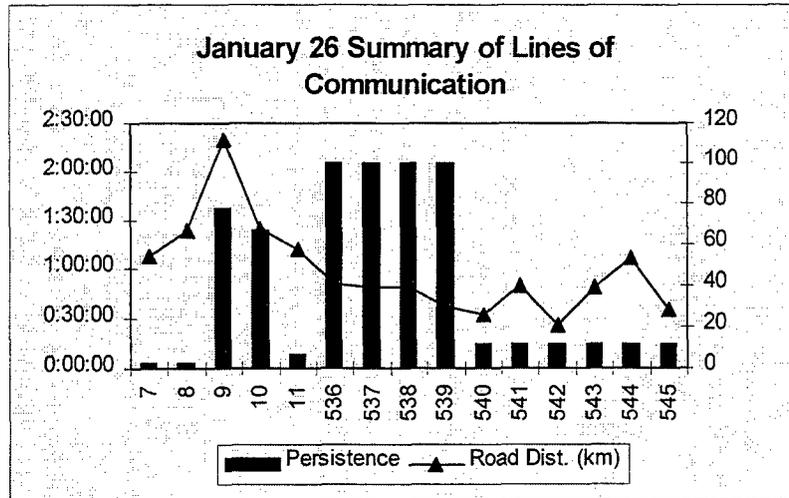
January 26 LOC Distribution



30

- This chart reinforces the dominance of the north and western coverage assigned to the Joint STARS aircraft. It is useful to note that the absence of observations to the east and south does not imply inactivity. In this case it shows that the sensor was not tasked to look in those regions.

January 26 Lines of Communication



31

- This summary of lines of communication for the 26th of January shows a wide disparity in the duration of coverage or persistence. Limited by having only a single Joint STARS the sensor was employed more diversely than current operational concepts dictate. The length of the lines of communication is not to be construed as a single convoy but the length of the observed trace left by traffic flow. The longest flow, LOC 9, is the roadway from Al Jahra west to the Tri-Border region which terminates at the location of the incursion into Saudi Arabian territory.

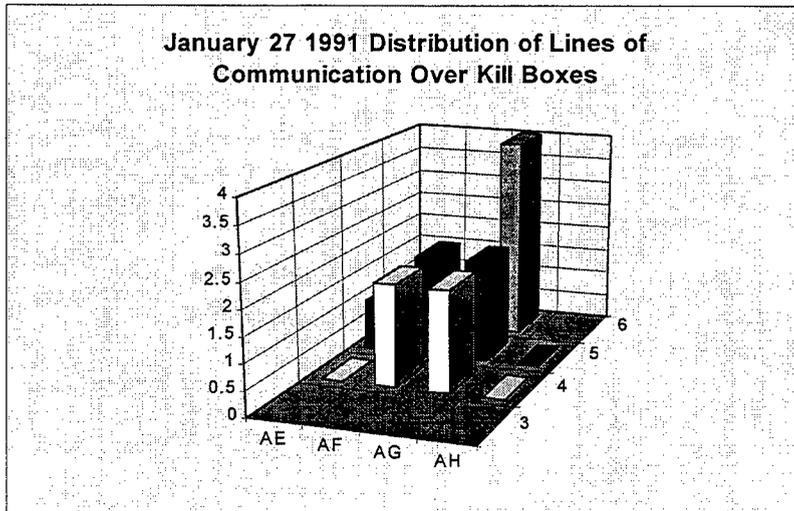
Summary of January 27 Data

- **Coverage Primarily to the west (Tri-Border) and Basra Highway**
 - **Western Coverage Shows Iraqi Incursion Into Saudi Arabia Between “Elbow” and Wadi al-Batin**
 - **Coherent Traffic Flow on Basra highway, Including Alternative Road use**
- **Clear Movement From Iraqi Units west of Ali Al Salem Airbase**
 - **Supporting Incursion West Through Defensive Positions at “Elbow”**
- **Limited Looks to Khafji Area**
 - **Looks of 5, 7, 9, 80, 17, and 12 Minutes**
 - **Artillery Position south of Emir’s Farm Preparation Clearly Evident**
 - **Coherent Movements south Around Al Wafra**

33

- **The night of the 27th revealed a fascinating and potentially revolutionary discovery from the Joint STARS MTI data. In addition to the coverage to the north and west, the Joint STARS aircraft intermittently looked south, during one coverage spending 80 minutes to the south of Kuwait City. During this time a pattern is observed in the Iraqi movements that foreshadows the strategic intent of the Battle of Khafji. In an arc spanning 40 miles west from the coastal point known as Ra’s al Qulay’ah to just north and west of the Al Jaber Airbase is clear evidence of the preparation of artillery positions. These seemingly random movements within this arc are earthmoving equipment digging the berms for the artillery designed to attack Coalition forces drawn into kill zones by retreating Iraqi forces.**
- **This, combined with the strong blocking defenses at the “Elbow” reveal the strategic intent of this plan: Probe and initiate contact with the Coalition ground forces believed to be in ARCENT and MARCENT, engage and fallback with the artillery prepared to inflict casualties.**

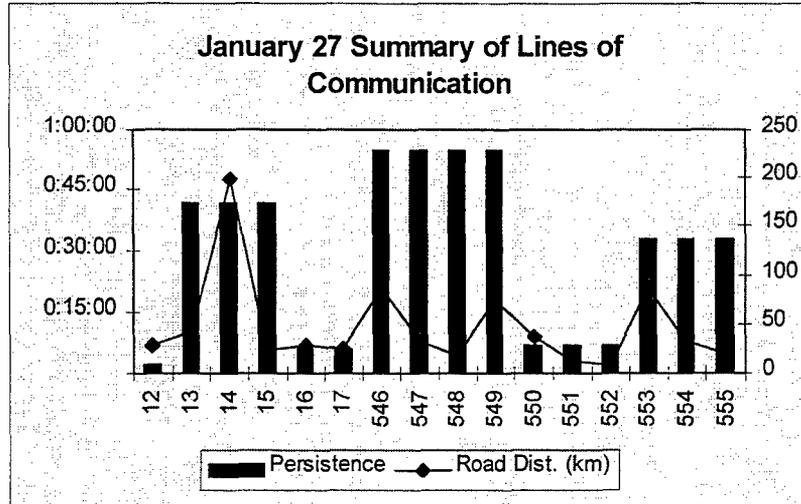
January 27 LOC Distribution



34

- The domination of the LOC database by the Basra highway reflects the observation of parallel roadway use. Kill boxes AF-4 and AG-4 indicate the amount of activity seen in the Saudi territory opposite the "Elbow"

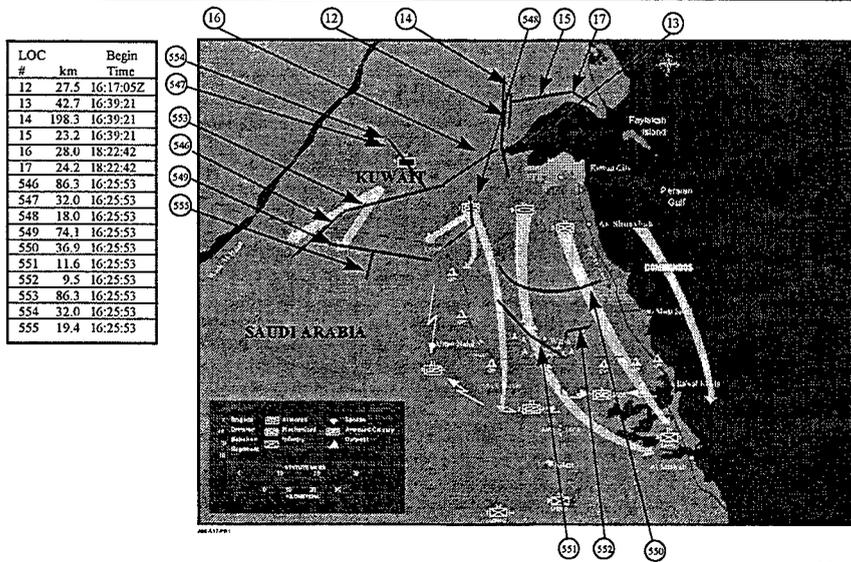
January 27 Lines of Communication



35

- As is seen on other days coverage there is a disparity in persistence where some LOC's are watched for (in this case) nearly an hour when others are observed for only a few minutes. The prioritization of the sensor will always raise questions but answers will be difficult to find outside of the emphasis on watching the Wadi Al-Batin and the initial belief that the southern probes at Khafji were a feint.

January 27 Lines of Communication



36

- The action observed by the Joint STARS aircraft on January 27, 1991 is once again dominated by movements in northern and western Kuwait with significant probes of Saudi territory observed west of OP-6. The preparation of the artillery positions from east of OP-6 to the coast provide remarkable insight into the Iraqi operational plan. The clear movements of units from west of Ali Al Salem in support of the western probes raises the question of this unit's identity. On G-day it has been determined that this area was occupied by the 6th Armored Division with three infantry divisions located on the border to the south (20th, 30th, and 16th). From the Joint STARS data alone it is unclear when these units moved into position but it is likely that movements observed in late January consisted of elements of these divisions.

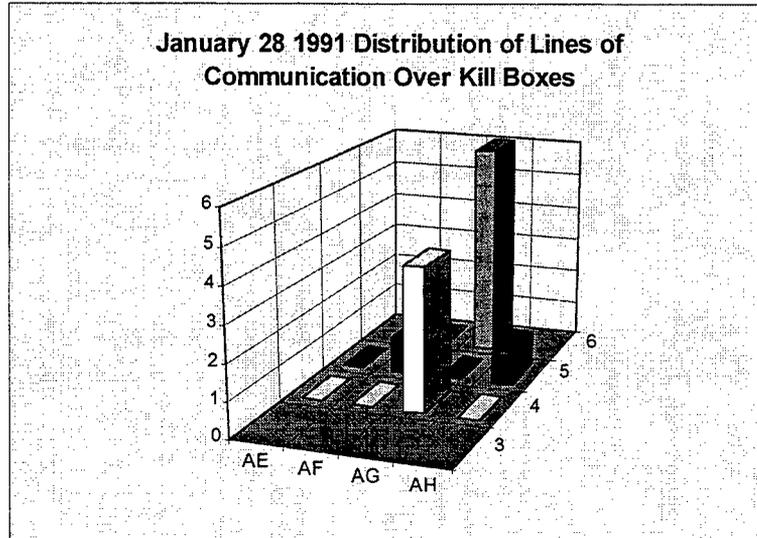
Summary of January 28 Data

- **Coverage Primarily to the west and Basra Highway With Numerous Brief Looks to south**
 - **Western Coverage Shows Iraqi Incursion into Saudi Arabia Between “Elbow” and Wadi al-Batin With Potential Engagement Visible at 24:42:55Z**
 - **Coherent Traffic Flow on Basra Highway Reveals Traffic Coming From west of Highway**
- **Clear Movement From Al Jahra**
- **Looks to Khafji Area Center on Al Wafra**
 - **Interdiction of 70+ Vehicle Convoy**
 - **Coherent Movements south From Kuwait City to Ahmed Al Jaber Airbase**
 - **Incursion at OP-4**
 - **Looks of 8, 4, 36, 31, 24, 8, 15, 4 Minutes**

37

- **On the 27th of January Saddam Hussein traveled to Barsa and approved the operational plan known collectively as the Battle of Khafji. As stated above this maneuver plan was designed to probe the Coalition lines and make contact, then after engaging Coalition ground forces the Iraqis were to fallback and inflict heavy casualties from previously prepared defensive positions. Thus on the 28th of January evidence is seen of the movements in southern Kuwait in preparation for the main thrust the following day. Joint STARS coverage for the 28th of January again focused on the activity to the north and west but numerous brief looks to the south captured evidence of the movements of the 5th Mechanized Division towards the coast and the 3rd Armor Division movement towards Al Wafra.**
- **Perhaps in a telling coincidence, the Air Tasking Order process that previously required Joint STARS to pass targeting data through the ABCCC element was amended and on the 28th of January the ATO had F-15E aircraft directly assigned to Joint STARS.**

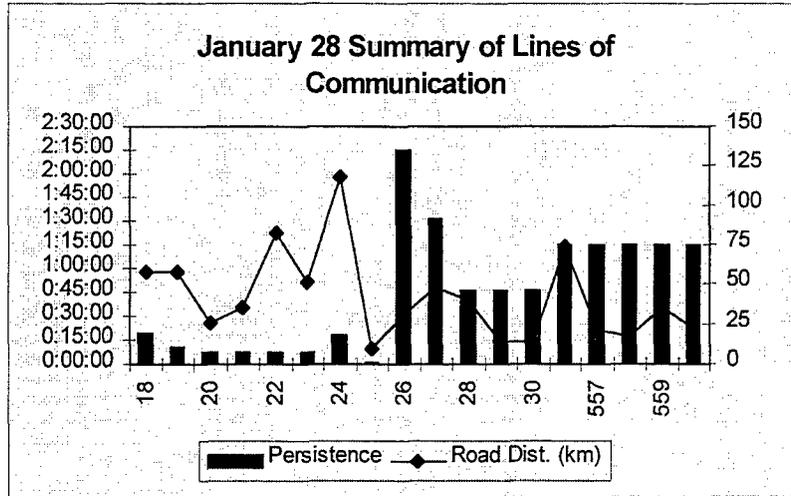
January 28 LOC Distribution



38

- **Observed coherent movements again are dominated by kill box AG-6 with AG-4 revealing activity towards the south and along the Coast Road. AG-4 activity includes the Al Wafra oilfields. AH-5 contains the northern reaches of the Coast Road and flow from Kuwait City.**

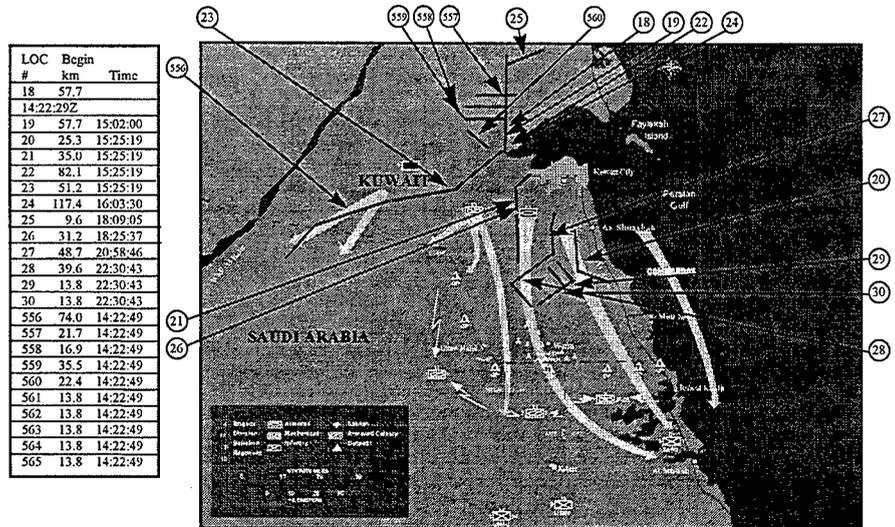
January 28 Lines of Communication



39

- Of note is the short duration of the initial looks, especially in comparison to later, longer persistence coverage.

January 28 Lines of Communication



40

- Joint STARS MTI coverage on the 28 of January was again primarily to the north and west, the brief Joint STARS surveillance of Kuwait revealed some general movements in southern Kuwait. Extensive movement is observed in northern Kuwait including evidence of alternate road use. Clear movement from Al Jahra to the west that then turning south into Saudi territory represents a large amount of vehicle traffic. Of note is that the concertina wire strung paralleling the border is consistently visible north of the incursion.
- 0100 OP-2 detects tanks and APC (from 5th Mechanized) moving in the Al Wafra oil field and call in airstrikes
- Two six man Marine recce units inserted in the night remain in the town of Al Khafji.

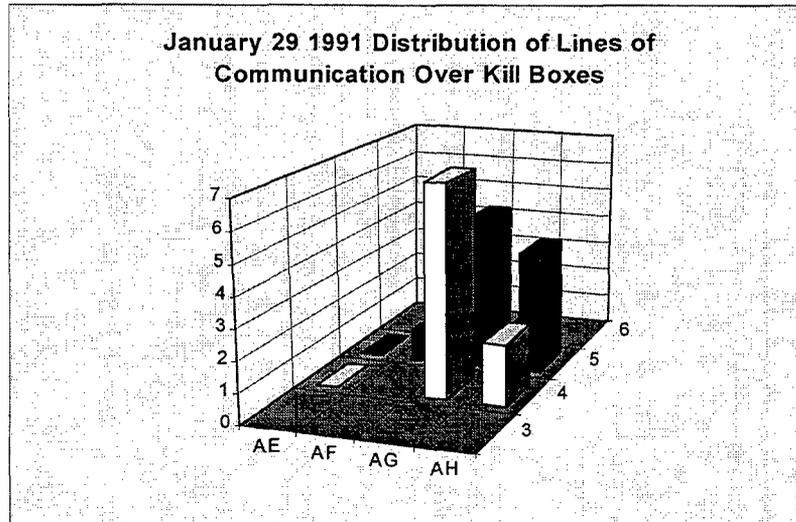
Summary of January 29 Data

- **Coverage Changes to Emphasize south**
 - Looks of 67, 15, 31, 27, 63 Minutes
- **Clear Movement on Most Major Arteries Including Along Coast From Al Ahmad Towards Khafji**
- **Weather Clutter is Apparent**
- **Operationally This Was The First Day of The Battle**

41

- **The 29th of January marks the initiation of the Iraqi battle plan, with OP-4, OP-6, and OP-8 calling in reports of Iraqi movements. As a result there is significant coverage of areas to the south, including some longer duration looks. Coastal areas see some weather returns, making observations of the traffic east of the Coast Road difficult.**

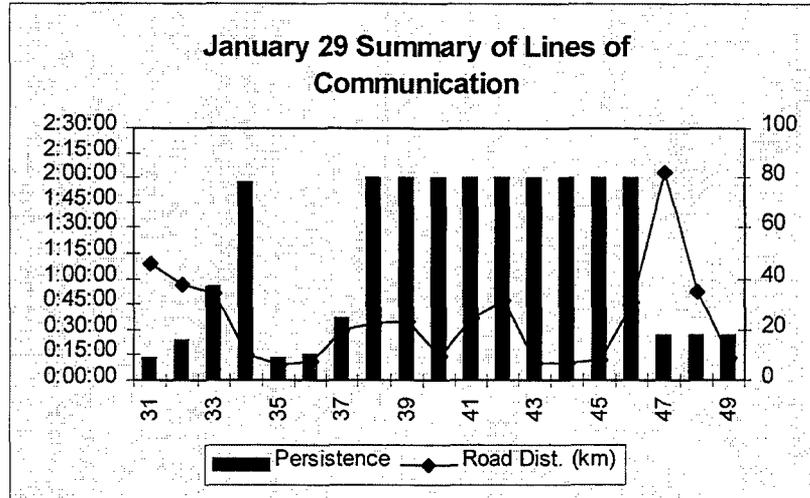
January 29 LOC Distribution



42

- The observed lines of communication on the 29th of January reflect the coverage south of Kuwait City. AG-5, AG-6 show activity as well as the kill boxes adjacent to them on the coast.

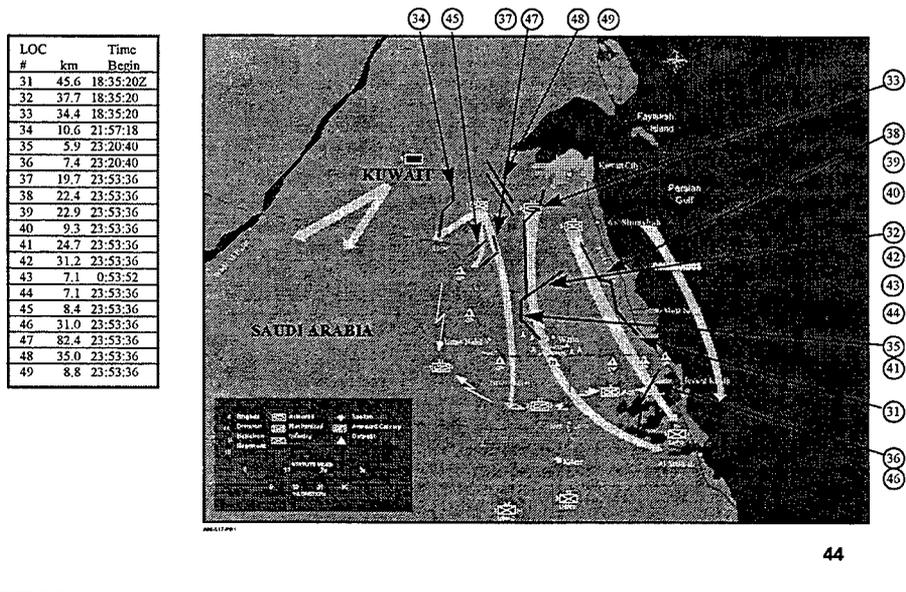
January 29 Lines of Communication



43

- Due to the significance of the action on the 29th the Joint STARS sensor spent more times looking to the areas to the south of Kuwait City, resulting in more extensive coverage than previously. Most lines of communication range in distance between twenty and thirty kilometers.

January 29 Lines of Communication



- Emphasis on southern Kuwait is in evidence on the 29th of January as the Iraqis make their initial moves towards Khafji. Joint STARS MTI coverage is more frequent. The increased persistence results in a fascinating view of the battle as it unfolded. Both 5th Mechanized Division and 3rd Armor are seen moving south along with movements towards OP-6.
- Significant events of the 29th include:
 - CENTCOM J-2 informing General Horner that Iraq had deployed FROG missile units to Kuwait, raising concern of the threat of chemical weapons.
 - Marine Ground surveillance teams detect Iraqi vehicles in Al Wafra and call in air strikes.
 - 1st Mechanized Division leaves its cantonment area
 - At 1835Z OP-6 reports Iraqi movement 'south of the berm'
 - At 1926Z OP-4 spots 1st Mechanized vehicles 'south of the berm'
 - ANGLICOS at OP-8 retreat south from Khafji when Iraqi tanks and APC cross causeway and enter Khafji
 - At 2130 the OP-4 fratricide occurs from both surface-to-surface and air-to-surface fires
 - Al Mutaire, JFCE Commander learns Iraqi mechanized forces (15th Brigade of 5th Mechanized Division) are heading down the road to Khafji and calls for air strikes.
 - During the night 15 Iraqi Patrol boats are detected and are attacked by British Aircraft.
 - OP-6 observes approaching Iraqi forces and withdraw, Iraqis occupy OP-6 but subsequently retreat after attack by TOW and air strikes.
 - General Glosson, surprised by the reports of Iraqi attacks, informs General Horner who orders more sorties and Joint STARS support (40 minutes coverage of Kuwait for every 20 minutes coverage farther west).
 - Major General Sultan conducts personal reconnaissance and confirms that Iraqi forces are in Khafji.

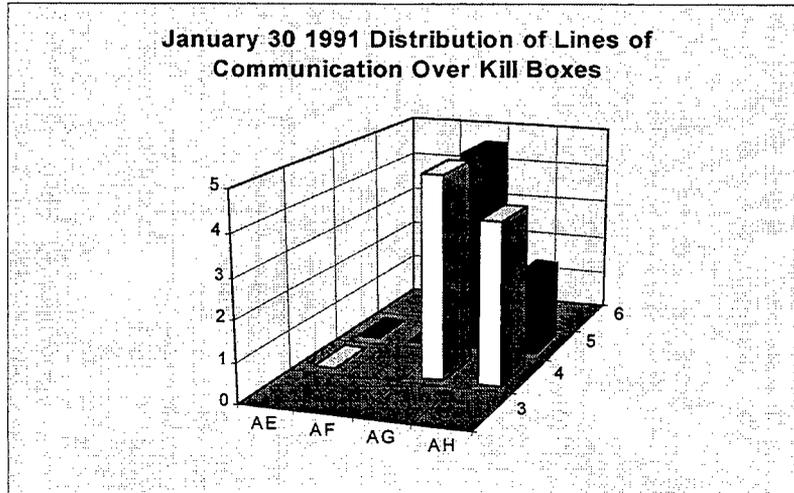
Summary of January 30 Data

- **Continued Coverage of Movement South From Kuwait City Towards Al Jaber Airbase**
 - Looks of 7, 6, 15, 27, 16, 92, 24 Minutes
 - Support of Defensive Position at “Elbow” (OP-6)
 - Artillery Position Preparation
- **Coast Road Traffic Towards Khafji**
- **Basra Highway Traffic**
- **Al Jahra Road and Road From “Ice Cube Tray”**
- **Movement In Vicinity of OP-7**
- **Possible Disruption of Movement North and West of Al Wafra**
 - Alternative Road Use

45

- **Starting early on the 30th of January the action starts to pick up in the southern KTO. OP-6 was evacuated at 0100 and Iraqi forces temporarily occupy it until they are forced to flee by TOW and air attacks. General Horner, upon hearing this from General Glosson, orders more air support and the greater coverage by the Joint STARS aircraft. During the day General Sultan develops the plan for the recapture of Khafji by the Joint Forces Command east under the command of Colonel Turki Al Firmi. The well reported request by Prince Khalid for air support at Khafji is delivered starting at 1700Z and continues through the night. At dusk the first attempt to liberate Khafji fails but the follow up attack succeeds.**

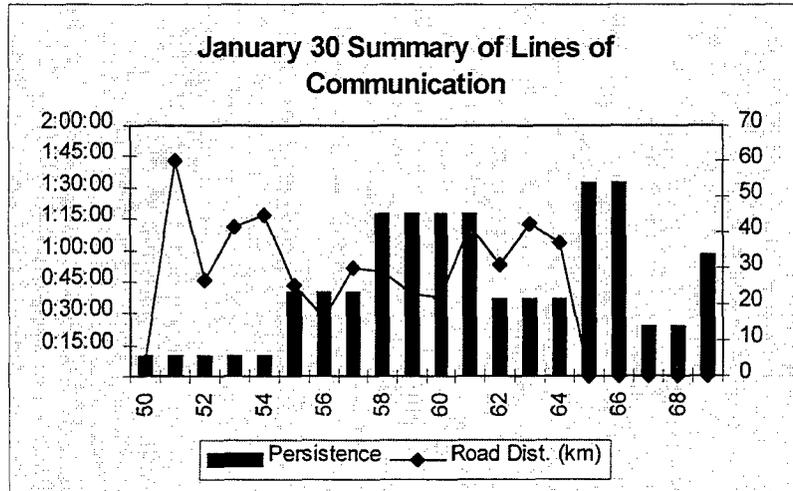
January 30 LOC Distribution



46

- The observations of lines of communication on the 30th of January reflect the concentrated coverages to the south of Kuwait City. Kill boxes AG-4 and AG-5 represent the movements of 3rd Armor division south and the Coast Road (AH-4 and AH-5) pertain to 3rd Mechanized Division.

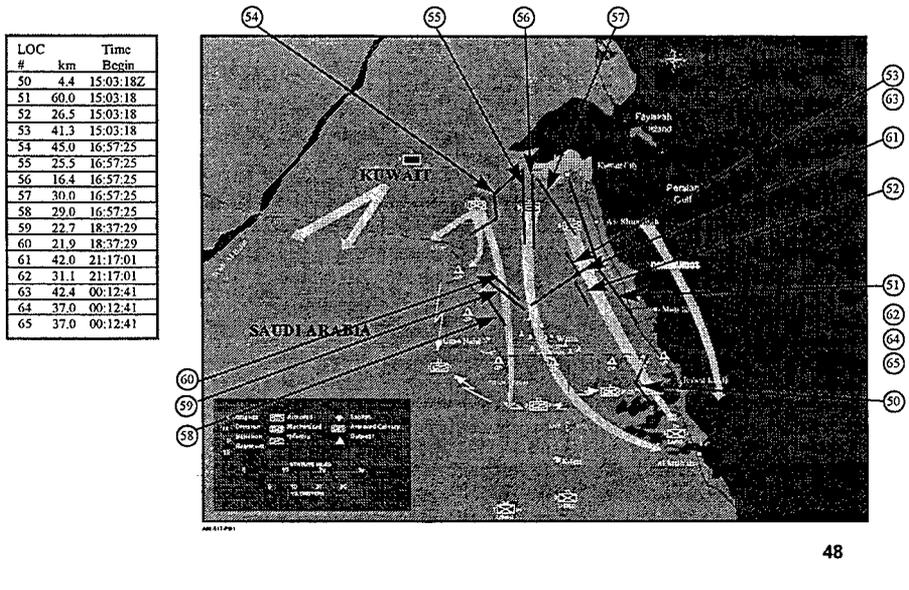
January 30 Lines of Communication



47

- The greater emphasis on the southern sector is reflected in the longer periods of coverage seen on the 30th of January. The missing distances for LOC 65 through 69 are an anomaly in the data.

January 30 Lines of Communication



- The 30th of January saw more Joint STARS coverage of southern Kuwait as the significance of the Iraqi threat was realized. Movement is observed along the Coast Road and south from Al Jahra and Kuwait City as well as movement north of Al Wafra near the Al Jaber Airbase. The amount of Coalition air power concentrated over Al Wafra may explain the lack of any observed coherent movement.
- Major General Sultan develops plan for Joint Forces Command east under Turk Al Firmi's leadership to surround Al Khafji and isolate the Iraqis
- Prince Khalid arrives at JFC east (1500Z) and requests air support of JFCE forces near Al Khafji
- Air support begins 1630 and continues through the night.
- First attack on Al Khafji by forces of 2nd SANG fails (1800), later second attack allows Marines to escape.
- With his forces under heavy air attack Iraqi General Mahoud requests permission from Baghdad to break off the offensive, When told to continue 'The Mother of All Battles' Mahoud remarks 'the Mother is killing her children'.
- Sunrise 31 January AC-130 shot down by SAM north of Al Khafji.

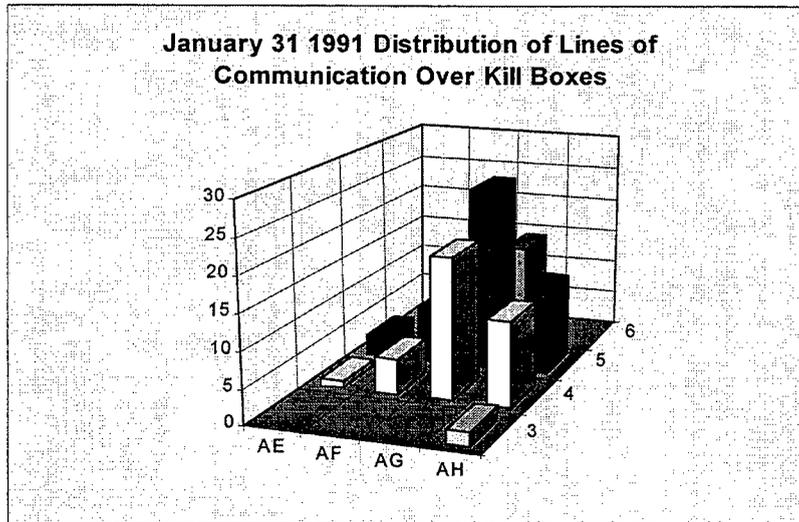
Summary of January 31 Data

- **Great Data But Intermittent Coverage.**
 - Seven Distinct 'Looks' of Varying Duration:
98, 16, 24, 52, 86, 75 Minutes
- **Movement Seen On All Major Axes:**
 - Basra Highway
 - Coast Road All the Way to Khafji
 - Road to Al Jaber Airbase
 - Incursions West of "Elbow", OP-5
 - Defensive Positions at "Elbow" and "Heel"

49

- **Joint STARS surveillance on the 31st of January was distributed over time, with breaks between looks ranging from 30 minutes to over an hour. As a result, the lines of communication data is presented for each distinctive coverage. Overall, activity is seen on all observed lines of communication especially the postulated 6th Armor division de-camping west of the Ali Al Salem Airbase. Also of interest is the apparent interdiction of a 15 mile column along the Coast Road 1720Z. Other columns in the area on the coast east of Al Wafra show traffic tie-ups and halted advances.**
- **(From Trainor, p. 287) Summarizing action from the 31 of January: "Three battles were fought simultaneously. One battle along Ops by Marines with air support preventing Iraqis from reaching the huge (nine mile by four mile) logistics base at Kibrit. Second battle at Khafji fought by Saudi-led forces supported by airpower. The third battle, the most destructive for the Iraqis, was fought solely by Coalition air power along roads between Kuwait City and the border and mostly during dark when the Iraqis attempted to move. This battle continued until the 3rd of February as senior planners and aircrews began to fully comprehend the impact of their new tools (Joint STARS).**

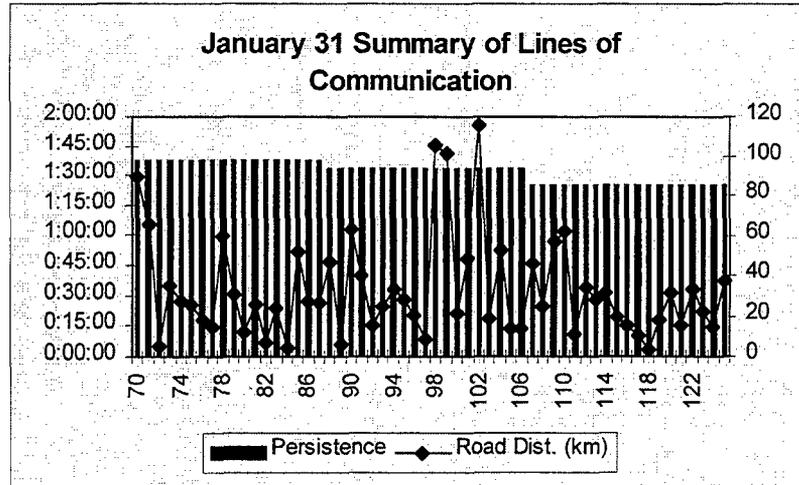
January 31 LOC Distribution



50

- The geographic distribution of the lines of communication reflect the extensive Iraqi movements south of Kuwait City to the Saudi Border. The vertical scale of this chart also diminishes the large number of LOC's identified. This is somewhat offset by the repeated looks by the Joint STARS radar.

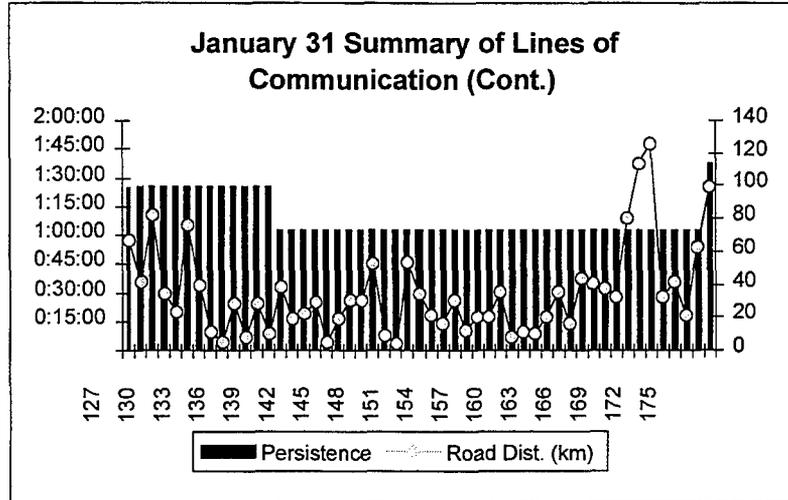
January 31 Lines of Communication



51

- Two aspects of this chart are immediately apparent, first the larger number of identified coherent movements (data is continued on next chart). Second, the persistence is higher than most other days data. The result is a remarkable database of recorded Iraqi movement on a critical day of the battle. The 31st saw Iraqi General Mahoud direct his the brigades in Khafji to break contact and retreat back into Kuwait after the two-pronged attack by the 8th Mechanized Infantry Battalion of SANG and the Qatari tank company on the right and the 7th SANG battalion on the right.

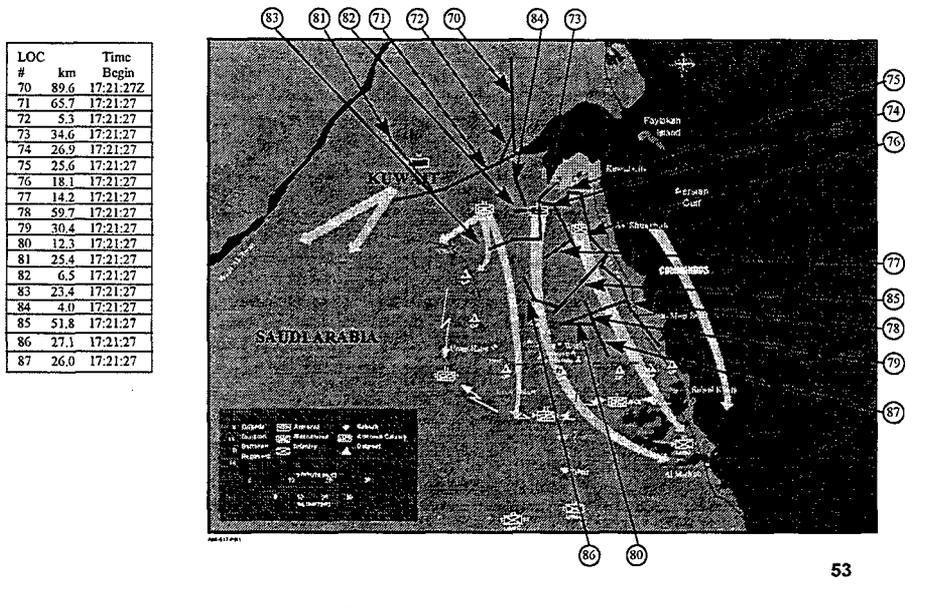
January 31 Lines of Communication (Cont.)



52

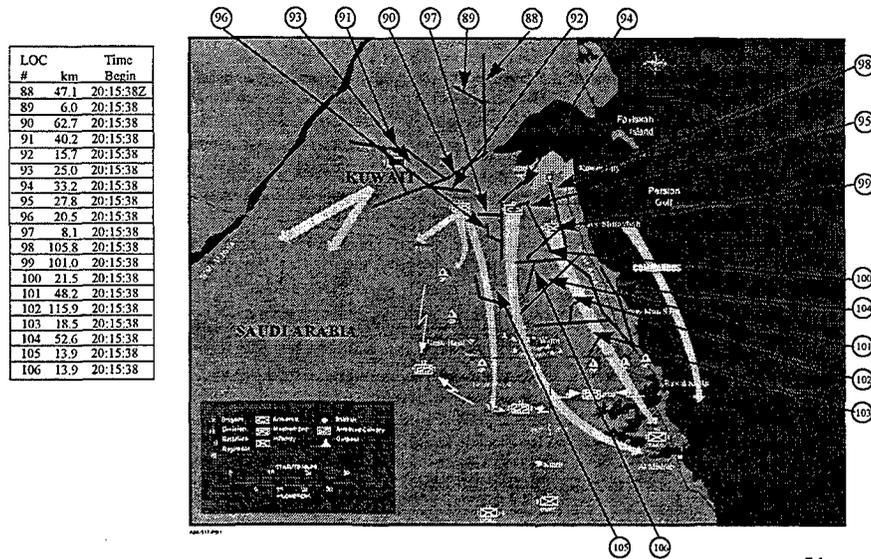
- Additional Line of communication data for the 31st of January.

January 31 Lines of Communication - Look 1



- On the night of 31 January/1 Feb the Joint STARS made seven distinct looks at the southern portion of Kuwait. The first look occurred between 1700Z and 1800Z and revealed coherent movement on most observed lines of communication. Look 1 shows clear movement south out of Al Jahra and Kuwait City continuing down the Coast Road and also breaking east to the defensive positions opposite OP-6.
- at 1050Z General Mahmoud directs his brigades to break contact and retreat into Kuwait
- At 1330Z Khafji was re-captured

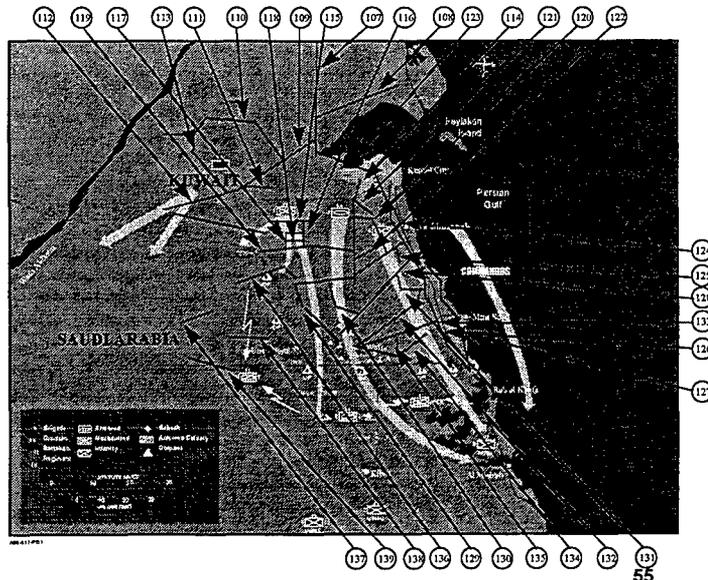
January 31 Lines of Communication - Look 2



- The second look on the 31st of January occurs around 2000Z and shows similar patterns observed in the previous look. Decantonment west of the Ali Al Salem Airbase is evident as well as significant traffic down the Coast Road. Disrupted lines of communication are observed throughout the KTO and lend evidence to the effect of air power.

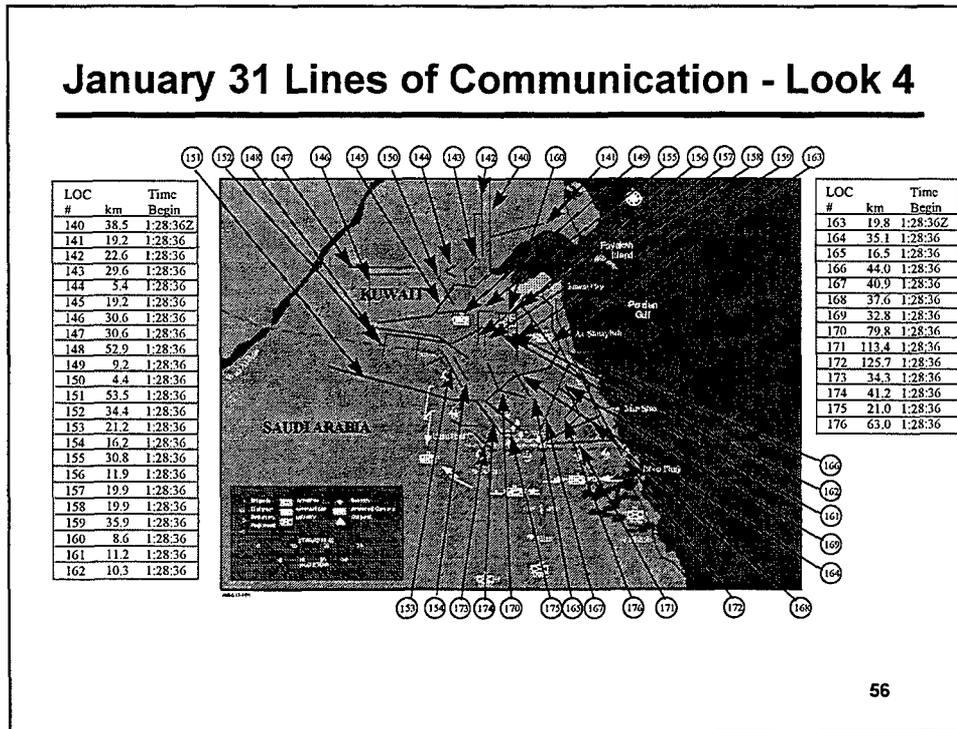
January 31 Lines of Communication - Look 3

LOC #	km	Time Begin
107	46.3	23:17:52Z
108	25.0	23:17:52
109	57.3	23:17:52
110	11.1	23:17:52
111	34.1	23:17:52
112	34.1	23:17:52
113	27.7	23:17:52
114	31.6	23:17:52
115	19.4	23:17:52
116	14.9	23:17:52
117	10.0	23:17:52
118	3.6	23:17:52
119	17.7	23:17:52
120	31.4	23:17:52
121	15.7	23:17:52
122	33.1	23:17:52
123	22.2	23:17:52
124	14.2	23:17:52
125	37.7	23:17:52
126	65.0	23:17:52
127	67.4	23:17:52
128	41.9	23:17:52
129	81.7	23:17:52
130	34.5	23:17:52
131	23.8	23:17:52
132	76.3	23:17:52
133	39.3	23:17:52
134	11.2	23:17:52
135	5.0	23:17:52
136	27.9	23:17:52
137	7.7	23:17:52
138	28.0	23:17:52
139	10.0	23:17:52



- The third look on the 31 of January (2330Z) reveals the extent of Iraqi movements throughout the KTO with significant emphasis put on the Coast Road. It is during this look that Joint STARS observes an apparent air strike on the 15 mile column moving south to reinforce Khafji (LOC 133).
- Movements in Saudi territory, well west of OP-5 and OP-6 are seen with possible air interdiction as well.

January 31 Lines of Communication - Look 4



- The fourth look at the KTO on the 31st of January shows activity on nearly all lines of communication ranging from the Basra highway to the North, the western incursion into Saudi territory West of OP-6, and the extensive movements surrounding the Al Wafra oilfields. Of particular note is the appearance of alternative parallel routes to the Basra highway. Close-up examination appears to verify effects of air attacks at disrupting these arteries.
- Also of interest is the movement into Saudi territory between OP-5 and OP-6, south of the defensive positions.

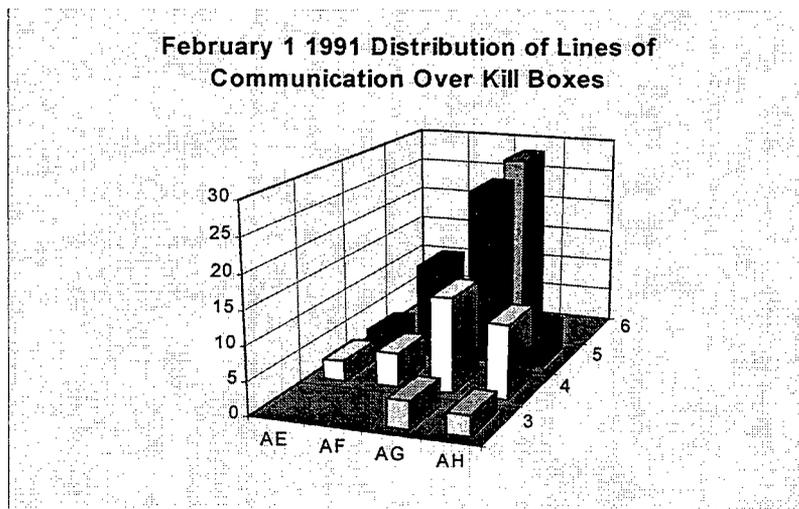
Summary of February 1 Data

- **Best Persistence of Study Time Period**
 - Three Distinct ‘Looks’ Offer Excellent Persistence: 51, 66, 30 Minutes
- **Movement Seen On All Major Axes:**
 - Basra Highway and to the west, Indicating Supply or Reinforcement From northwestern Positions
 - Coast Road All the Way to Khafji
 - Road to Al Jaber Airbase, Especially “Ice Cube Tray”
 - Incursions west of “Elbow”, OP-5
 - Defensive Positions at “Elbow” and “Heel”
 - Artillery Positions south of Emir’s Farm

57

- **On the first of February the coverage of the Joint STARS aircraft changed from multiple looks to a more stable, persistent coverage with the best surveillance occurring for an hour around midnight. The data here is divided into six observations, covering the entire KTO. In general, movement was seen on all observed lines of communication.**

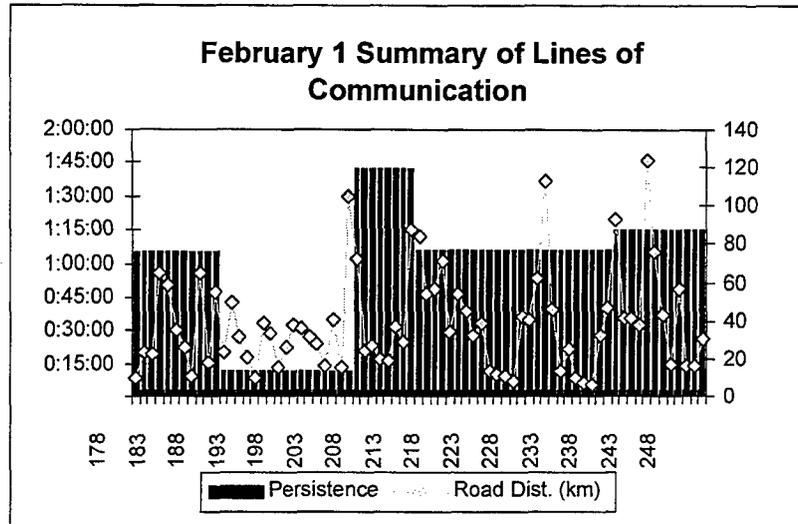
February 1 LOC Distribution



58

- With good persistence a large number of lines of communication were observed on 1 February. The data is again dominated by the Basra-Al Jahra highway but with the increased air activity to the south more movements were seen in kill boxes AG-3, AG-4, AH-3 and AH-4.

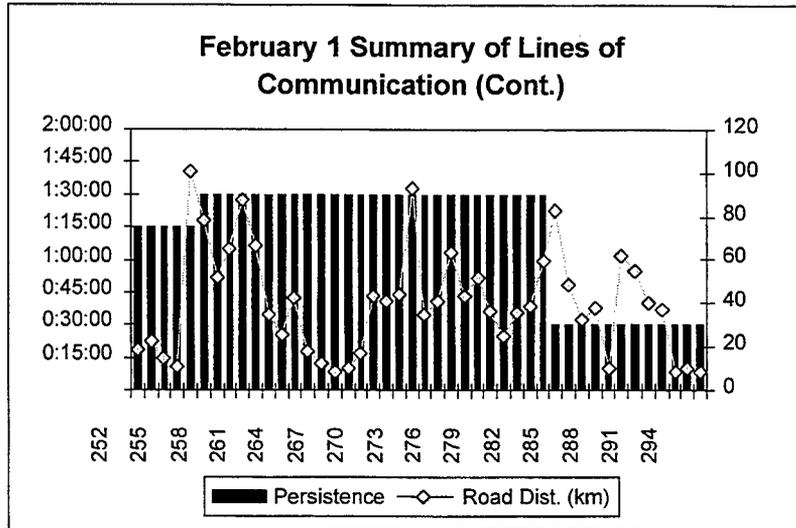
February 1 Lines of Communication



59

- The following two charts illustrate the persistence of coverage and the numerous lines of communication observed.

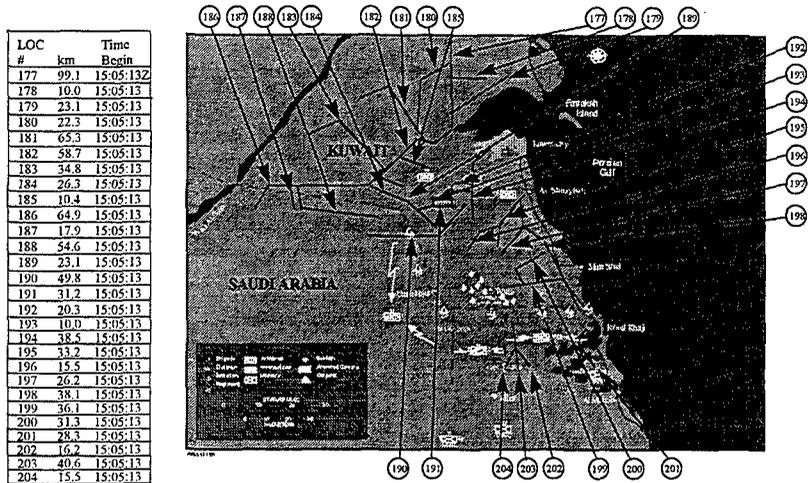
February 1 Lines of Communication (Cont.)



60

- Continuation of February 1 data.

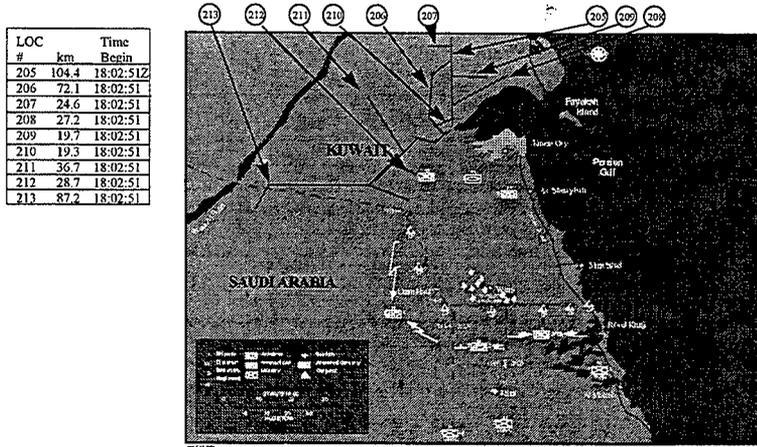
February 1 Lines of Communication: Looks 1-2



61

- The first look at the KTO on February 1st again shows activity on all major lines of communication, including distinctive tactical formations showing in the western penetration as well as south of the Al Wafra oilfields. Along the coast disrupted traffic is observed on parts of the known lines of communication, subjective evidence of air interdiction. Note also the parallel route of traffic well west of the Basra highway.

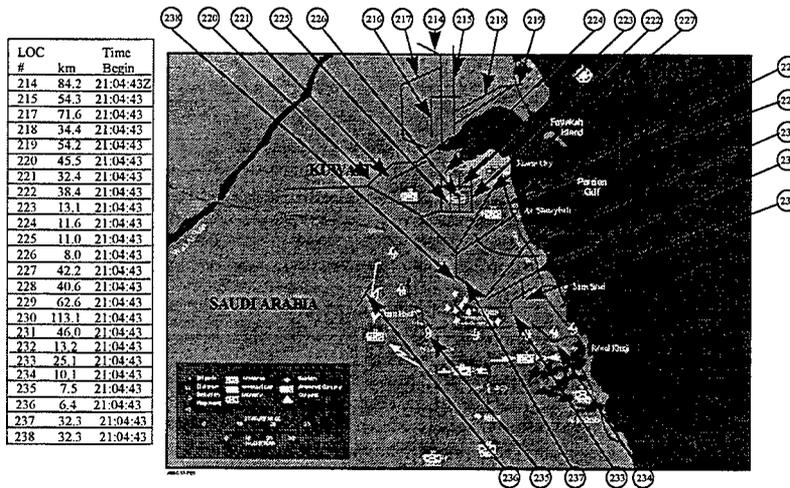
February 1 Lines of Communication: Look 3



62

- The third look at the KTO on 1 February focused on the North and West, identifying movements along the Basra highway as well as an alternative route somewhat to the West.

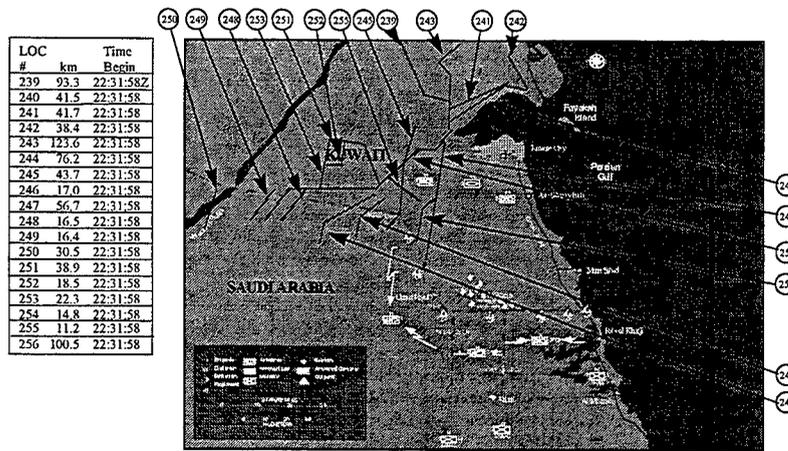
February 1 Lines of Communication: Look 4



63

- The fourth look on the first of February shows activity on most lines of communication. Of particular interest is the apparent de-cantonment of a significant number of vehicles Southwest of Kuwait City in the location normally associated with 3rd Armor Division. This grid indicates controlled traffic management with traffic flowing first West and then South easterly towards Umm Gudair Oilfield (West of Al Jaber Airbase). Also clearly evident is the artillery firing positions South of the Al Burqan Oilfield and traffic down the coast. West of the heel shows indication of units maneuvering as well.

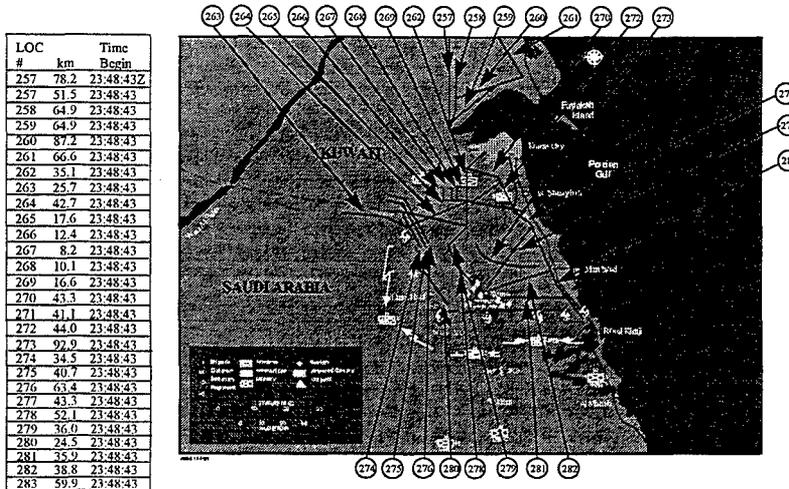
February 1 Lines of Communication: Look 5



64

- Look 5 on February 1st concentrates on the north and Western regions but reveals numerous columns probing Saudi territory from OP-6 West all the way to the Wadi al-Batin. The southerly movement from Al Jahra is a new line of communication that bears some consideration. It could be an alternative route developed due to previous interdiction efforts or new routing to expedite force delivery.
- Generally observations of movements in Iraqi territory have not been considered for this study however there is clear evidence that traffic coming into the Basra highway network has some sources from the Rumaila Airbase and Oil Field complex. The significance of this is that is the location of a number of Republican Guard units including the Medina and Hammurabi Divisions.

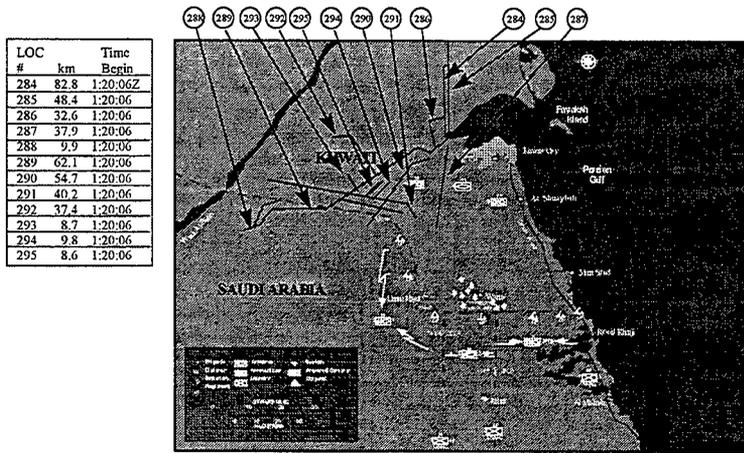
February 1 Lines of Communication: Look 6



65

- The sixth look on the first of February offers clear definitions of the defensive positions at OP-6, between AP-4 and OP-5 (“Heel”) as well as the artillery firing positions South of the Al Burqan oilfields. Additionally, managed traffic flow is again observed in the area northwest of Al Jaber Airbase where 3rd Armor was thought to be encamped. Traffic along the Coast Road and into Al Wafra is also observed.

February 1 Lines of Communication: Look 7



66

- **Look 7 focuses on the North and West with a great representation of the probe into Saudi just East of the Wadi al-Batin. Traffic on the Basra highway is observed along with an alternate roadway and two flows are seen out of Al Jahra: One to the South and another in a Southwesterly fashion towards the “Elbow”. Closer examination indicates that the road from Al Jahra was disrupted and clear evidence of diverted traffic is seen.**

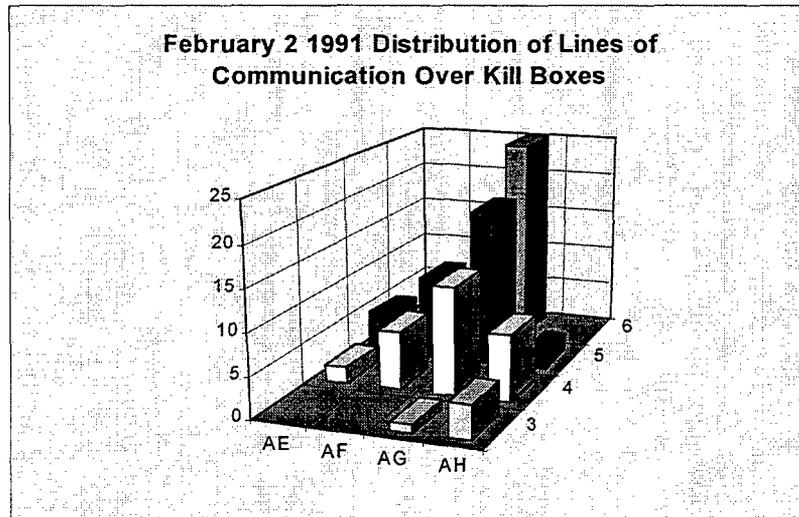
Summary of February 2 Data

- **Most Erratic Coverage of Study Time Period.**
Mainly Coverage west And north
 - Eighteen 'Looks' Are Confusing And Persistence is Lacking Until Last Look Starting at 00:48:14Z
 - Looks of 2, 9, 10, 28, 8, 5, 100 Minutes
- **Movement Again Seen On All Major Axes:**
 - Basra Highway
 - Coast Road All the Way to Khafji
 - Road to Al Jaber Airbase
 - Incursions west of "Elbow", OP-5
 - Defensive Positions at "Elbow" and "Heel"
- **Some Noise in Data Late in Coverage**

67

- **On the 2nd of February the Joint STARS radar was tasked to cover numerous areas and as a result the coverage of the southern portion of Kuwait was often interrupted, sometimes for extended periods of time. The result of this is a high number of looks which as seen previously increase the number of observed lines of communications and complicate the analysis to some degree. However, despite the generally shorter times spent on any particular area the data does reveal movements on all major axes.**

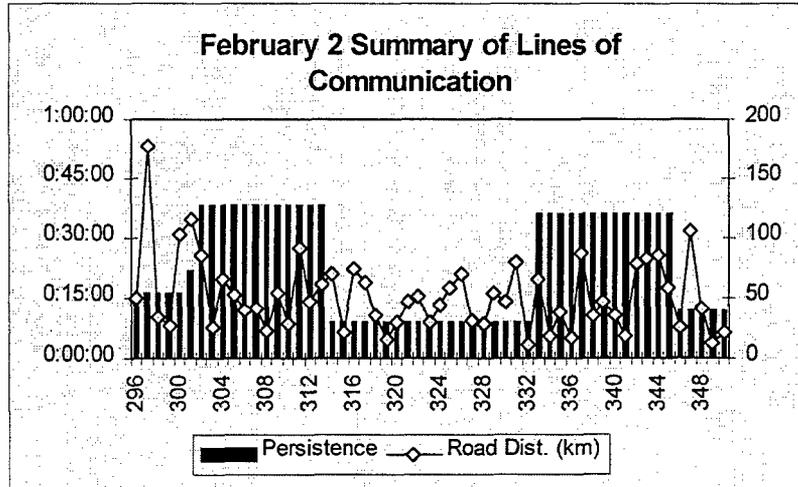
February 2 LOC Distribution



68

- The high number of lines of communication caused by the multiple looks is reflected in the chart. Coverage is again dominated by the Basra highway and western looks, although fewer lines of communication existed to the west. Significant data is collected on the southern portion of the KTO as reflected by kill boxes AG-3, AG-4, AH-3, and AH-4. Activity north and west of Ali Al Salem Airbase is seen in the AE-5 and AF-5 kill boxes.

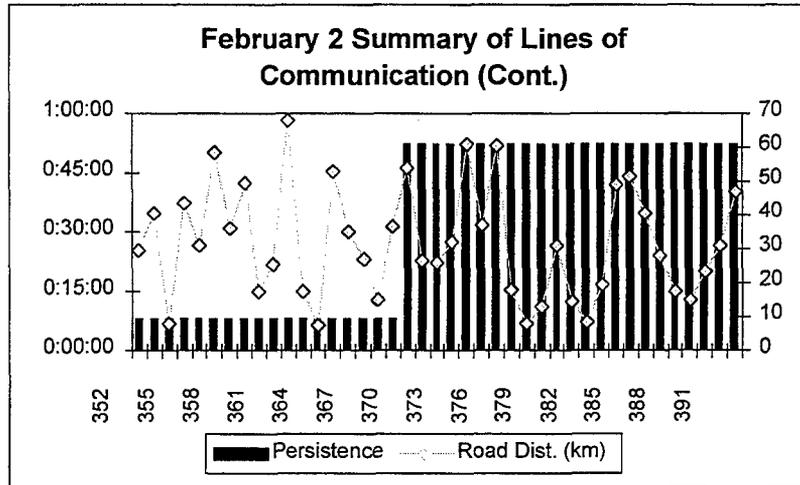
February 2 Lines of Communication



69

- The following two charts graphically show the shorter duration looks conducted by the Joint STARS aircraft on the 2nd of February. Note also the high count of observed coherent movements.

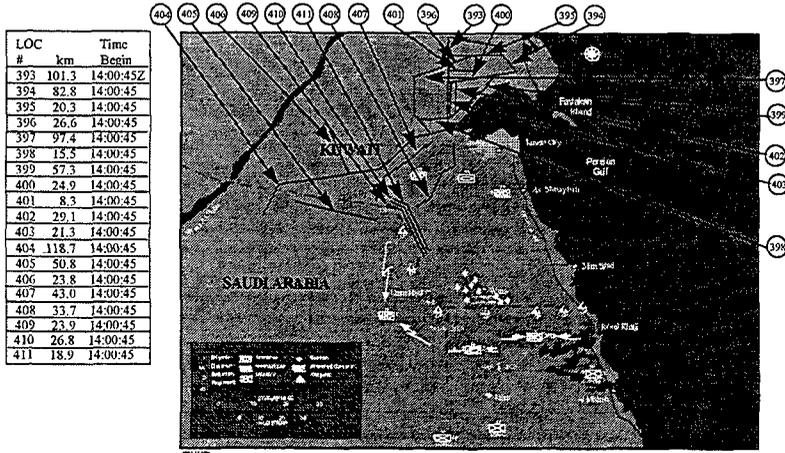
February 2 Lines of Communication (Cont.)



70

- Continuation of previous chart.

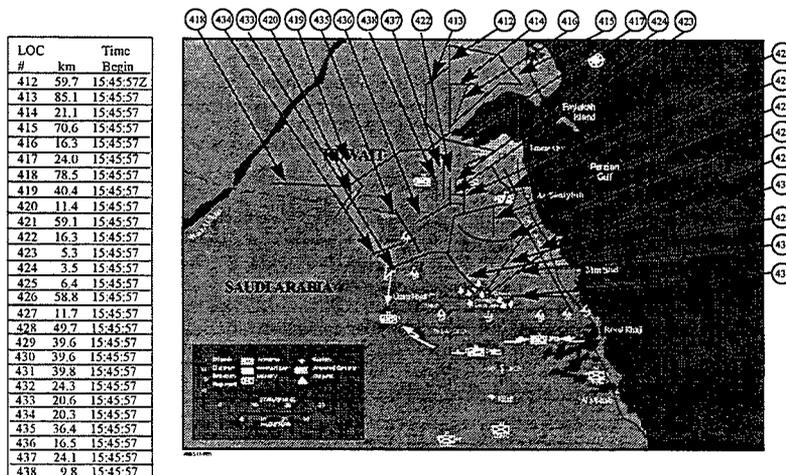
February 3 Lines of Communication - Look 1



71

- The first look on the 3rd of February occurs at dusk (1400Z) and shows a great deal of activity surrounding the Basra highway. The defensive positions at the Elbow are clearly evident as well as activity West of Ali Al Salem Airbase supporting the Western probes.

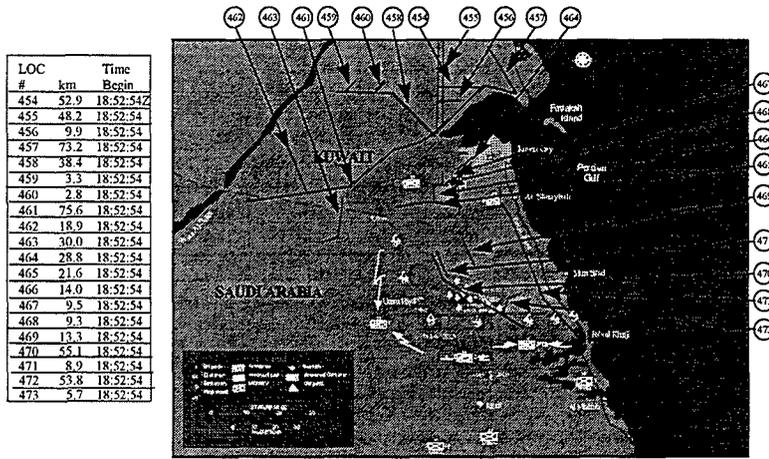
February 3 Lines of Communication - Look 2



72

- Look 2 on February 3 (1540Z) shows activity on most of the known lines of communication. Of particular interest is the clear view of the artillery positions South of the Al Burqan oil fields. The previously observed Southwesterly movement from just North of Al Jaber Airbase towards the OP-5/OP-6 gap appears to be interrupted as does the roadways West of Bubiyan Island.

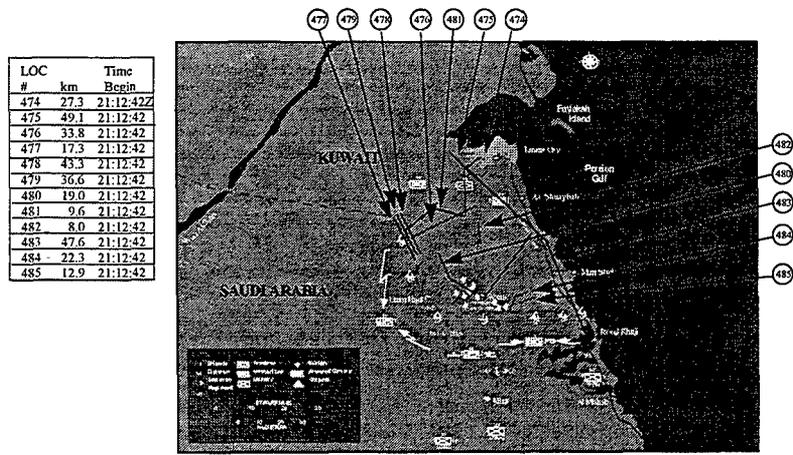
3 Feb 1991 Lines of Communication - Look 5



73

- Look 5 on February 3rd (1830Z) features clear movement on the Coast Road and the Basra highway as well as alternative routing into Al Wafra. A new line of communication appears West of the Basra highway that indicates vehicle traffic moving Southeasterly past the Ali Al Salem Airbase. The lack of coherent movements along other previously seen lines of communication indicate that many roads were impassable at this time (or under constant attack).

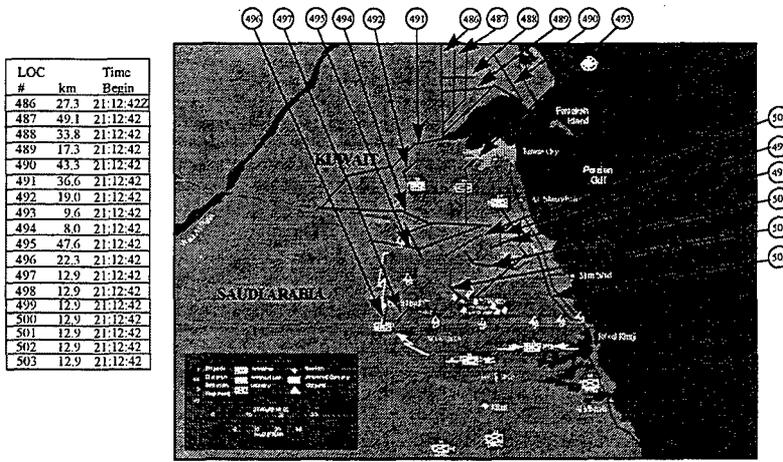
3 Feb 1991 Lines of Communication - Look 7



74

- By 2100Z movement is seen in the vicinity of Al Wafra including to the East of the oilfields. The defensive positions opposite OP-6 are clearly evident as well as a new line of communication (475) from Al Jahra through the 5th Mechanized Division's cantonment area along a pipeline service road. This indicates that the passageways through Kuwait City proper may have been interdicted or disrupted enough to warrant utilizing a low grade service road.

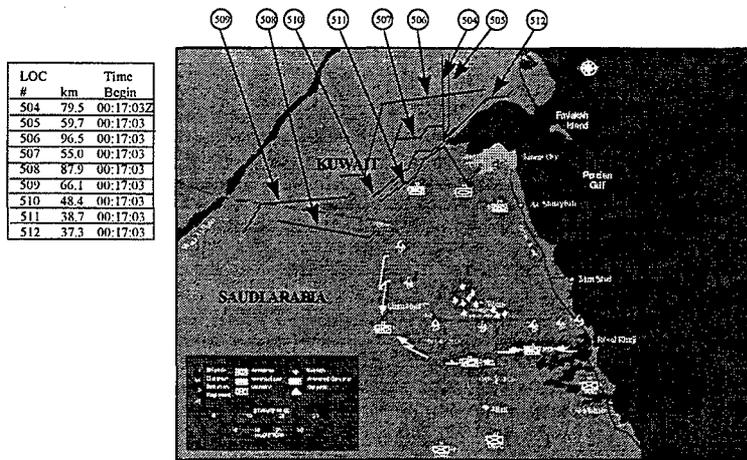
3 Feb 1991 Lines of Communication - Look 8



75

- The eighth look at the KTO on the third of February shows extensive alternate road use in the Northern region between the Basra highway and Bubiyan Island as well as many disrupted flows in the Southern portion of Kuwait. The artillery positions South of the Al Burqan oilfields are visible and surrounding lines of communication appear incomplete. Directly West of OP-4 there appears to be activity associated with a light scout unit. At this point in time it is not evident if this would be Iraqi or Coalition forces.

3 Feb 1991 Lines of Communication - Look 9



76

- The last look on the third of February occurred at midnight and centered on the areas to the North and West. Of note is the appearance of an alternative route (506) that bypasses the heavily traveled (and attacked) Basra highway and its link through Al Jahra to the West. Clear evidence is seen of disruption on the road west of Al Jahra just north of the “Elbow” as well as an alternate bypass of the Basra-Al Jahra interchange (Northwest of Ali Al Salem Airbase).

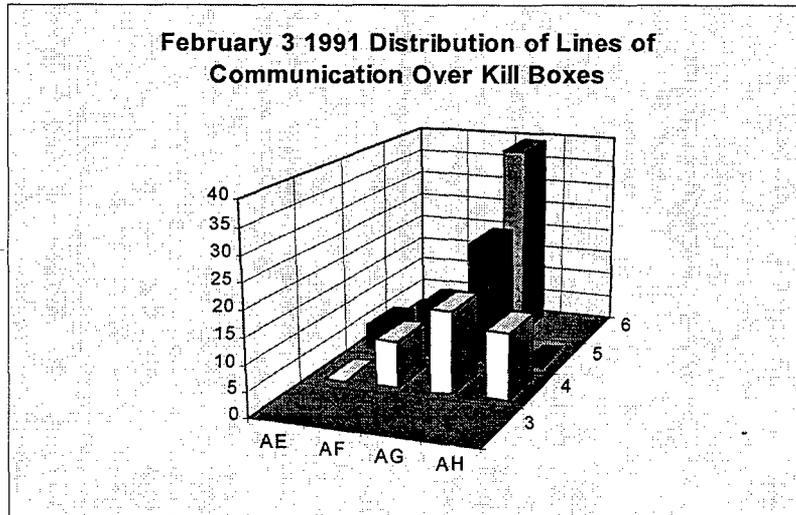
Summary of February 3 Data

- **Mainly western Coverage Early, Great eastern Coverage After 1900Z**
 - Three Long 'looks' Cover Area south of Kuwait City
- **Movement Again Seen On All Major Axes:**
 - Basra Highway
 - Coast Road All the Way to Khafji
 - Road to Al Jaber Airbase
 - Incursions west of "Elbow", OP-5
 - Defensive Positions at "Elbow" and "Heel"
- **Khafji Coverage and Close-up of Al Wafra**
 - Looks of 63, 4,185, 114 Minutes. 4 Minute Look is close-up of Division at "Ice Cube Tray"

77

- **On the last day of the time period studied the coverage begins covering the west and after 1900Z (midnight local) extensive surveillance of the southern portion of the KTO is conducted. The result is excellent observations of Iraqi movements throughout the area. Of interest is a peculiar track formation observed in the cantonment area west of the Ali Al Salem Airbase. A 4 minute close-up reveals a complex marshaling of vehicles through six distinct intersections. Correlation of this data to known troop movement doctrine could help identify the composition of the force maneuvering,**

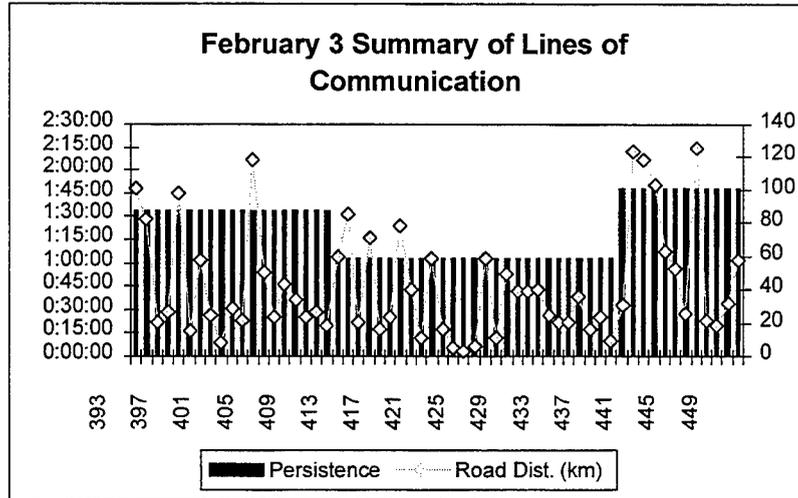
February 3 LOC Distribution



78

- As seen throughout the study time period the Basra highway is the dominant line of communication. Numerous alternative and feeder arteries are observed and the results are reflected again in the high count of lines of communication in kill box AG-6. Kill boxes AF-4, AG-4, and AH-4 constitute the south Central portion of Kuwait and a significant number of movements were observed there on the 3rd of February.

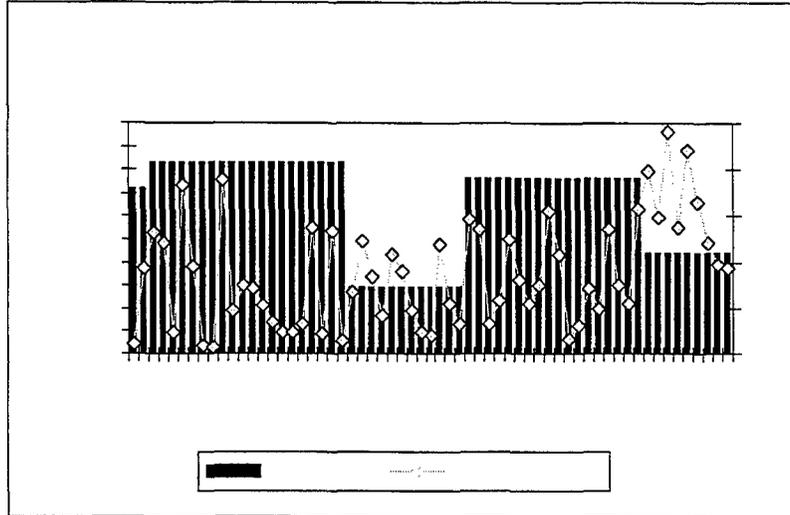
February 3 Lines of Communication



79

- Persistence for the 3rd of February is overall above average with an extended look after midnight local time. The multiple looks contribute to the high number of lines of communications observed.

February 3 Lines of Communication (Cont.)



80

- Continuation of 3 February data.

Joint STARS Data Analysis

Data Analysis

81

- **This next section addresses the approach to the analysis of EMD Joint STARS MTI data. As stated in the introduction, the two Joint STARS aircraft that were deployed to Saudi Arabia in January 1991 were development systems and a low risk approach was taken to ensure that the software would operate reliably. As a result key data elements now routinely collected were withheld, resulting in a more complex analysis task than if current (1997) data were available.**
- **Some of the missing data elements (Doppler Radial Velocity, Wheeled/Track Indicator, Cross Range Error Estimate) transform the data analysis from a tracking problem to one of pattern recognition. This section discusses the technical approach developed by Northrop Grumman SBMS to process the MTI data in order to derive the necessary quantitative metrics, in particular, vehicle count, inter-vehicular spacing, and velocity.**

Analysis Plan

- **Background Research**
- **Data Collection**
- **Data Reduction**
- **Analysis**

82

- **To introduce the data analysis section a discussion of sources of information on the Gulf War and the Battle of Khafji will be presented.**
- **Data collection in the context of this report will center on the methodology developed to visually screen MTI data for recognizable or coherent patterns of movement. A requirement of the customer was to provide the data in a format usable by an open computer system, thus some discussion will address transferring data between the various machines. Data concerning airpower sorties was a problem, no definitive data was identified to correlate versus observed trends in movement. Alternative approaches will be discussed.**
- **The data reduction section will speak to some detail on the methodology developed to ascertain velocity and positions from the raw MTI data. The manual nature of this process prohibited the computation of the full set of metrics versus the 560 lines of communication. However the mapping of the observed movements provides significant insight into the Battle of Khafji.**

Background Research

- Open Literature
- Classified Mission Logs
- Interviews With Key Personnel

Results Inputted to a Time Line

83

- The background research into the Battle of Khafji was aided by a number of extensive reports, including the Gulf War Air Power Survey (GWAPS), the Conduct of the Persian Gulf War Report to Congress. Gordan and Trainor's "The General's War" is arguably the best overall discussion of the Gulf War and Dr. Jim Titus of Air University at Maxwell AFB probably has done the most extensive research on the topic of the Battle of Khafji, including an extensive annotated bibliography of the holdings at the Air Force Historical Research Archives (AFHRA). Other sources on the Internet have augmented these sources but the aforementioned works provided the basis of the background research.
- On the classified side, the mission logs from Joint STARS , ABCCC , TACC were reviewed as well as General Corder's remarkable hold file at AFHRA.
- After Joint STARS returned from Desert Storm many interviews were held with key personnel, these have been well documented at Northrop Grumman. Dr. Ken Pollack of the Washington Institute for Near east Policy was interviewed in the course of the research and provided valuable insight into operational plans of the Iraqi army.
- An initial research tool was a spreadsheet timeline that attempted to overlay known events and Joint STARS coverage. In attempting to synopsize the action this was a useful tool.

Approach to Desert Storm Data

- **CONOPS Developed 'On-the-Fly'**
- **Lack of Doppler Radial Velocity and CRE**
 - **Increases Complexity of Analysis**
- **No Raw Data Recorded**
 - **Dwell Time Estimation**
- **Higher False Alarm Rate**
- **Weather Returns**

*Generation of Required Quantitative Data Requires
Modification of Analytic Tools For Specific Use*

84

- **The concept of operations for the Joint STARS aircraft was developed just before the arrival of the aircraft in theater. During the missions, lessons were learned and the system software was 'tinkered' with. It is remarkable that an 85% mission rate was achieved and that the two aircraft were able to operate the full 49 days from their arrival to the end of hostilities. Of special note was the modification of the ATO to assign attack aircraft to the Joint STARS directly.**
- **The pointing of the radar, and the associated time spent covering a particular area will always be a source of speculation for the analyst...**

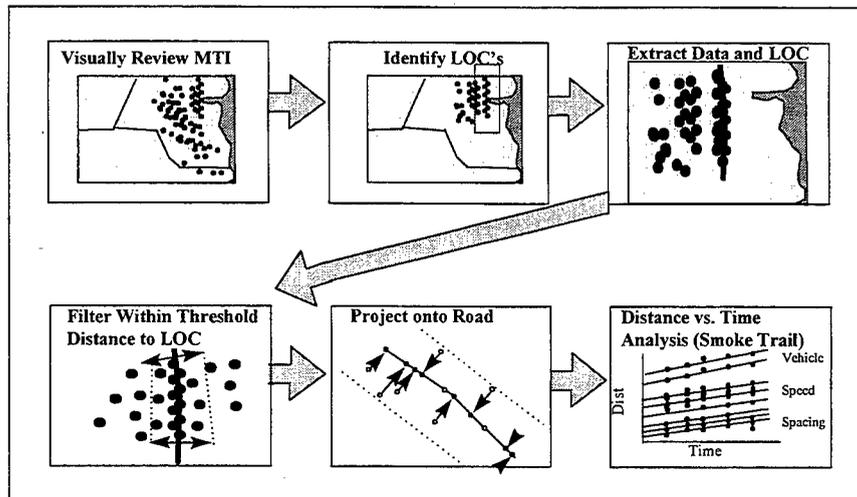
Data Collection

- **Step 1: Visually Inspect Data Using JSX For Regions of Interest**
- **Step 2: Isolate Frames of Potential Convoys or Tactical/Operational Maneuvering**
- **Step 3: Extract Subset of MTI Data**
- **Step 4: Populate LOC Database**

85

- **The first step in the data collection process was to run the MTI data through the Joint STARS Exploitation workstation (JSX). This software tool allows the operator to overlay data onto of cartographic, terrain, and image data and to move back and forth through time at selectable frequency. Additionally, and perhaps most important feature, is the ability to display multiple frames of data simultaneously. This capability isolates clear lines of movement which the subconscious processes remarkably easily. These coherent movements are defined as lines of communication.**
- **Having selected a series of frames and a particular geographic region, this data is extracted using a simple mouse point-and-click approach. This data is then transferred to the UNIX system where it is reformatted from the more complex MTI historical database format to one that is readable by any spreadsheet program.**
- **From here the technical approach was conducted using the software package Mathematica.**

Analytic Process



86

- 1. The intention was to assign road-projected MTI points to linear features that are as nearly complete as possible, in the following sense: a linear feature, at each observation time, should have *at most one* road-projected MTI point with which it is associated; if, for some observation time, there is no MTI point associated, then the linear feature can be sampled (i.e., evaluated) at that time to generate an interpolated value for the coordinates of the (unobserved) road-projected MTI point in order to fill in the time series. The slope of the linear feature, i.e., the velocity of the corresponding "vehicle", can then be imputed to each of the road-projected (both real and interpolated) MTI points.
- 2. At the same time there should be *at most one* road-projected MTI point to each linear feature at each observation time. The analysts have available, for each linear feature, a list of all the road-projected MTI points that contributed to the bin which defined the linear feature. The analysts also know the time of observation of each MTI point. Regardless of the number of these contributing points (whether less than, equal to, or greater than the number of observation times), the team was able to readily figure which of the contributing road-projected MTI points is closest to the linear feature's evaluated position at each observation time. The closest point at each time is declared to be the associated point for that time.

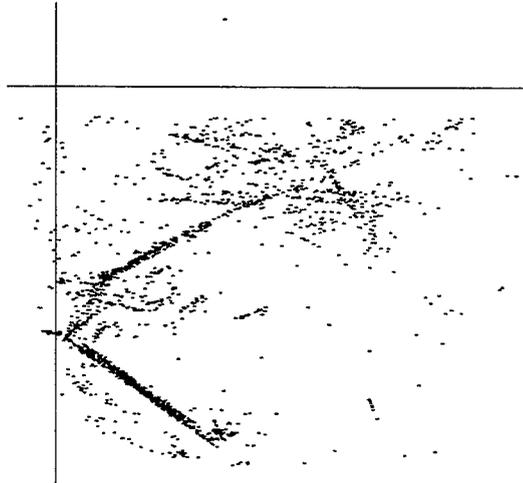
Line of Communication Analysis

- **Convert Filtered MTI Reports From (X, Y, t) to Hough Space (Distance Along LOC, t)**
- **Analysis of Resulting Plot (“Smoke Trails”) Reveals:**
 - **Vehicle Count**
 - **Inter-Vehicle Spacing**
 - **Velocity**
 - **Convoy Movements**

87

- **5. If a single MTI point contributed to more than one linear feature (high-count bin), then we could assign, to that MTI point, the closest linear feature (at that observation time) to which it contributed, and we could then remove that MTI's ID from the lists of contributing MTI points for all the other linear features. Continuing in this way, every MTI point which contributed to any linear feature would be assured of having a linear feature assigned to it, and that linear feature would be the closest one. No MTI point would have more than one linear feature assigned to it. But not necessarily every linear feature would be assigned to at least one MTI point; a linear feature might not be assigned to any MTI point -- *which is an undesirable result.***
- **6. Are there more road-projected MTI points than there are high-count linear features? PROBABLY, BUT NOT NECESSARILY. (It depends upon the count-threshold used in declaring a bin to be a high-count bin.)**
- **7. *A limiting case:* In Hough space, there are many lines but all could have nearly the same slope with only slightly different intercepts; all the Hough lines could pass through all of the same bins, giving all the high-count {m, b} bins exactly the same list of contributing MTI points. There would then be n linear features, each with the same m contributing MTI points, with $n > m$. We would want our association algorithm to work even in this case.**

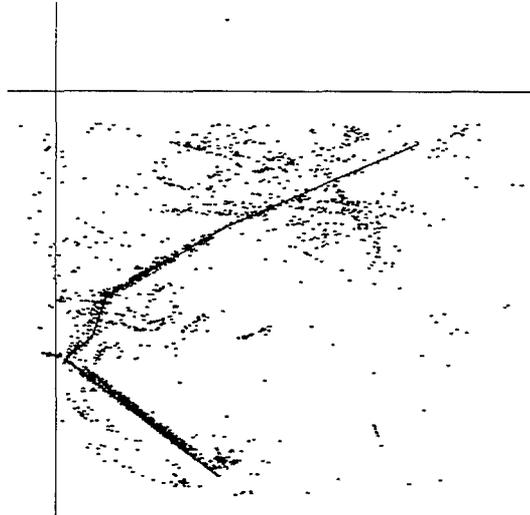
MTI Data Analysis - Raw Data



88

- **This chart shows the accumulation of MTI data over a series of frames (or time). The line of communication is visible as the concentration of reports in a linear pattern. In this case this corresponds to a known highway, other cases the vehicles are moving off-road or on unmarked roadways.**

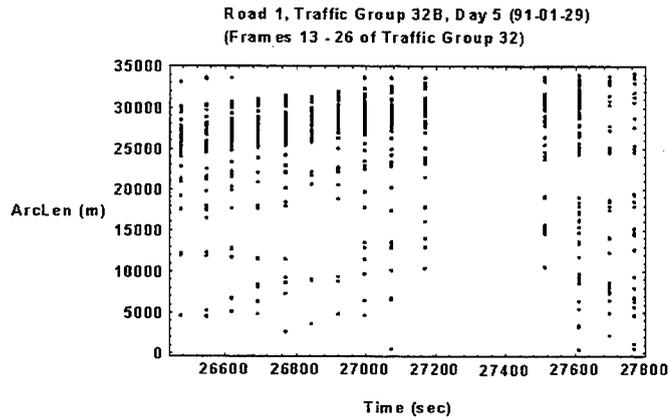
MTI Data Analysis - Raw Data With Road



89

- **The analytic approach to estimating target dynamics requires referencing a line of communication. This chart shows the raw MTI data with a line of communication overlaid.**

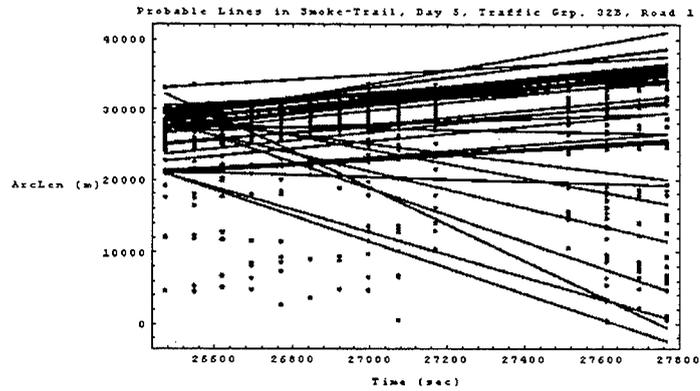
MTI Data Analysis - Smoke Trail



90

- **The Smoke Trail plot is a representation of positional data over time. The vertical axis shows progression down the roadway or line of communication. The horizontal axis is time. The human eye can detect patterns of linear features quite easily, the mathematical approach to edge detection by contrast is quite demanding. The phenomena of a linear feature holds the missing data from the 1991 EMD Joint STARS MTI data. Each linear feature represents a target or vehicle, its slope represents speed, and the offset to other lines reveals inter-vehicular spacing.**

MTI Data Analysis - Linear Features



91

- The Hough technique fits lines to the various groups of MTI 'dots'. This chart shows a variety of possible vehicles.

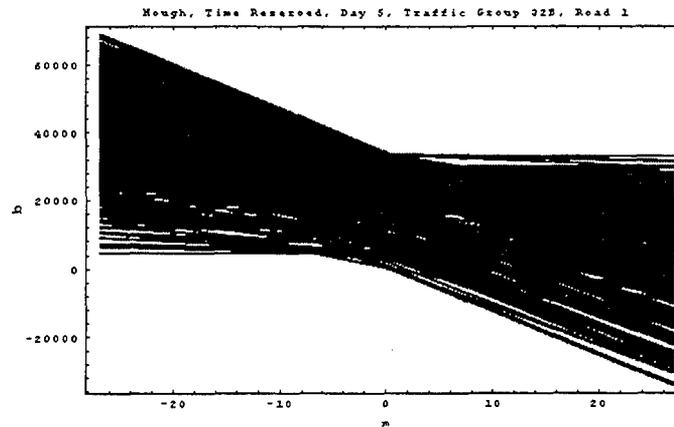
MTI Data Analysis - Raw Hough Data



92

- **Examining a larger set, however, can be overwhelming. This chart depicts that difficulty in automating the Hough analysis. Each LOC dataset must be processed interactively to accommodate the peculiarities of each dataset.**

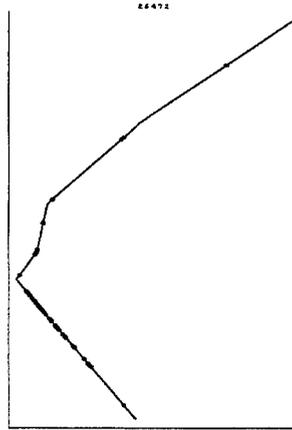
MTI Data Analysis - Hough Space (Cont.)



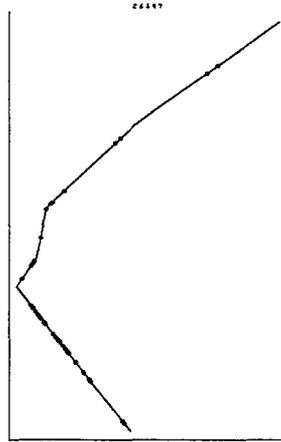
93

- This chart shows the occurrence of multiple intersections in Hough Space. Each line corresponds to one point in the Smoke Trails plot.

MTI Data Analysis - Roadway Projection

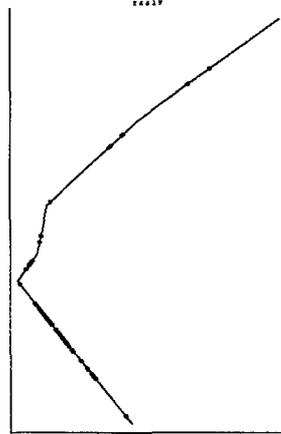


MTI Data Analysis - Roadway Projection



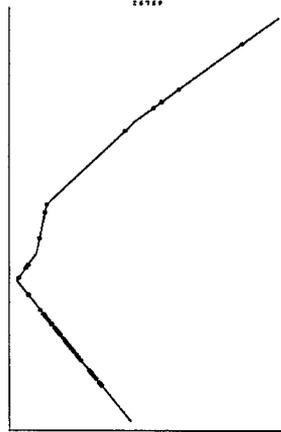
95

MTI Data Analysis - Roadway Projection



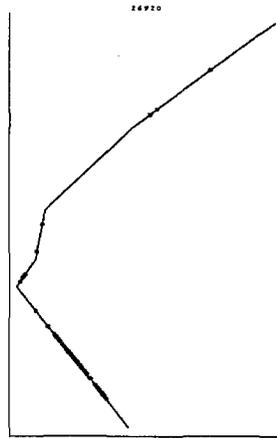
96

MTI Data Analysis - Roadway Projection



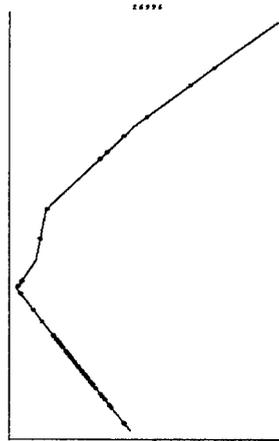
98

MTI Data Analysis - Roadway Projection



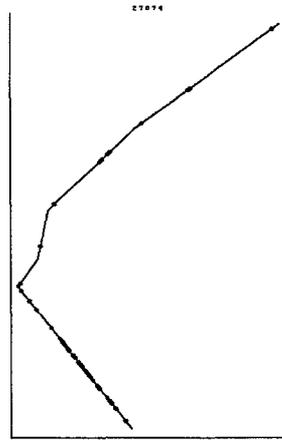
100

MTI Data Analysis - Roadway Projection



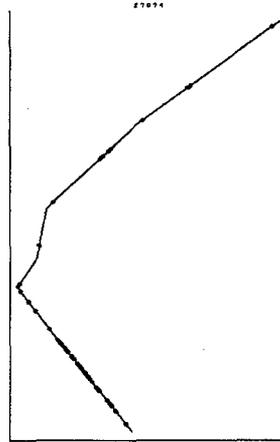
101

MTI Data Analysis - Roadway Projection



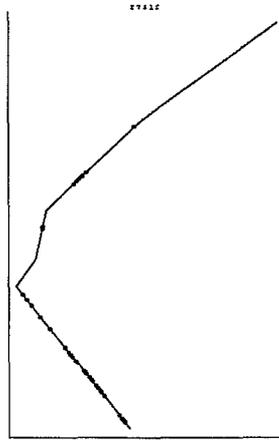
102

MTI Data Analysis - Roadway Projection



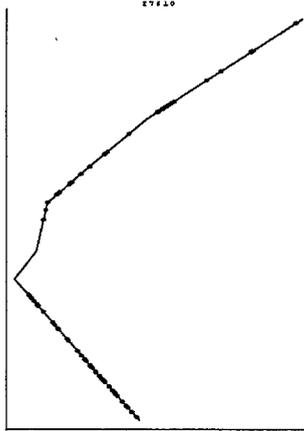
103

MTI Data Analysis - Roadway Projection



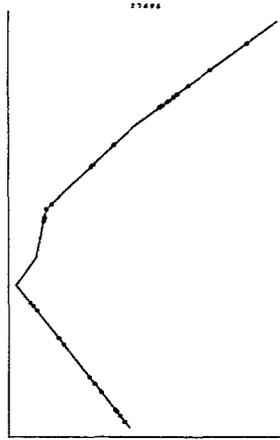
104

MTI Data Analysis - Roadway Projection



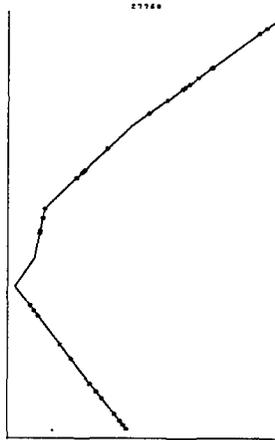
105

MTI Data Analysis - Roadway Projection



106

MTI Data Analysis - Roadway Projection

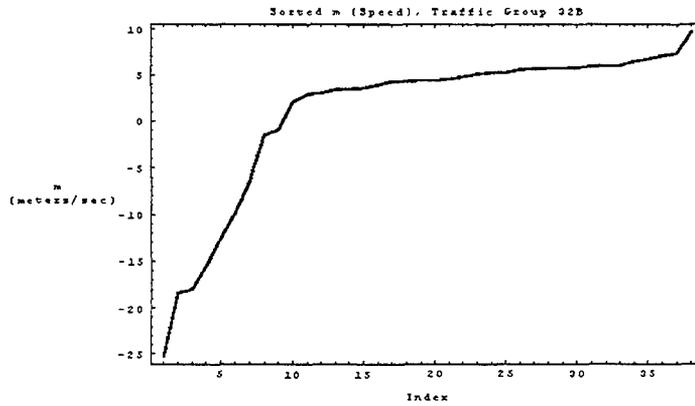


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MTI Data Analysis - Inclusion of Velocity

- **Slope Dimension in Hough Space Allows Estimation of Speed and Direction: Doppler Radial Velocity**

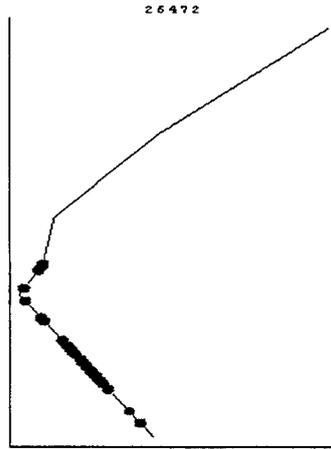
MTI Data Analysis - Estimated Velocity



109

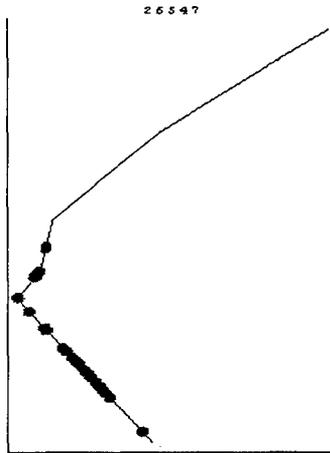
- The estimation of velocity can be discerned from the data after extensive analysis.

Road Projection With Direction/Velocity



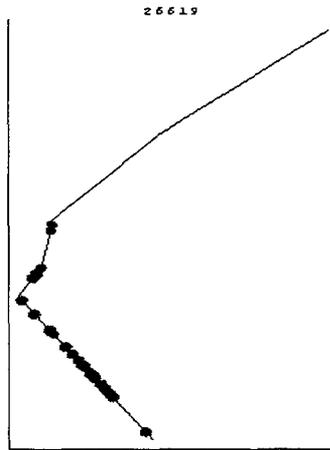
110

Road Projection With Direction/Velocity



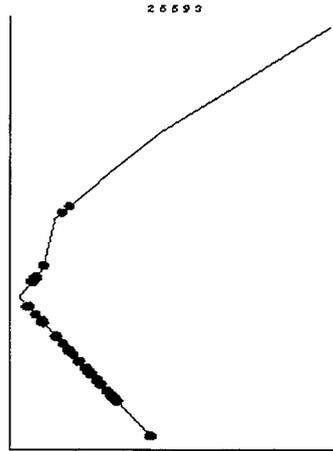
111

Road Projection With Direction/Velocity



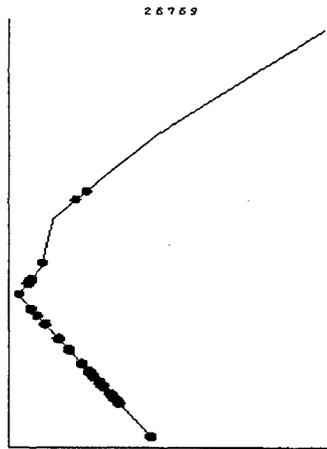
112

Road Projection With Direction/Velocity



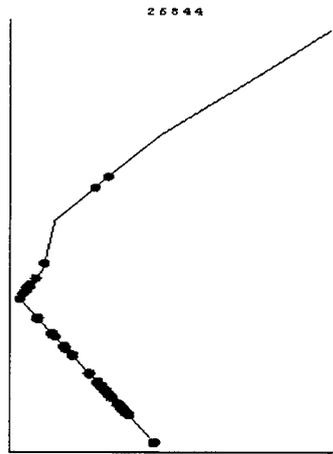
113

Road Projection With Direction/Velocity



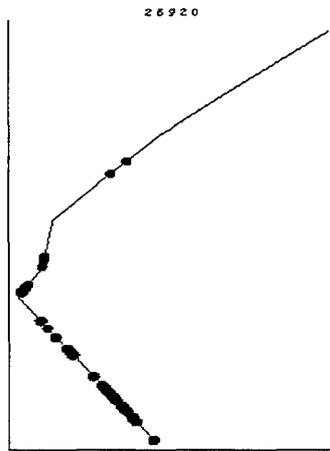
114

Road Projection With Direction/Velocity



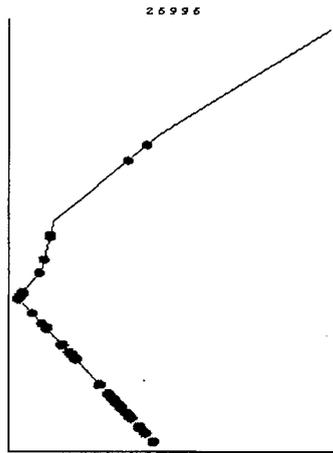
115

Road Projection With Direction/Velocity



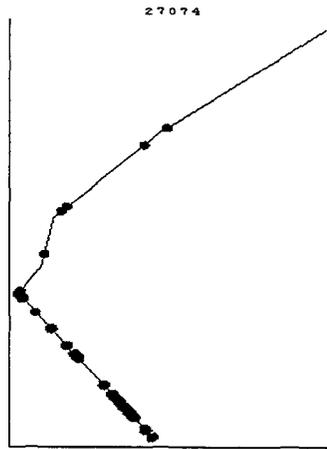
116

Road Projection With Direction/Velocity



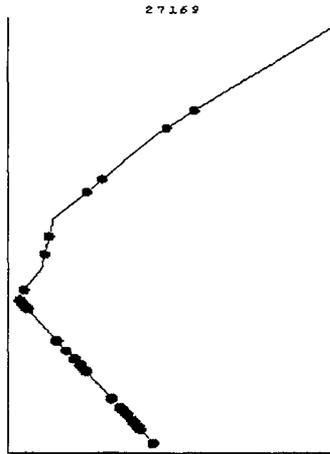
117

Road Projection With Direction/Velocity



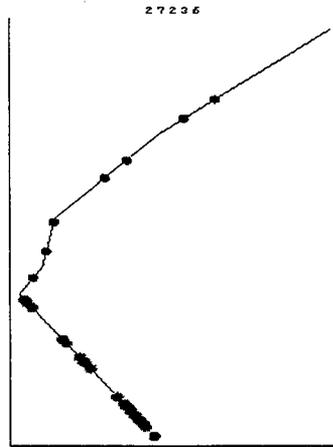
118

Road Projection With Direction/Velocity



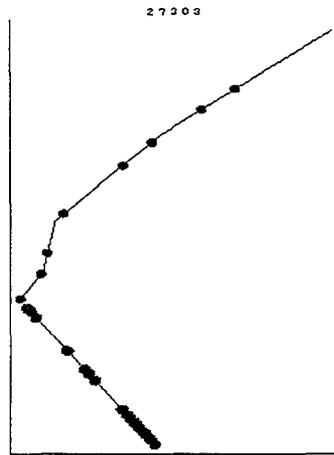
119

Road Projection With Direction/Velocity



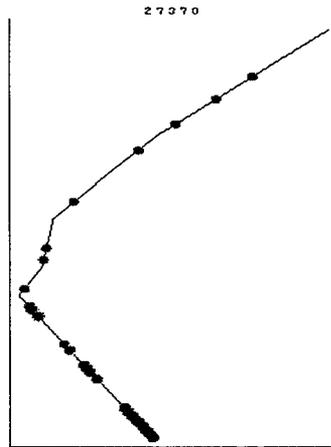
120

Road Projection With Direction/Velocity



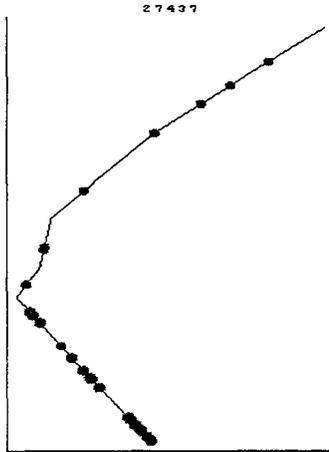
121

Road Projection With Direction/Velocity



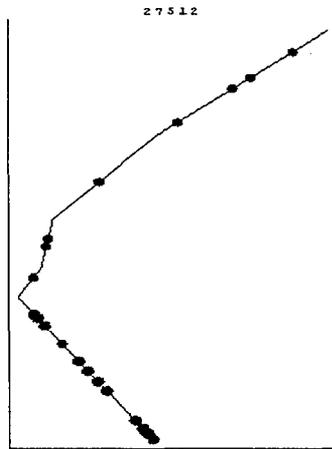
122

Road Projection With Direction/Velocity



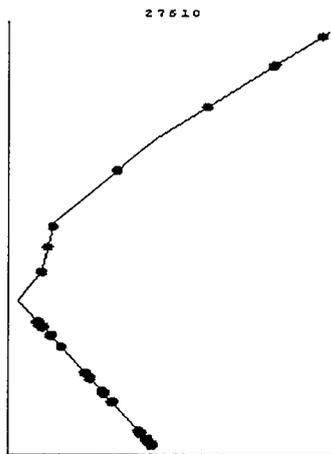
123

Road Projection With Direction/Velocity



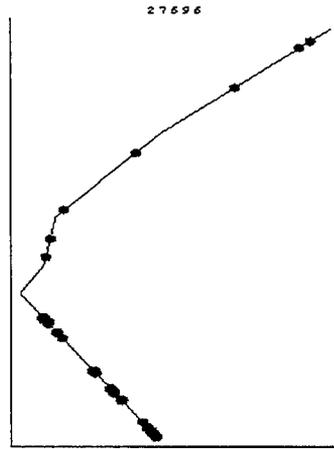
124

Road Projection With Direction/Velocity



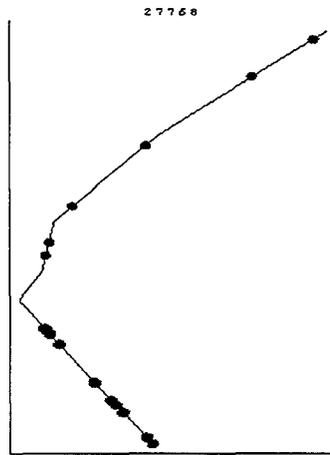
125

Road Projection With Direction/Velocity



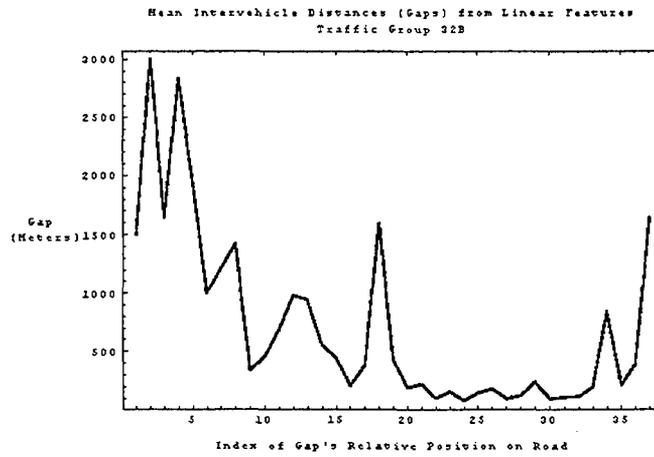
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Road Projection With Direction/Velocity



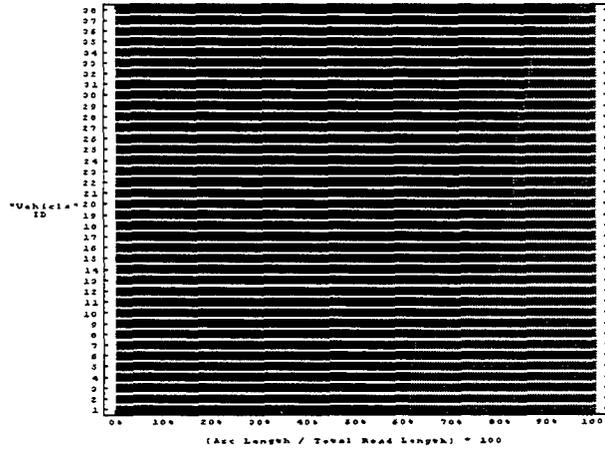
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MTI Data Analysis - Inter-Vehicular Space

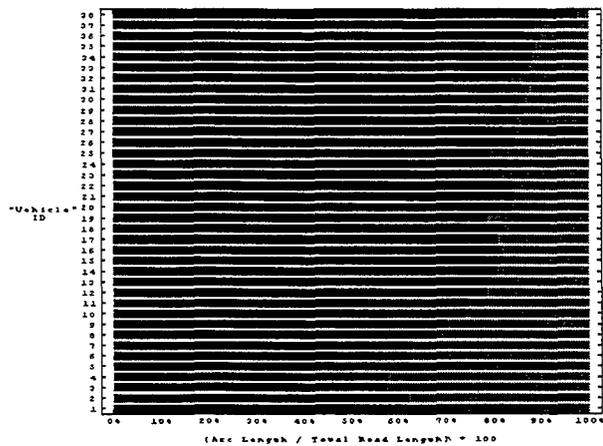


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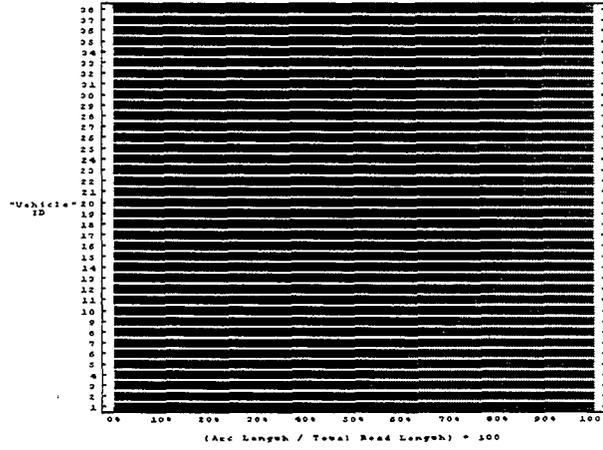
Distance-Position Index Of Each Linear Feature ("Vehicle")
vs. Percentage Acc Length
16472 Seconds, Traffic Group 222



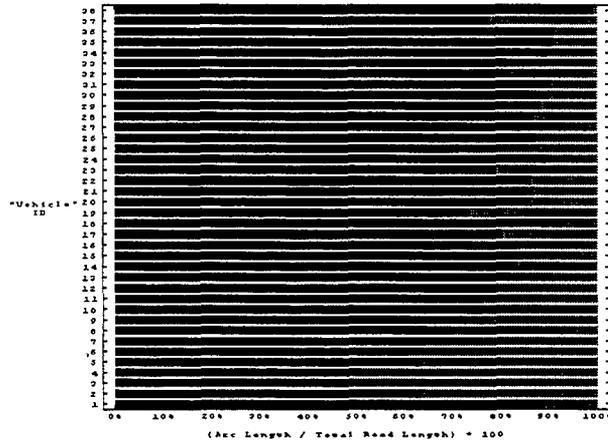
Source-Position Index Of Each Linear Feature ("Vehicle")
vs. Percentage Arc Length
18587 Seconds, Traffic Group 028



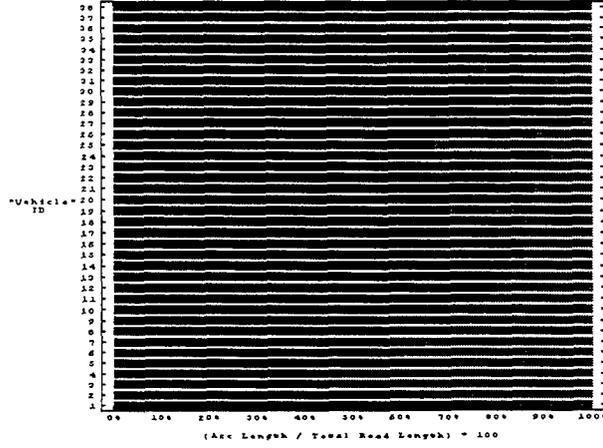
Source-Position Index Of Each Linear Feature ("Vehicle")
vs. Percentage Acc Length
28819 Seconds, Traffic Group 228



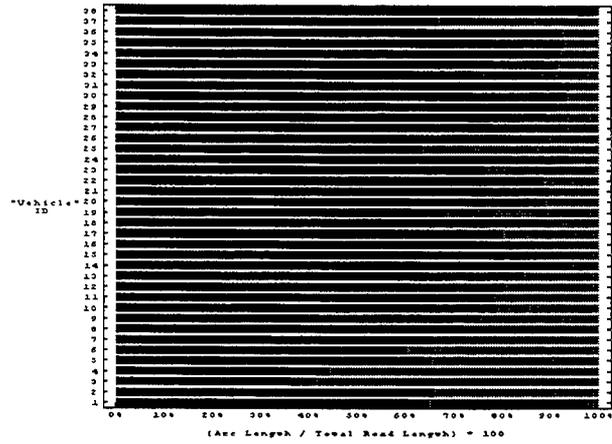
Share-Position Index Of Each Linear Feature ("Vehicle")
 vs. Percentage Acc Length
 2690 Seconds, Traffic Group 028



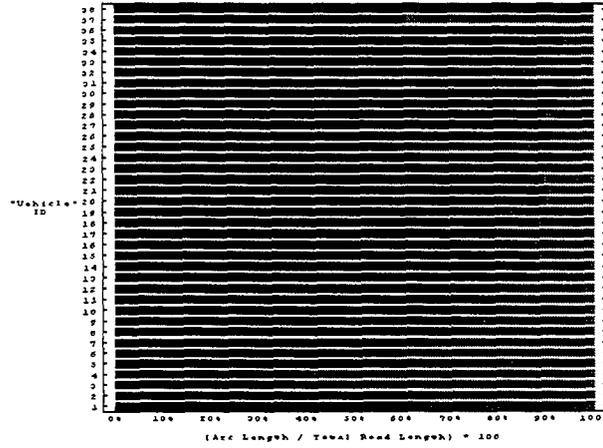
Source-Partition Index Of Each Linear Feature ("Vehicle")
 vs. Percentage Arc Length
 24789 Seconds, Traffic Group 32B



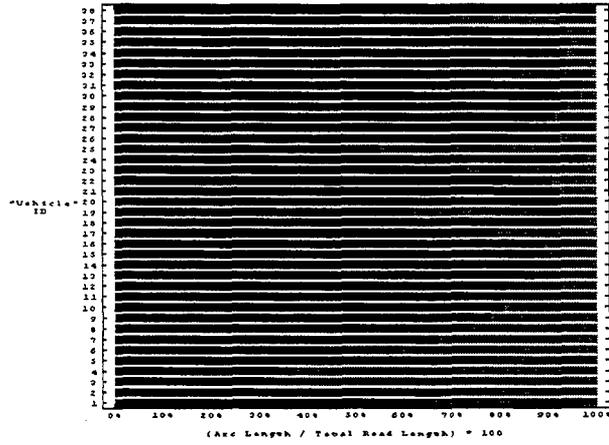
Start-Position Index Of Each Linear Feature ("Vehicle")
 vs. Percentage Acc Length
 26844 Seconds, Traffic Group 328



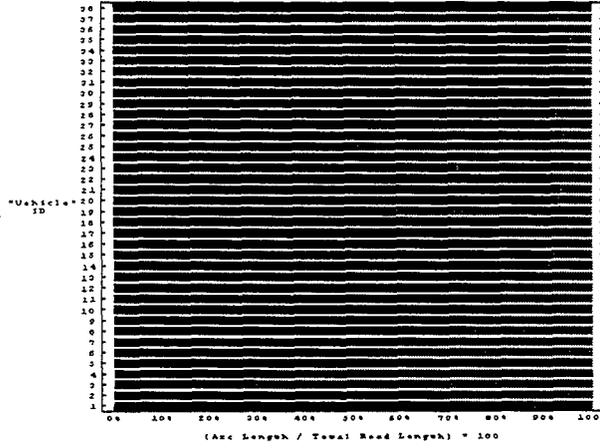
Space-Position Index of Each Linear Feature ("Vehicle")
 vs. Percentage Arc Length
 24920 Seconds, Traffic Group 029



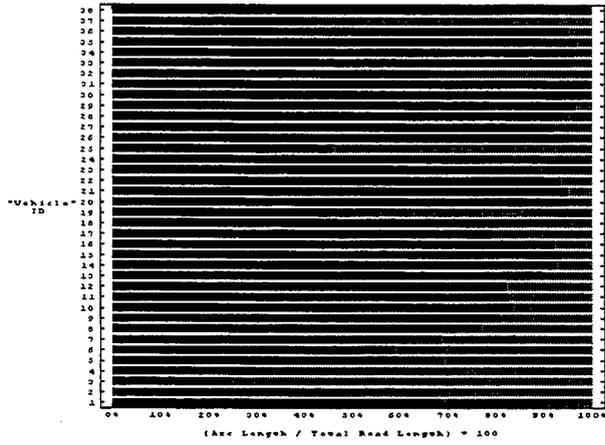
State-Position Index Of Each Linear Feature ("Vehicle")
vs. Percentage Acc Length
16996 Seconds, Traffic Group 023

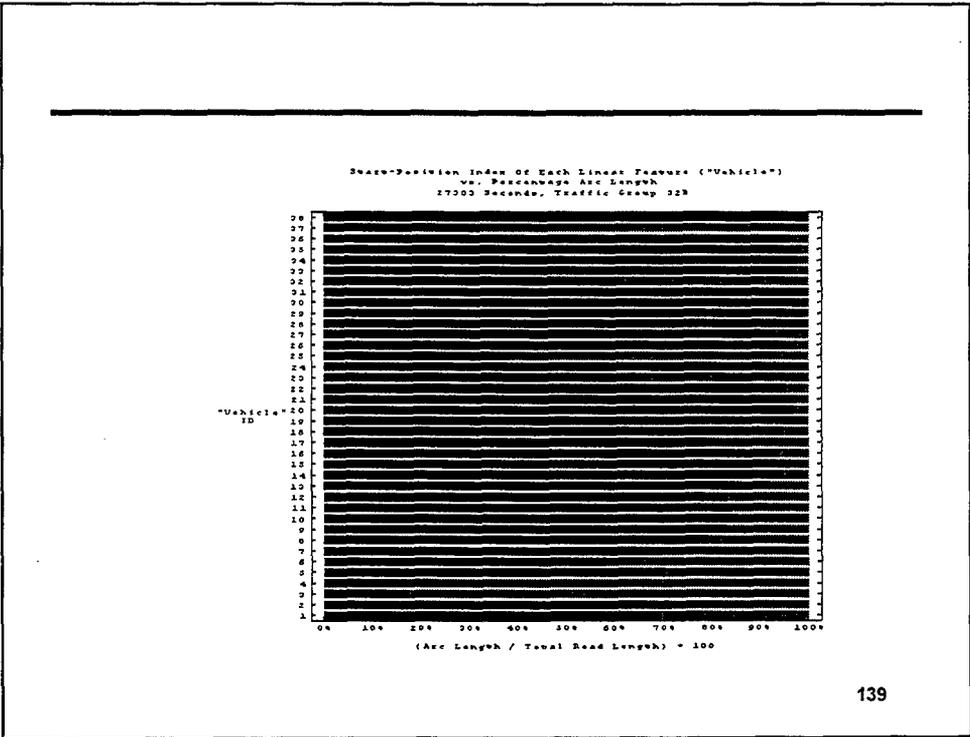


Swath-Position Index of Each Linear Feature ("Vehicle")
vs. Percentage Arc Length
27074 Seconds, Traffic Group 323

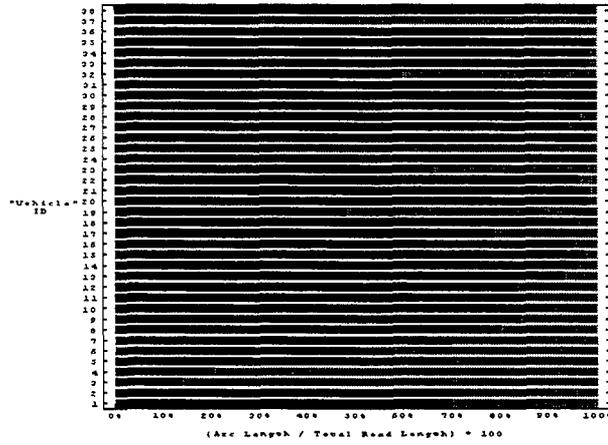


Space-Position Index Of Each Linear Feature ("Vehicle")
vs. Percentage Arc Length
27169 Seconds, Traffic Group 328

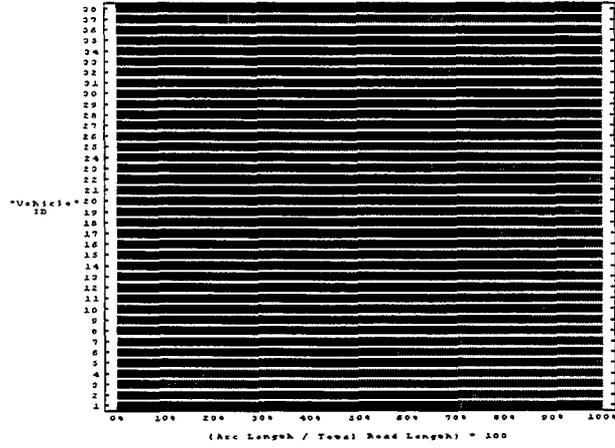




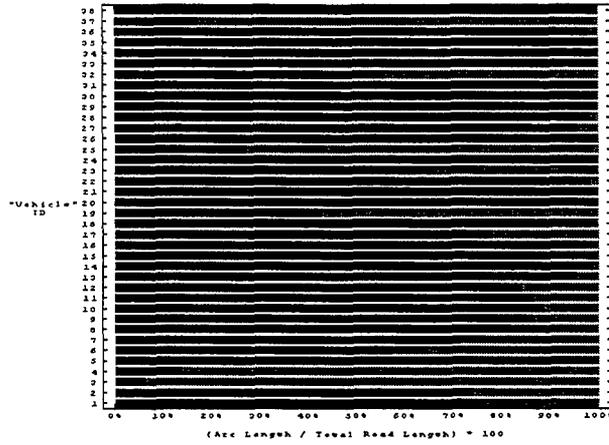
Space-Position Index of Each Linear Feature ("Vehicle")
vs. Percentage Arc Length
27570 Seconds, Traffic Group 023



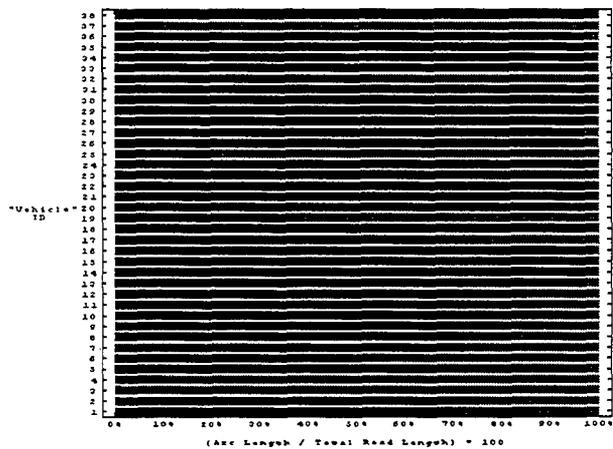
Space-Position Index of Each Linear Feature ("Vehicle")
vs. Percentage Arc Length
29437 Seconds, Traffic Group 323



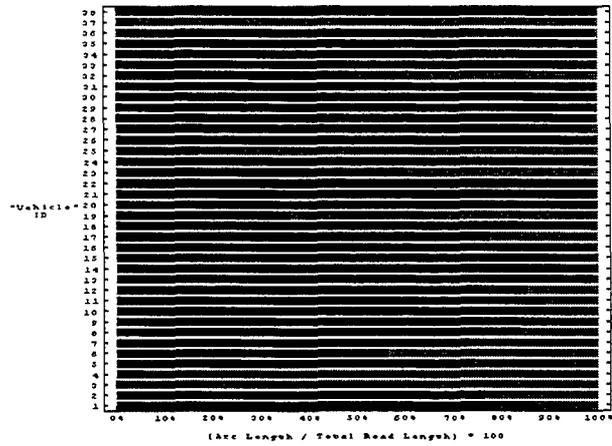
Stack-Partition Index of Each Linear Feature ("Vehicle")
vs. Percentage Acc Length
27512 Second, Traffic Group 023



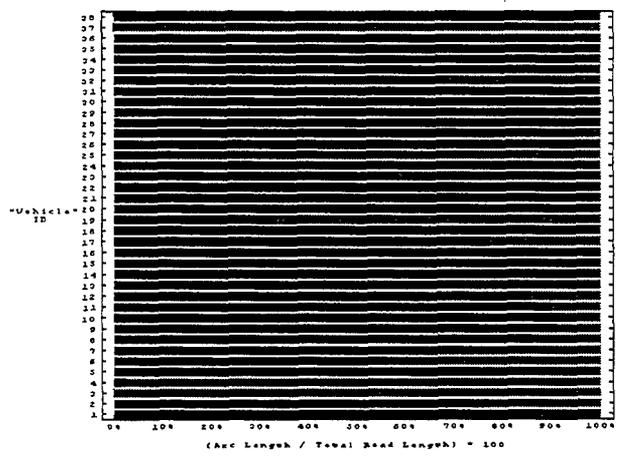
Space-Position Index Of Each Linear Feature ("Vehicle")
vs. Percentage Arc Length
27610 Seconds, Traffic Group 329



Space-Position Index of Each Linear Feature ("Vehicle")
 vs. Percentage Arc Length
 27898 Seconds, Traffic Group 328



State-Position Index Of Each Linear Feature ("Vehicle")
vs. Percentage Arc Length
27768 Records, Traffic Group 323



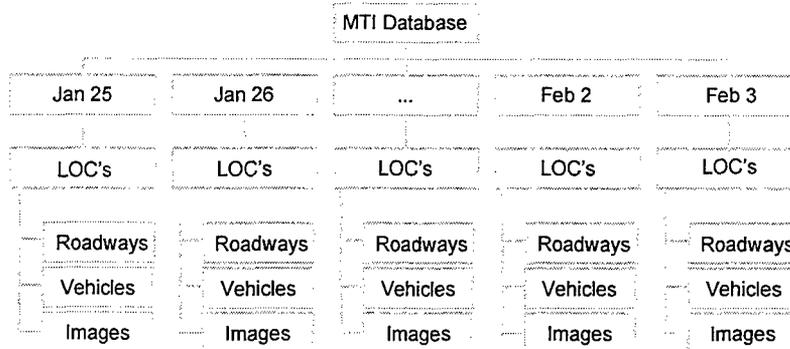
Database Approach

- **Screen Data To Reduce Volume**
- **Port From VMS Environment to UNIX**
- **Organize Chronologically**
- **Format Data Such That It Is Readable By Any Software (Including PC Spreadsheets)**

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- **The intent of the database design was to make the lines of communication database as portable and usable as possible. This was accomplished by using comma-delimited column format that is easily readable by both spreadsheets and FORTRAN, C requires reading the commas! The numbering scheme of the lines of communication is arbitrary and the sequencing is not entirely progressive as the data was reviewed mid-way through the analysis and additional lines of communication were noted.**

Database Design



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- The structure of the database is broken out by day (actually Joint STARS mission start day) and contain the line of communication vertices, the relevant MTI data points and screen images of the raw data.

Results

- **Line of Communication Database Reveals Operational and Tactical Maneuvers Across KTO**
 - Road Traffic
 - Column Movement
 - Preparation of Defensive Positions
 - Limited Observations of Air Interdiction
- **Metric Computation Proved Too Time Consuming to Meet Study Schedule**

Joint STARS Data Analysis

Follow-on Study Concepts

Follow-On Efforts

- **Further Analysis of USAF Operations in Support of the Halt Phase During The Persian Gulf War**
- **Joint STARS Data Augmentation of Other Surveillance Assets**
- **Enhance Understanding of Battle Management Operations**
- **Enhance Simulation Fidelity of Large Force Operations**

Analysis of Halt Phase Operations

- **Expand MTI Data Analysis to Include First Joint STARS Mission (19 January 1991).**
- **Augment Understanding of Iraqi Preparations For Planned Invasion**
 - Logistics
 - Preparation of Defensive Positions
- **Expand Characterization of USAF Interdiction Operations**

Joint STARS Targeting Information Allows Merging of Halt and Counteroffensive Operations

Analysis of Halt Phase Operations (Cont.)

- **Study results to date strongly support the current Air Force effort to focus on the "Halt Phase" early in a conflict, E.g..., Identification of patterns of preparation for an attack and the utility of near-real- time targeting of convoys moving into position for attack and re-supply and support convoys.**
- **Specific areas of interest include:**
 - **Opening the time frame to include both days prior to and after the Khafji window to further study attack preparations & Iraqi reaction to Air Attacks, I.e.... convoy procedures/doctrine.**
 - **Correlation of MTI data with other Intelligence data.**
 - **Further analysis of Joint STARS targeting effectiveness**
 - **Further analysis of Iraqi probes/incursions into Saudi Arabia**

Augmentation of Other Surveillance Assets

- **Continuous Joint STARS Coverage of Corps Area Provides Unprecedented Situation Awareness**
- **Using Information Gleaned From MTI and SAR, Patterns Can Be Identified That Can Be Further Examined By Other Assets**
 - Traffic Flows
 - Formations and Defensive Position Preparations
- **Correlation to Other Data (SIGINT)**

Joint STARS Real-Time Wide Area Coverage Allows Other Surveillance Assets To Be More Efficiently Tasked

Battle Management Operations

- **The Joint STARS Directed Air Attacks At The Battle of Khafji**
- **Assessment of These Operations Can Confirm Elements of ACC Concept of Decentralized Engagement Authority to C4I Platforms (Joint STARS)**
- **Decentralized Real Time Targeting Provides Great Force Multiplier**

Reduction of Sensor-To-Shooter Timelines

Simulation of Large Force Operations

- **The Entire Desert Storm MTI Database Can Be Filtered Using Technologies Developed By This Study**
 - Data Can Be Analyzed Using Advanced Algorithms Such As Semi-Automated Movement Analysis (SAMA), Traffic Flow Analysis (TFA)
- **Resulting Analysis Would Provide DIS PDU Database of Multi-Divisional Maneuvers Including**
 - Convoy Traffic
 - Formations and Defensive Position Preparation