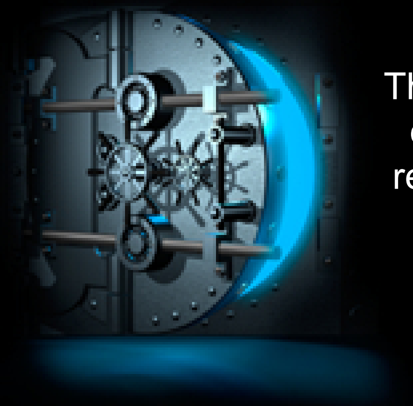

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Monterey, California

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SYSTEMATIC ANALYSIS
OF
COMPLEX DYNAMIC SYSTEMS:
THE CASE OF THE USS *VINCENNES*

by

Kristen Ann Dotterway

June 1992

Principal Advisor: Nancy C. Roberts

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Recent studies on the Vincennes incident have centered around the impact of stress in decision making. This thesis, which is a case analysis of a historical event, offers another perspective through the use of organizational and contextual factors as a means to ascertain 'what happened" when the USS Vincennes shot down Iran Air Flight 655. Data extracted from the unclassified investigation report by Rear Admiral William M. Fogarty and the transcripts from the Senate Hearing before the Committee on Armed Services were analyzed quantitatively, through regression and correlation analysis in conjunction with a graphical analysis and interpretation, in an effort to resolve the lack of reconciliation between system and recollected data by witnesses. A comparative analysis was also conducted between these archival sources of data and interview data from Captain Will Rogers, III, former Commanding Officer of the Vincennes. Additionally, to identify "causal factors" that led to the outcome, further analysis using the Events Path Model, Dynamic Systems Model, and Cybernetic Model of Mutual Causality was conducted. The findings of the quantitative analysis portion supports Captain Rogers' argument, which included a track number issue and the existence of another aircraft. Among the "causal factors" identified contributing to the accidental shoot down, the most significant finding revealed was the failure to identify and differentiate between two aircraft, which was primarily due to the functional lack of negative feedback as a control mechanism that keeps a system stable and under control. Consequently, the issue of stress was not as significant as ws originally diagnosed

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Nancy C. Roberts

22b TELEPHONE *(Include Area code)*
(408) 646-2742

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Systematic Analysis of Complex Dynamic Systems:
The Case of the USS *Vincennes*

by

Kristen Ann Dotterway
Captain, United States Air Force
B.S., United States Air Force Academy

Submitted in partial fulfillment
of the requirements for the degree of

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Author: Kristen Ann Dotterway

Approved by: Nancy C. Roberts, Principal Advisor

Allan W. Tulloch, CDR, Associate Advisor

Carl R. Jones, Chairman
Command, Control, and Communications Academic Group

ABSTRACT

Recent studies on the *Vincennes* incident have centered around the impact of stress in decision making. This thesis, which is a case analysis of a historical event, offers another perspective through the use of organizational and contextual factors as a means to ascertain "what happened" when the USS *Vincennes* shot down Iran Air Flight 655. Data extracted from the unclassified investigation report by Rear Admiral William M. Fogarty and the transcripts from the Senate Hearing before the Committee on Armed Services were analyzed quantitatively, through regression and correlation analysis in conjunction with a graphical analysis and interpretation, in an effort to resolve the lack of reconciliation between system and recollected data by witnesses. A comparative analysis was also conducted between these archival sources of data and interview data from Captain Will Rogers, III, former Commanding Officer of the *Vincennes*. Additionally, to identify "causal factors" that led to the outcome, further analysis using the Events Path Model, Dynamic Systems Model, and Cybernetic Model of Mutual Causality was conducted. The findings of the quantitative analysis portion supports Captain Rogers' argument, which included a track number issue and the existence of another aircraft. Among the "causal factors" identified contributing to the accidental shoot down, the most significant finding revealed was the failure to identify and differentiate between two aircraft, which was primarily due to the functional lack of negative feedback as a control mechanism that keeps a system stable and under control. Consequently, the issue of stress was not as significant as was originally diagnosed.

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I. INTRODUCTION

A. THE RESEARCH QUESTIONS

On 3 July 1988, Iran Air Flight 655 was intercepted by two Standard missiles from the Aegis cruiser, USS *Vincennes* (CG 49), killing 290 passengers. Granted, in any rapidly developing situation, it is often difficult to fully ascertain what is really going on, and military personnel have, at times, shot at contacts without being 100 percent certain whether the contact was a friend or a foe. Yet, how is it that a billion dollar warship designed to track and classify multiple aircraft in a combat environment shot down a commercial airliner? How is it that the system data showed the contact to be ascending, while many crew members in the Combat Information Center (CIC) thought the contact was descending? And finally, how is it that the findings of Rear Admiral William M. Fogarty, assigned as the investigating officer to ascertain the circumstances surrounding the downing of Flight 655, differed from the interpretation of Captain Will Rogers, III, the Commanding Officer of the *Vincennes*?

The findings of the Fogarty investigation attributed poor decision making as a result of stress as being a significant cause behind the disagreement in system data and the participants' accounts. This thesis, using both a quantitative and qualitative approach, will attempt to show that the issue of stress was not as significant of a factor as was originally diagnosed. Regarding causal factors, the failure to identify and differentiate between two aircraft was primarily due to the functional lack of negative feedback as a control mechanism to keep the system balanced and stable. Essentially, the focus of this thesis is to provide another interpretation as to what happened as well as attempts to provide an explanation as to the above disparities.

B. STRUCTURE OF THESIS

To address these questions, a historical case on the *Vincennes* incident is presented in Chapter II to provide background and to give the reader an overview as to the sequence of events. Chapter III summarizes and compares two analyses and interpretations of the outcome, one initiated by the investigating team headed by Rear Admiral William M. Fogarty and the other produced by Captain Rogers of the *Vincennes*. The author also provides her own analysis, which was limited to unclassified research materials and sources such as the Fogarty report, unclassified version, Senate Hearing before the Committee on Armed Services, and personal interviews with Captain Rogers, in which the results of the analysis find support for the Rogers' interpretation of the events. Probing for "causal factors" that produced the downing of Iran Air Flight 655, the author uses three different approaches to trace "causal factors" as shown in Chapter IV. The results of the overall probe indicated that there were a multitude of "causal factors," in which their relationships and the local context generated as a consequence, significantly contributed to the accidental shoot down of a civilian airliner. Finally, Chapter V consists of the conclusion and recommendations.

C. METHODOLOGY

This thesis employed multiple research methods in its design. Qualitative methods, such as interviews and archival research were used, to write a historical case on the *Vincennes* incident. Quantitative methods, such as regression and correlation analysis in conjunction with a graphical analysis and interpretation of the data, were used to analyze the discrepancies between two interpretations of the events and their outcome. Lastly, three models were used to ascertain "causal factors": The Events Path Model, which is a linear causal model that facilitates path analysis and the how context can be transformed over time, the Dynamic Systems Model, which is useful for identifying interdependencies and understanding how change affects other aspects of a system, and the Cybernetic Model of Mutual Causality, which is useful for flow analysis, determining the extent of negative feedback or for positive feedback required to facilitate a stabilization or change process in a system.

D. SCOPE/BENEFITS

This thesis is a historical examination of U.S. Naval operations in the Persian Gulf during the 1988 time frame, with particular emphasis on the accidental shoot down of Flight 655 in the Strait of Hormuz. Although this thesis examines a singular event in military history, the analysis involves a broad scope of inquiry concerning organizational and contextual factors regarding CIC decision making. This thesis is not an attempt to find out truth, nor is it intended to be judgmental, but rather, it attempts to develop ways at which complex dynamic problems as illustrated by the *Vincennes* can be studied and to emphasize the need to employ systems thinking and methodologies to augment the diagnostic process regarding systems problems and accidents. The hope is that the *Vincennes* incident can serve as a source of learning, because it represents the "worst case scenario" a military unit and commander might have to contend with during the course of a mission: Having to make a high risk decision based on ambiguous information in a volatile, uncertain task environment under tight time constraints. By incorporating a systems analysis approach to the naval investigation process, a more complete and accurate problem diagnosis of complex dynamic problems will occur and enable the Navy to more effectively direct its resources to solving the "real" problem versus an "apparent" problem.

II. THE *VINCENNES* INCIDENT

A. OVERVIEW

At approximately 1054 local time, 3 July 1988, the Aegis cruiser, USS *Vincennes* (CG 49), shot down a civilian airliner, Iran Air Flight 655, with two Standard missiles. The airliner was on a routine, international flight from Bandar Abbas, Iran, to Dubai, United Arab Emirates, and was flying on a designated commercial airway. The missiles intercepted the airliner at a range of eight nautical miles (NM) from the *Vincennes* at an altitude of 13,500 feet. All 290 passengers and crew were killed. (Fogarty, 1988, pp. 4 and 6)[1] Figures II-1 shows a geographical map of the Persian Gulf region.

B. HISTORY

1. U.S. Presence in the Gulf

The U.S. has maintained a naval presence in the Gulf for over 40 years starting in 1948 with the establishment of the U.S. Naval Forces, Persian Gulf Command. This patrol force, consisting of small surface ships, was redesignated the Middle East Force (MEF) in August 1949. The original mission of the MEF was multi-fold: "to show the flag, support U.S. relationships with regional states, provide emergency services at sea, procure and ship fuel oil, and to conduct hydrographic surveys." (Glenn and Warner, 1987, p. 10) From its inception, the MEF's mission and associated force structure grew in size, complexity and scope. The growth was particularly evident during the 1980s due

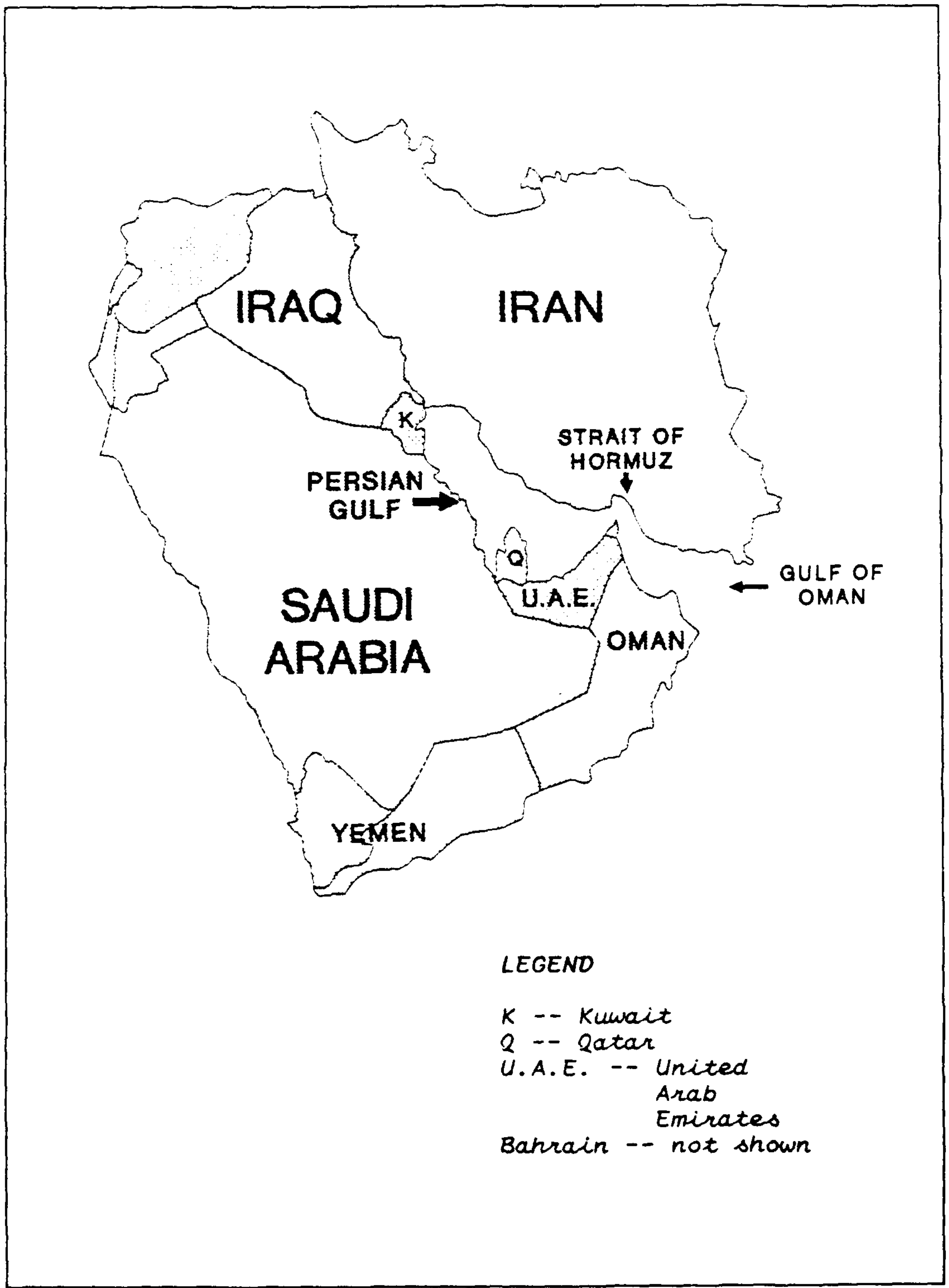


Figure II-1. Geographical Map of the Persian Gulf Region to Soviet aggression in Afghanistan and the Iran-Iraq War. The MEF's increased responsibilities included the maintenance of air and sea lines of communication, the demonstration of U.S. resolve, performance of maritime surveillance operations, interaction with local navies through participation in exercises, and the promotion of goodwill through port visits. (Glenn and Warner, 1987, p. 10)

2. U.S. Interest in the Gulf

During the 1980's, oil was the principal strategic economic interest of the U.S. in the Persian Gulf region, where 50 to 60 percent of the world's known oil reserves were located. Other reasons for U.S. interest were the potential for escalation in the Iran-Iraq War and possible regional destabilization. (Glenn and Warner, 1987, p. 16)

3. Iran-Iraq War

Hostilities between Iran and Iraq had existed for centuries, with the border between the two countries under constant dispute. Hoping to take advantage of internal disturbances in Iran that precipitated from the Iranian revolution in 1979, Iraq launched a strike into Iran on 22 September 1980. Iraq expected the Iranian Army to collapse and the government in Tehran to agree to a cease fire; however, Iran remained steadfast despite the advance of Iraqi forces. A year later, in a series of counter attacks, Iran regained most of the Iraqi occupied territory and the conflict essentially transformed into a static "war of attrition in which the line of battle...moved little more than a few miles from the pre-war border." (Glenn and Warner, 1987, p. 8)

4. The Tanker War

During the first three years of the war, the ships that were attacked were directly involved with combat resupply (Glenn and Warner, 1987, p. 8). On 27 March 1984,

> Iraq escalated the air war, into what has been called the 'Tanker War,' by attacking Iran's economic shipping and oil installations. Iraq's objectives were to prevent or reduce the importation of vital materials required by Iran for its war effort, to reduce or terminate Iran's oil revenues which helped finance the war, and to internationalize the war. (Glenn and Warner, 1987, p. 8)

From 27 March 1984 to 17 June 1987, a total of 248 ships were attacked. Iraq initiated 153 of these attacks while Iran conducted 95. Although the Tanker War did not cause serious disruptions in oil flow to the West, Kuwait came under increasing pressure from Iranian attacks. Kuwait needed protection for her tankers and began to explore various options to include assistance from the Soviet Union. (Glenn and Warner, 1987, p. 9) The U.S. response to Kuwait's requests for assistance was to

> expedite procedures for the registry of eleven Kuwaiti oil tankers under the American flag [and]...to provide appropriate protection by U.S. military forces...to the eleven reflagged Kuwaiti oil tankers while operating in the Persian Gulf region and transiting the Strait of Hormuz. (Glenn and Warner, 1987, p. 12)

5. The *Stark* Incident

On the evening of 17 May 1987, the Frigate USS *Stark* (FFG 31) was on escort patrol duty in the Persian Gulf and was informed by a U.S. Airborne Warning and Control System (AWACS) aircraft that an Iraqi Air Force F-1 aircraft was about 200 miles away flying south along the Saudi Arabian coast. The *Stark's* on-board air search radar detected the Iraqi F-1 at a range of 70 nautical miles (NM) from the ship. At 43

NM, the *Stark's* radar operator noticed that the ship had been locked on by the fire control radar for about five seconds, at which time he requested permission of the Tactical Action Officer TAO) to issue a standard warning to the closing Iraqi fighter. He was told to wait, considering the F-1 might change course. Attempts were made to inform the captain, but he could not be located. Meanwhile, at the 22.5 NM point, the Iraqi F-1 fired its first Exocet missile. It appeared as a contact about 15 degrees off port bow and was initially identified as a surface contact. The ship was locked on again, and at the 15 NM point a second Exocet missile was fired from the Iraqi fighter. At about 12 NM, the first warning message was broadcasted, and the TAO ordered the chaff launchers to be armed. But it was too late. By this time, the Iraqi aircraft had already fired its second missile. At 2109 local time (L), the first Exocet hit the *Stark*. About thirty seconds later, the second missile struck the ship. A total of 37 sailors were killed. Appendix B contains a more detailed account of the *Stark* incident. (Sharp Investigation, 1987)

6. Increased U.S. Involvement

After the *Stark* incident, U.S. naval operations in the Persian Gulf increased in scope and intensity. Concurrently, Iranian and Iraqi attacks on shipping escalated as the Iran-Iraq War continued to simmer: "Between January and June 1988, Iran conducted 42 attacks on tankers in the Persian Gulf, primarily through speedboat and frigate gunfire or naval mines, and Iraq launched 27 attacks, primarily using missile armed jets." (Sagan, 1991, pp. 97-8) Table II-1 shows the total number of attacks per year by Iran and Iraq in the Tanker War while Table II-2 shows the number of attacks each month in 1988.[2]

TABLE II-1

ATTACKS ON SHIPS IN THE PERSIAN GULF BY BELLIGERENT, 1981-88

ATTACKER	'81	'82	'83	'84	'85	'86	'87	'88	TOTAL
IRAQ	5	22	16	53	33	66	89	38	322
IRAN	0	0	0	18	14	45	92	52	221
TOTAL	5	22	16	71	47	111	181	90	543
Source: O'Rourke, 1989, p. 43									

TABLE II-2

ATTACKS ON SHIPS IN THE PERSIAN GULF BY BELLIGERENT, 1988

ATTACKER	JAN	FEB	MAR	APR	MAY	JUN	JUL to AUG	TOTAL
IRAQ	8	5	6	0	7	1	11	38
IRAN	7	7	13	7	5	3	10	52
TOTAL	15	12	19	7	12	4	21	90
Source: O'Rourke, 1989, p. 43								

April 1988 was a tumultuous month for American forces in the Persian Gulf. Increased Iranian aggression caused a "reconsideration" of U.S. policy for that region. Dr Scott D. Sagan, Assistant Professor of Political Science at Stanford University, provides a succinct account of events leading up to and including Operation PRAYING MANTIS, which commenced on 18 April 1988:

> Until April 1988, the U.S. government resisted requests from Saudi Arabia and the United Arab Emirates to expand U.S. naval escort protection to non U.S. flagships in the Gulf, but the escalating conflict produced a reconsideration in Washington. On March 6, U.S. helicopters on a reconnaissance mission were fired upon by Iranian forces, and on April 14, the frigate USS *Samuel B. Roberts* was severely damaged when she struck what was believed to be an Iranian mine laid well outside the declared war-exclusion zone. In response, on April 18, the U.S. government

> ordered a significant retaliatory attack [Operation PRAYING MANTIS] against Iranian oil platforms[3] ...and President Reagan personally approved a mid-battle request from the on-site commanders to attack other threatening Iranian naval vessels in the area. At the end of April, Secretary of Defense Frank Carlucci announced that the U.S. protective umbrella would be expanded to include any friendly or neutral vessel in the Persian Gulf outside of the war-exclusion zone. (1991, p. 98)[4]

Along with these events, Iran reportedly began building a new Silkworm launching facility on Abu Musa Island near the Strait of Hormuz and resumed work on other launching facilities on the Iranian side of the Strait. This further elevated the threat to seaborne traffic. Upon completion of the construction work, Iran would have the ability to fire Silkworm missiles into the Strait with minimal warning time to the ships in the area. The primary reason that prompted the deployment of the *Vincennes* to the area was to counter this emerging Iranian missile capability. The secondary reason was to respond to increased activity by Iranian fighters flying out of Bandar Abbas. (O'Rourke, 1989, p. 43) Figure II-2 shows a chronology of events in the Persian Gulf.

C. AIR OPERATIONS

1. Commercial Air Activity

The airways in the Persian Gulf were crowded despite the Iran-Iraq War, with 18 commercial airways covering over half of the navigable waters in the region. A total of 12 of the 18 airways (67%) crossed the Strait of Hormuz. Although the commercial air picture was complex, it was described as "ordered" during naval briefings to ships entering the area. Consistent with the large number of airways servicing the Gulf, well over 1,500 flights would pass through on a weekly basis. Air carriers that did not

- January 1987
  --Kuwaitis ask U.S. to reflag tankers

- March 1987
  --U.S. agrees to reflagging scheme

- May 1987
  --USS *Stark* attacked by Iraqi jet

- July 1987
  --U.S. tanker escort operations begin
  --USS *Bridgeton* hits Iranian mine

- September 1987
  --U.S. helicpoters attack *Iran Ajr* laying mines
  --*Iran Ajr* captured by U.S. forces and sunk

- October 1987
  --U.S.-registered tanker *Sea Isle City* hit by Iranian missile while anchored in Kuwaiti waters
  --U.S. attacks two Iranian oil platforms

- April 1988
  --USS *Samuel B. Roberts* hits Iranian mine
  --U.S. attacks Iranian oil platforms and naval vessels

- July 1988
  --USS *Vincennes* downs Iranian airliner

- August 1988
  --Iran and Iraq negotiate a cease fire agreement

Source: Hayes, 1989, p. 40

Figure II-2. Persian Gulf Chronology of Events approach Iran during any phase of their flight would normally fly at high altitudes (20,000 feet and higher) over the area.[5] (Fogarty, 1988, pp. 14 and 16) Another observation pertinent to commercial aircraft crossing the Gulf was that in-flight modification to their modes and codes had been noted, which was a misuse of the Identification Friend or Foe (IFF) system. By either intentionally or unintentionally changing these modes and codes, the aircraft would send out misinformation as to its real identity.[6] In other words, if an aircraft misidentified itself and squawked an incorrect mode and code other than what was assigned, it could be misidentified and considered hostile or an enemy aircraft, when in fact it was not. Also, changing modes and codes could imply questionable intentions to a radar tracker tracking the aircraft's flight as well as exacerbate the radar tracker's deconfliction problem. The consequences of changing these assigned modes and codes could be lethal, especially when flying over an area that was prone to military hostilities with a large amount of both civilian and military aircraft flying in the same airspace. (Fogarty, 1988, pp. 14 and 16; Friedman, 1989, p. 73)

Information regarding commercial airline activity was promulgated by Commander, Joint Task Force Middle East (CJTFME) to U.S. naval vessels in the Persian Gulf. On 28 June 1988, CJTFME sent a message containing commercial airline schedules which showed that Iran Air Flight 655 was scheduled to depart Bandar Abbas at 0620Z or 0950L every Tuesday and Sunday of each week.[7] As for IFF data, "the only commercial IFF information available to any [Joint Task Force Middle East] JTFME unit was pass-down items from other Middle East Force ships." (Fogarty, 1988, p. 15)

Other data pertaining to the commercial air picture were obtained in introductory briefings to the Middle East Force. The CJTFME briefers would discuss the commercial air picture in general, but would not focus on specific airways or particular commercial airline schedules. The briefers mentioned the "complex, but ordered commercial air picture" and emphasized caution if contacts deviated from their normal operating patterns. The use of international and military air distress channels was also briefed, and ships were instructed to contact civilian airliners through the International Air Distress (IAD) channel. (Fogarty, 1988, p. 14)

Aside from the CJTFME inchop briefs, a Notice to Airman (NOTAM) was published on 8 September 1987 and was distributed to Persian Gulf countries through the International Civilian Aviation Organization (ICAO) and State Department agencies. This NOTAM, which was issued as a result of the *Stark* incident, notified all Persian Gulf countries of the increased defensive precautions U.S. naval ships would be taking. (Fogarty, 1988, p. 15)

2. Military Air Activity

Iranian Air Force operating patterns changed significantly at Bandar Abbas a month prior to 3 July 1988 (Fogarty, 1988, p. 10). Iranian F-4s scrambled daily from Bandar Abbas during Operation PRAYING MANTIS. On one occasion, after failing to respond to warnings issued from the USS *Wainwright* over both military and international air distress channels, an Iranian F-4 continued to close this ship in an attack profile. Two missiles were launched from the *Wainwright*, severely damaging the F-4. (Perkins, 1989, p. 70)

On 18 June 1988, the *Vincennes* was alerted by CJTFME as to the changing patterns and more aggressive behavior of Iranian F-4s operating from Bandar Abbas. Additionally, the *Vincennes* was forewarned of the recent deployment of Iranian F-14s to Bandar Abbas, which CJTFME interpreted as an increased threat to U.S. forces in the area. Although F-14s were not normally used for iron bomb attacks, in which unguided bombs would be dropped, the fighter aircraft could be modified and used in that capacity. Additionally, intelligence reports had underscored Iranian attempts to modify their F-4s and F-14s for anti-surface attack roles (Rogers, 1992). This modification would require the F-14 to come within two NM of the target in order to engage. On 2 July 1988, CJTFME also warned the Middle East Force (MEF) of increased Iranian military activity in a retaliatory response to successful Iraqi attacks on Iranian oil facilities. (Fogarty, 1988, pp. 10-11) The MEF was also alerted as to possible Iranian suicide or kamikaze attacks on shipping during the Fourth of July weekend (Friedman, 1989, p. 73). In addition to these warnings, Iranian and Iraqi military aircraft were observed squawking all IFF modes and codes, and at times following commercial air routes within the Persian Gulf. (Fogarty, 1988, pp. 4, 11, and 16)

CJTFME also tabulated the number of challenges and warnings conducted by MEF forces from 2 June 1988 to 2 July 1988. Of the 150 challenges issued, 125 or 83 percent were directed to Iranian military aircraft while only two or 1.3 percent were directed towards commercial aircraft. These challenges were normally issued to aircraft showing a potentially hostile flight pattern or to answer questions of intent. (Fogarty, 1988, p. 16; Rogers, 1992)

D. THE USS *VINCENNES*

The *Vincennes* was selected to deploy to the Persian Gulf to counter the emerging Iranian Silkworm missile threat. On 20 April 1988, the *Vincennes* received a short notice deployment order to the Persian Gulf while participating in Fleet Exercise 88-2 (FLEETEX 88-2). She was directed to detach early from the exercise and return to home port to prepare for her new mission. By 25 April 1988, the *Vincennes* was enroute to the Persian Gulf. Her transit was from San Diego, California, to Subic Bay, Republic of the Philippines (RP) for training, and then onward to the Persian Gulf with a projected arrival date of 16 May 1988. (Fogarty, 1988, pp. 17-18) Incidentally, the *Vincennes* was the first and only cruiser of its type to be deployed to the Persian Gulf region at that time (Rogers, 1992).

1. Training and Readiness

Upon notice of her deployment to the Persian Gulf, a self-assessment was conducted and the *Vincennes* was found to be in the "highest state of training and readiness," having achieved top ratings (C-1 status) in Personnel, Supply, Training, and Equipment. The *Vincennes* also achieved M-1 status with no casualty reports (CASREPS) in the anti-air warfare (AAW), anti-mine warfare (AMW), anti-submarine warfare (ASW), anti-surface warfare (ASUW), command, control and communications (C3), and electronic warfare (EW) mission areas. In other words, all systems were "up and operational," and the ship was considered fully capable of conducting her mission. (Fogarty, 1988, p. 18; Rogers, 1992)

Before her deployment, the *Vincennes* participated in interim refresher training, FLEETEX 88-1, and a portion of FLEETEX 88-2. Table II-3 summarizes the training activities the *Vincennes* had undergone prior to 3 July 1988.[8] After completing interim refresher training, the *Vincennes* was found to be fully capable of performing duties as anti-air warfare coordinator in battle group operations. Although the *Vincennes* did not complete FLEETEX 88-2 or a normal MEF augmenter training schedule due to her accelerated transit to Subic Bay, she did participate in various training activities as outlined in Table II-3, to include three Rules of Engagement exercises (ROEX).

A highlight of the Subic Bay training experience included a two day intensive war at sea exercise (WASEX) conducted on 9-10 May 1988. The *Vincennes* was presented with virtually every type of scenario conceivable in order to prepare for her mission, which also included responding to attacking aircraft. During the post exercise critique session, the *Vincennes*' large screen display (LSD) was used to recreate the exercise events. This reconstruction revealed that the *Vincennes* had effectively discriminated against attack aircraft from numerous other air contacts to include normal air traffic and U.S. Air Force air-to-air missile participants in the area of Clark Air Force Base and Crow Valley, Republic of the Philippines. (Fogarty, 1988, pp. 18-19; Rogers, 1992)

TABLE II-3

TRAINING SUMMARY ABOARD *VINCENNES*

TYPE OF TRAINING	DATE	REMARKS
Interim Refresher Training	26 Oct-5 Nov 87	Found fully capable in AAWC or LAAWC in battle group operations
FLEETEX 88-1	1-12 Feb 88	Training included anti-Silkworm and terrorist aircraft training, terrorist small boat defense and anti-swimmer defense training during a simulated escort mission
FLEETEX 88-2	8-19 Apr 88	Not completed. Training included WASEXs, Silkworm missile attacks, ROE, and fast patrol boat attack simulations
Subic Bay Training Period	9-12 May 88	Training included a WASEX, CIWS tracking and firing, Silkworm profiles, anti-intercept controlling, anti-fast patrol boat exercises (night and day), surface gunnery, and surface to air gunnery
WASEX	9-10 May 88	Discriminated threat aircraft from other air contacts
Aegis Training Center Briefs	11 May 88	Received lessons learned briefs on SPY-1A radar operations
ROEX	6-20 May 88	Tested interpretation and correct response to current ROE for MEF
JTFME CVBG Familiarization	21-24 May 88	Training included a WASEX, Silkworm profiles, surface capability and aircraft training

Source: Fogarty, 1988, pp. 18-19

Finally, on 20 May 1988, the *Vincennes* transferred to the operational control (inchopped) of CJTFME. Again, a self-assessment was conducted regarding training and readiness. A C-1 rating was achieved in Personnel, Equipment, Training, and Supply, while an M-1 rating was received in AAW, ASW, ASUW, AMW, C3, EW and Mobility. While in the Gulf of Oman, the *Vincennes* participated in JTFME carrier battle group (CVBG) familiarization training from 21-24 May 1988 as shown in the above table. (Fogarty, 1988, p. 19)

In sum, the commanding officer, tactical action officer (TAO) and air coordinator felt well prepared for their assignment in the Persian Gulf (Fogarty, 1988, p. 19).

2. Organization

On 3 July 1988, the *Vincennes*' primary watch organization was comprised of the operator positions as depicted in Table II-4. Also, a schematic of the *Vincennes*' Combat Information Center (CIC) layout is presented in Figure II-3 with key positions labelled to help the reader visualize the location of operator positions in relation to each other: The anti-air warfare coordinator (AAWC), tactical information coordinator (TIC), and the identification supervisor (IDS) were located in what was commonly known as "air alley." (Senate Hearing, 1988, p. 7)

TABLE II-4

WATCH ORGANIZATION

ACRONYM	TITLE
CO	Commanding Officer
XO	Executive Officer
TAO	Tactical Action Officer
OSDA	Own Ship Display Assistant
GW	Golf Whiskey
CIC Officer	Combat Information Officer
IAD Talker	International Air Distress Talker
CSC	Combat System Coordinator
TIC	Tactical Information Coordinator
IDS	Identification Supervisor
SLQ-32	AN/SLQ-32 Operator
EWS	Electronic Warfare Supervisor
MSS	Missile System Supervisor
RSC	Radar System Controller
ARC	Air Radar Controller
AAWC	Anti-Air Warfare Coordinator
ACS	Air Control Supervisor
Source: Fogarty, 1988, p. 21	

During transit and throughout the duration of her tour, the *Vincennes* trained and operated under a modified Composite Warfare Commander (CWC) concept for Persian Gulf operations, for there was no aircraft carrier specifically assigned to the Persian Gulf. She assumed duties as "Golf Whiskey"[9] or the force anti-air warfare coordinator as illustrated in Figure II-4.[10] (Rogers, 1992) In the Persian Gulf, "Golf Bravo," the Commander, Joint Task Force Middle East, was located aboard the USS

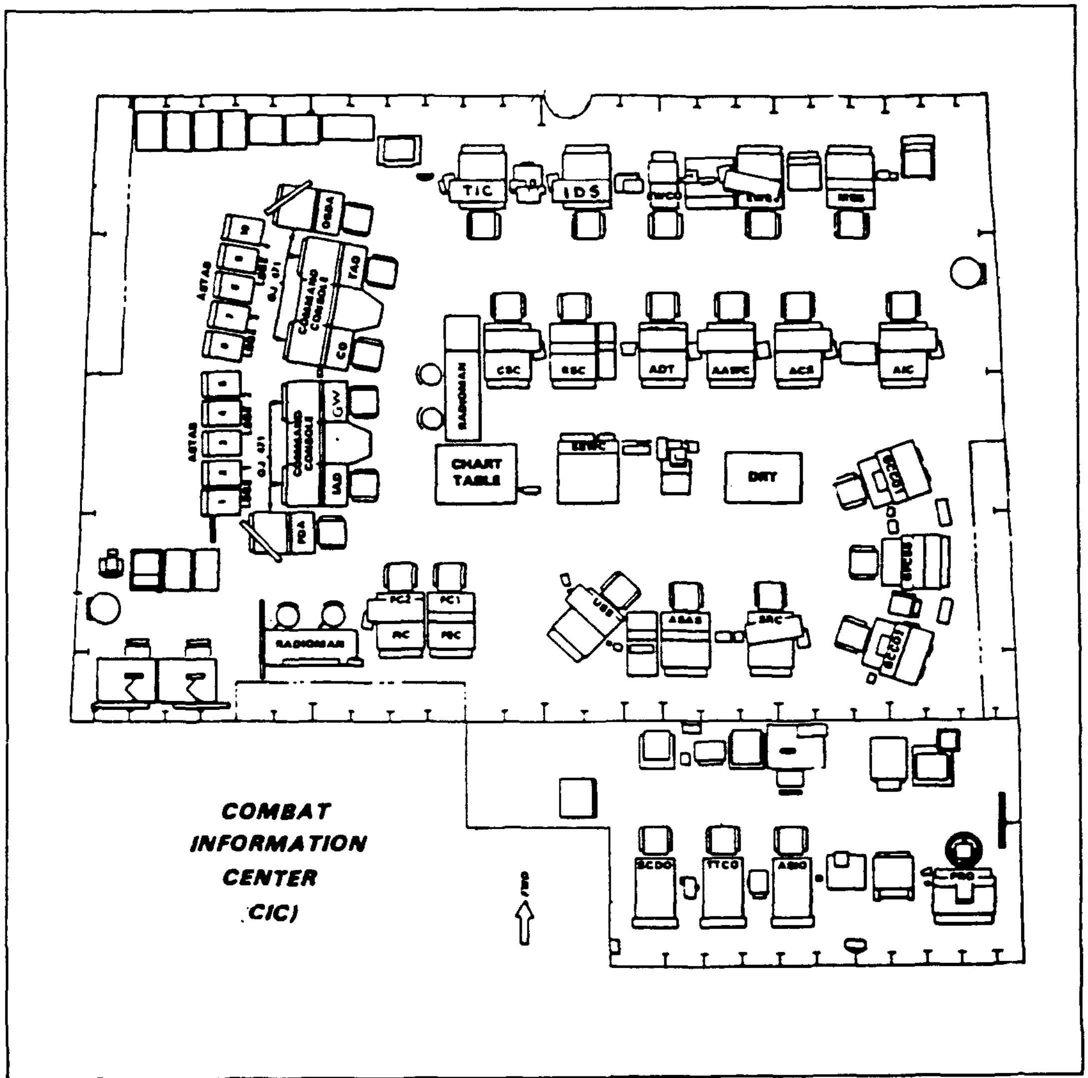


Figure II-3. *Vincennes'* Combat Information Center Schematic

Coronado. The area anti-surface coordinator function, "Golf Sierra," was assigned to the USS *Hancock*, which was responsible for surface activities. The force anti-air warfare coordinator function, "Golf Whiskey," was assigned to the *Vincennes* and was Golf Bravo's principal air advisor as shown in Figure II-4. The *Sides*, *Vincennes*, and *Montgomery* were the primary ships involved with the overall 3 July 1988 scenario. (Rogers, 1992)

Under normal Condition I and III operations,[11] Figure II-5 outlines the *Vincennes*' basic organizational framework where the captain commands by negation. However, during Persian Gulf operations and various other Condition III situations outside the Persian Gulf, the *Vincennes*' command organization adopted the following structure as shown in Figure II-6. (Rogers, 1992) This combat organizational structure essentially involved a watch tactical action officer (TAO) and an anti-air warfare (AAW) TAO set up, in which the AAW TAO was fully TAO-qualified. (Rogers, 1992) Golf Whiskey, or Captain Rogers, delegated air responsibilities to the AAW TAO, and this person acted on the captain's behalf when reporting to Golf Bravo. The AAW TAO's call sign was "Golf Whiskey," the military phonetic alphabet designator for the letters "G W." As considered by the commanding officer aboard the *Vincennes*, "'GW' was his primary force and ship air warfare advisor." (Fogarty, 1988, p. 46) Essentially, the Persian Gulf modifications to the *Vincennes*' CIC organization resulted in the removal of the AAW coordination function from the AAWC to the AAW TAO, leaving the AAWC primarily as a console operator (Fogarty, 1988, p. 46). Although the AAW TAO would run the air picture, he would still defer to the watch TAO for "own ship" concerns. As shown in Figure II-3,

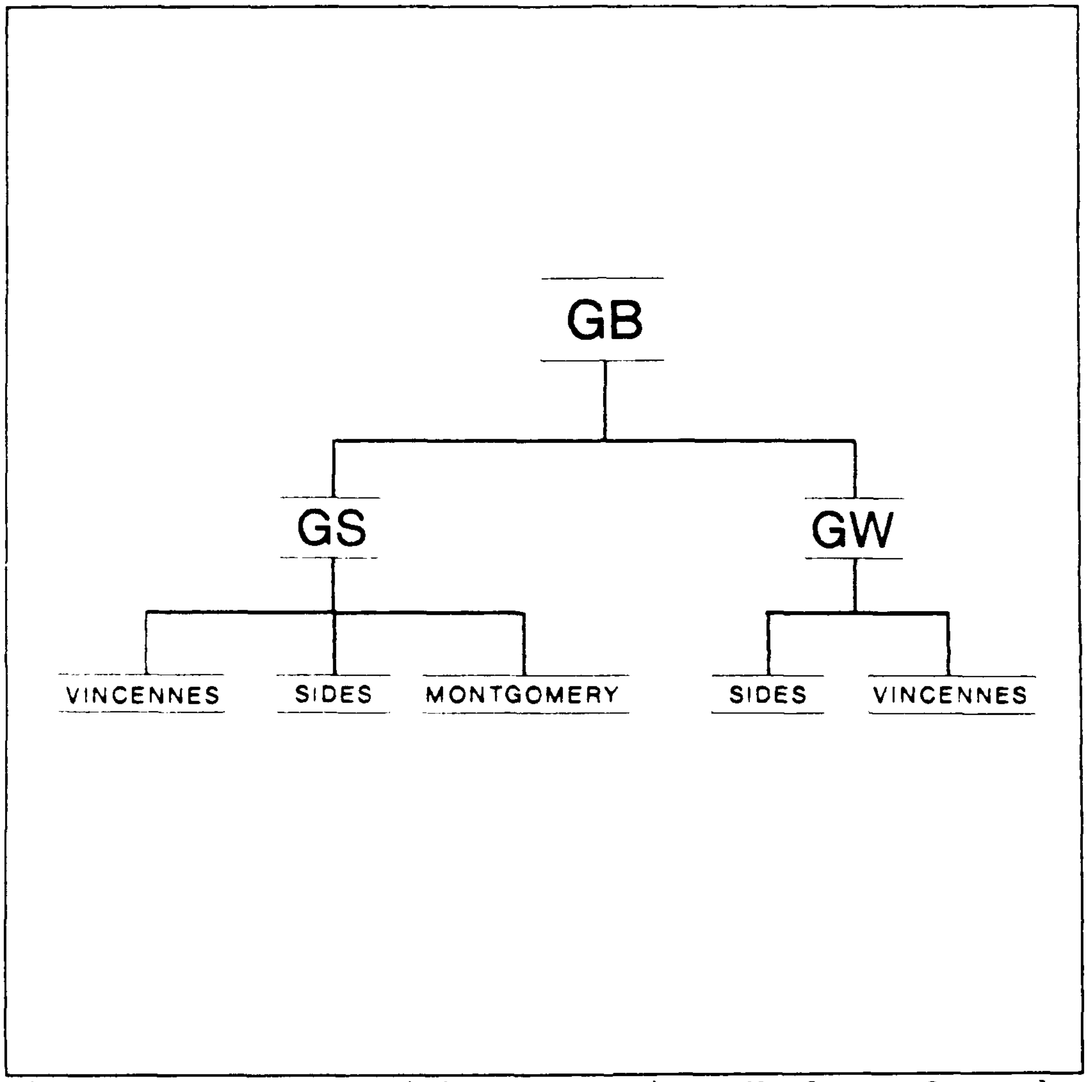


Figure II-4. Modified Composite Warfare Commander Organization Chart for the Persian Gulf--Abbreviated Version

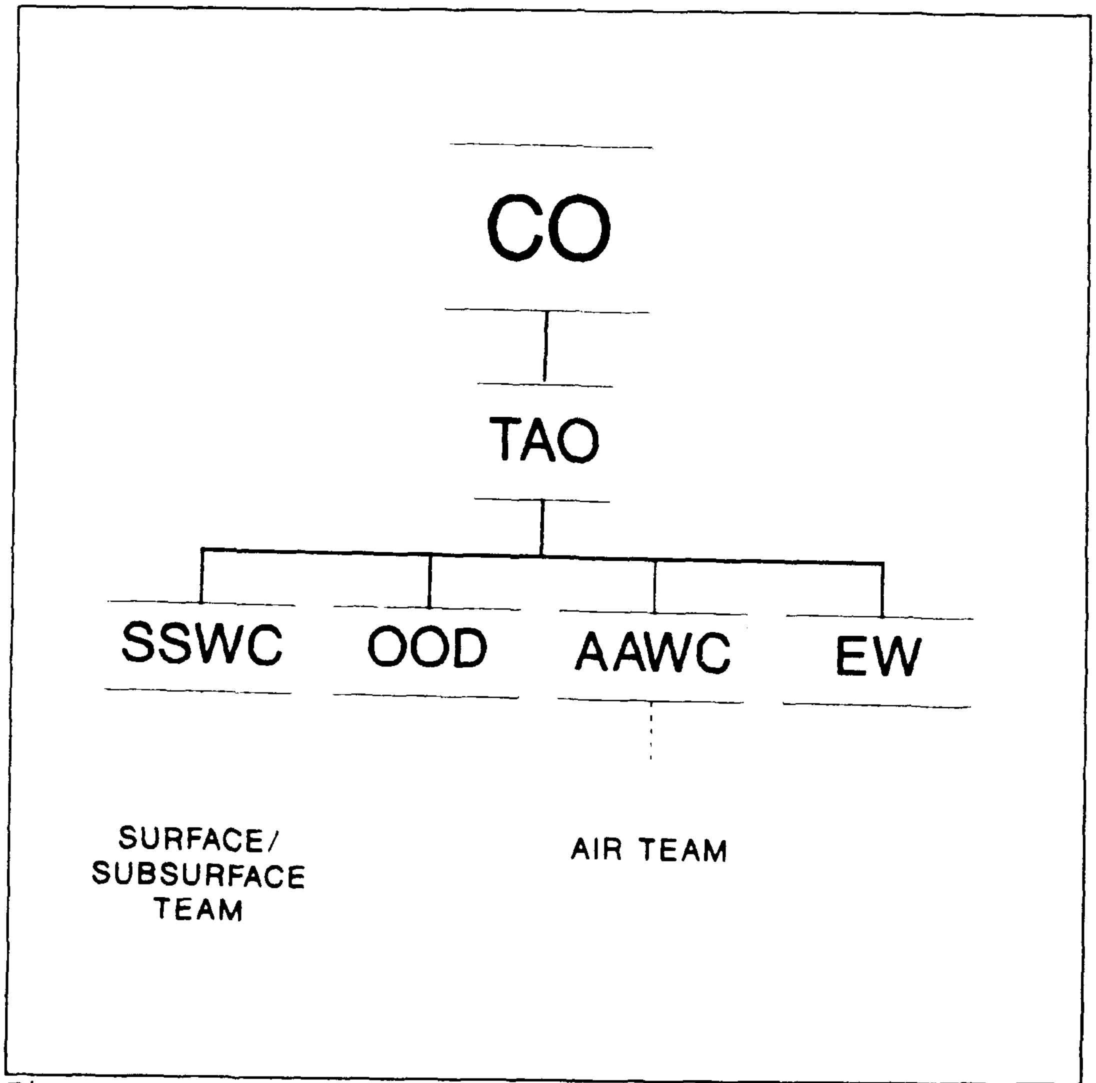


Figure II-5. *Vincennes'* Organization Chart--Abbreviated Version

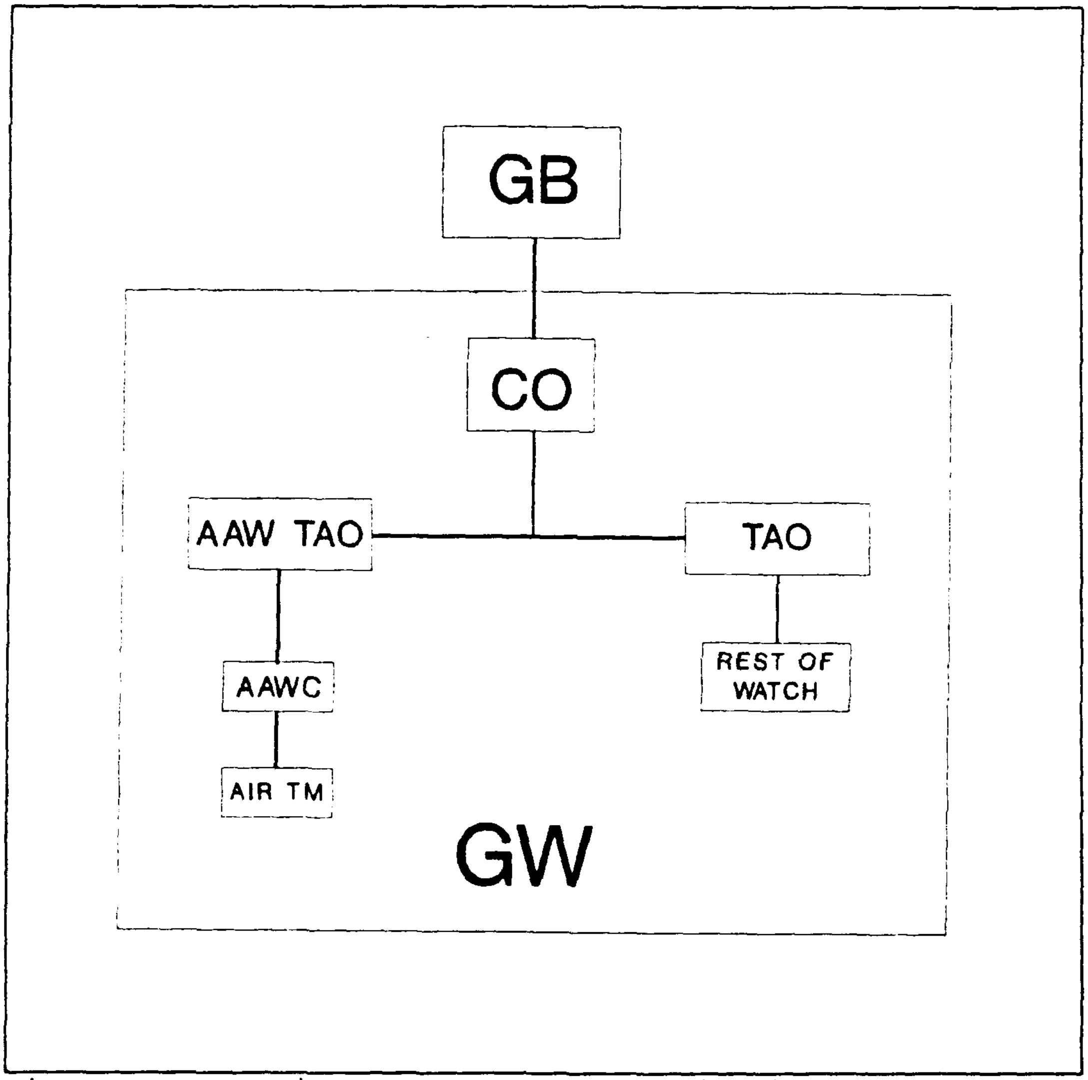


Figure II-6. *Vincennes'* Combat Organization Structure for Persian Gulf Operations--Abbreviated Version the watch TAO was seated to the commanding officer's right, while the AAW TAO labelled in the diagram as "GW" sat directly to the captain's left. (Rogers, 1992; Senate Hearing, 1988, pp. 6-7; and Fogarty, 1988, pp. 20-21)

3. Combat System Status

According to the naval investigation into the incident, the overall combat system status was in order. The Aegis system was working "exceptionally well" with no "serious degradations" or anomalies noted. Equipment preventive maintenance inspections were properly documented and accomplished on time. (Fogarty, 1988, pp. 21-22)

4. Communications

a. Internal

Contrary to the combat systems status, the on-board communications network was not effective. Normally, internal net 15 or 16 was designated for warfare coordinators such as the commanding officer (CO), tactical action officer (TAO), officer of the deck (OOD), surface/subsurface warfare coordinator (SSWC), and the tactical information coordinator (TIC). However, on 3 July 1988, the following Combat Information Center (CIC) operators were also using the net in addition to the designated warfare coordinators: Force warfare coordinator (FWC), identification supervisor (IDS), electronic warfare supervisor (EWS), radar system controller (RSC), situation report officer (SITREP officer), electronic warfare console operator (EWCO), as well as those stations that punched into the net as deemed necessary. The increased load caused static, garbling, and difficulties in hearing people talk due to inadequate volume amplification.

As a result of circuit degradation on 3 July 1988, internal communications had to be shifted between circuits 15 and 16. (Fogarty, 1988, p. 22; Rogers, 1992)

b. *External*

Regarding external communications, an AWACS was flying in the Northern Persian Gulf area on 3 July 1988, but its radar was out of range and was unable to provide link information to augment the *Vincennes'* tactical picture (Fogarty, 1988, p. 24).

5. Rules of Engagement

A copy of the current rules of engagement (ROE) for the Persian Gulf region was available on the *Vincennes* (Fogarty, 1988, p. 13). According to Admiral William J. Crowe, Jr., Chairman of the Joint Chiefs of Staff, the post-*Stark* ROE, under which the *Vincennes* was operating, emphasized the following regarding the commanding officer's primary responsibility:

> As a result of the *Stark* incident, our commanders were given a revised set of ROE which clarified their authority to take positive measures when hostile intent was manifested. It was emphasized that they do not have to be shot at before responding and that they have an unambiguous authority to protect their units and people. (Crowe, 1988, p. 1)

E. SEQUENCE OF EVENTS

1. Environmental Information

On 3 July 1988, the air temperature was a warm 28 degrees Centigrade with a sea temperature of 30 degrees Centigrade. Visibility was estimated at four to eight miles while the ceiling was scattered at 200 feet with heavy dust haze (Rogers, 1 May

1992). Humidity was gaged at 62 percent, and the surface pressure was 998.0 MB. Winds were at ten knots. An evaporation duct of 78.5 feet was also present. Additionally, there was strong evidence as to the presence of a surface duct reaching up to 485 feet, which encompassed the evaporation duct. Because of these ripe conditions for atmospheric ducting, radar detection ranges, when coupled with ducts, were known to be extended.[12] (Fogarty, 1988, p. 13)

2. Events Prior to the Surface Engagement

Intelligence sources warned of aggressive behavior by Iranian aircraft during the first week of July 1988 (Greeley, 1988, p. 21). Three days prior to the *Vincennes* incident, there was heightened air and naval activity in the Persian Gulf:

> Iraq conducted air strikes against Iranian oil facilities and shipping from 30 June through 2 July 1988. Iranian response was to step up ship attacks.... U.S. forces in the Persian Gulf were alerted to the probability of significant military activity resulting from Iranian retaliation for recent Iraqi military successes. (Fogarty, 1988, p. 4)

From the twilight hours of 2 July 1988 to the morning hours of the next day, the Iranian Revolutionary Guard Corps (IRGC) was challenging merchant ships, an established forerunner to merchant ship attacks:

> On the evening of 2 July, a Danish merchant [*Karama Maersk*] in international waters was harassed by Iranian gunboats. The merchant requested distress assistance from the United States, and the frigate *Montgomery* responded and fired a warning shot to stop their aggressive behavior.
>
> Only hours later, during the early morning of 3 July, a Pakistani merchant was also harassed...[and] issued a distress call. Soon thereafter there were explosions heard in the vicinity of a Liberian merchant, where numerous Iranian gunboats were gathered.... Later that morning, a third neutral merchant, this time a West German ship, was being closely tracked by two Iranian gunboats. (Senate Hearing, 1988, p. 9)

Prior to the surface engagement, there were three U.S. naval ships in the Strait of Hormuz region: USS *Vincennes*, USS *Elmer Montomery*, and USS *Sides*. At 0940L, the *Sides* was located 18 NM northeast of the *Vincennes* while the *Montgomery* was located five NM to the west of the *Vincennes* as shown by Figure II-7. In the meantime, the USS *Forrestal* (not shown) was in the Gulf of Oman. (Fogarty, 1988, pp. 23-24)

At 0942L, the Persian Gulf Surface Warfare Commander aboard the USS *Hancock* known as "Golf Sierra," directed the *Vincennes* to proceed north and investigate a report by the USS *Elmer Montgomery* of Iranian aggression towards a merchant ship. The *Montgomery* observed a total of 13 Iranian gunboats breaking into three groups, comprising three to four boats per group. Already on a routine morning patrol, the *Vincennes'* Light Airborne Multipurpose System Mark III helicopter (LAMPS MK III), or OCEAN LORD 25, was vectored north to investigate the Iranian activity. At approximately 0945L, the helicopter received small arms fire from one of the gunboats. As authorized by Golf Sierra, the *Vincennes* took tactical control of the *Montgomery* and both ships proceeded at high speed toward the returning helicopter. Seven of the Iranian gunboats were observed turning towards the U.S. ships. This closing action was interpreted as a demonstration of hostile intent. Consequently, Captain Will Rogers, III, Commanding Officer of the *Vincennes*, requested and then received permission from CJTFME to engage the small boats with gunfire. At about 1013L, the *Vincennes* and *Montgomery* opened fire on closing Iranian small boats which had split into two groups of four and three boats each and included the boats that had fired upon OCEAN LORD

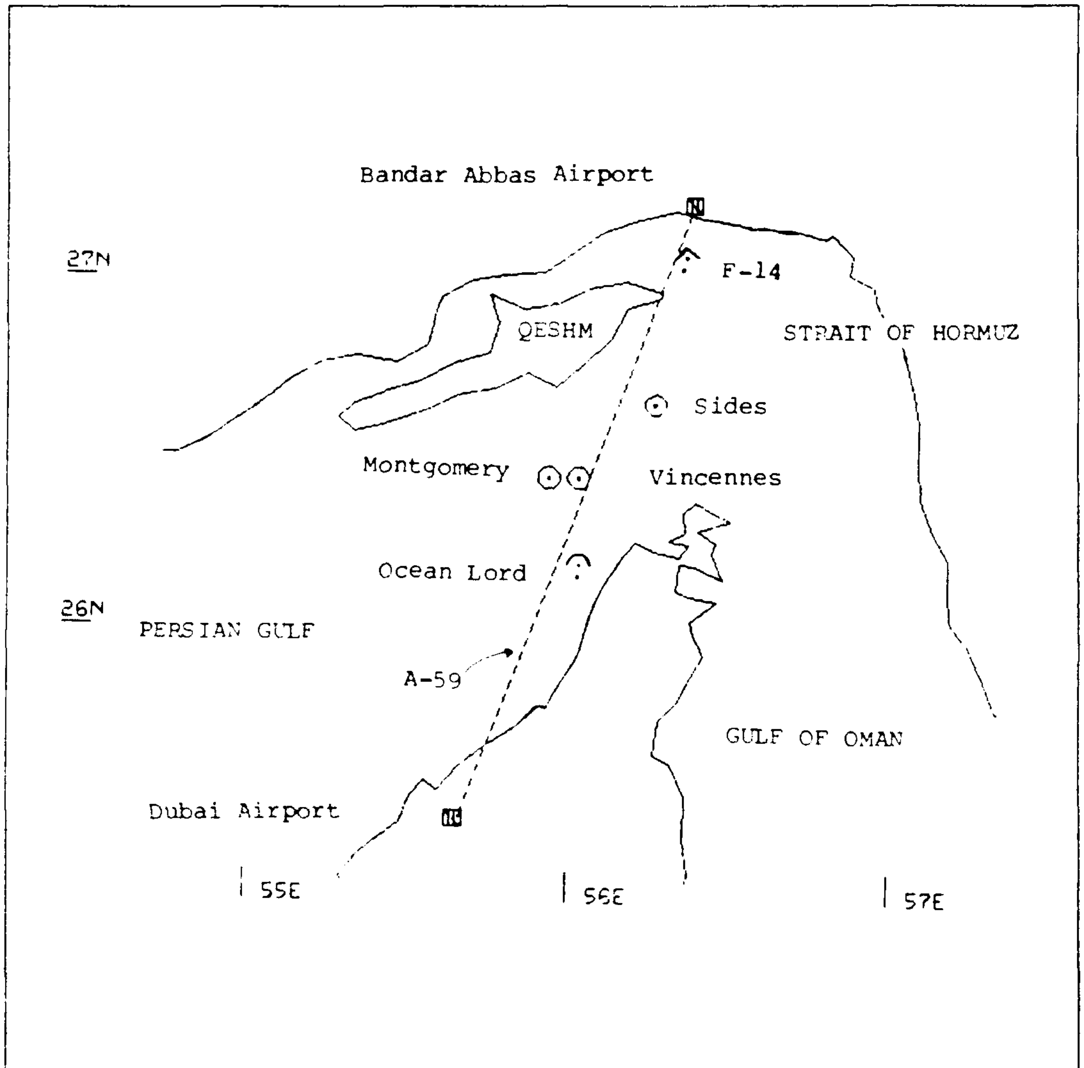


Figure II-7. Location of *Vincennes, Montgomery,* and *Sides* in Relation to Each Other in the Persian Gulf (not to scale)

25. The ships became immersed in a surface engagement with the Iranians. (Fogarty, 1988, pp. 5 and 24-25) See Figure II-8 showing the surface engagement time line in relation to the air engagement.

3. Surface Engagement

As shown in Figure II-8, the overall surface engagement lasted about 20 minutes, starting from 1013L and ending at 1033L. Both the *Vincennes* and the *Montgomery* exchanged gun fire with the IRGC boats, expending a total of 72 and 47 rounds of 5"/54 ammunition respectively (Fogarty, 1988, pp. 25-27).

Experience indicated that engagements with small gunboats were dangerous, because they were highly maneuverable and fast. IRGC small boat tactics presented the greatest threat to personnel and equipment due to their ability to make high speed massed attacks on their targets, raking the ships' superstructure with gunfire. (Fogarty, 1988, p. 27)

In the midst of the surface engagement, Iran Air Flight 655 took off from the joint civilian/military airport at Bandar Abbas at about 1017L after a 27 minute delay from its regularly scheduled departure time as depicted in Table II-5. The flight was directed by the Bandar Abbas air traffic control tower to "squawk" or emit IFF Mode III, code 6760. However, during the course of Flight 655's seven minute flight, the Bandar Abbas tower failed to relay the IAD warnings issued by the *Vincennes* to Flight 655 and also allowed it to fly a relatively low altitude air route in close proximity to hostilities that had been transpiring for several hours (Fogarty, 1988, p. 42). Flight 655 began its normal climb out to an assigned altitude of 14,000 feet following air corridor Amber-59

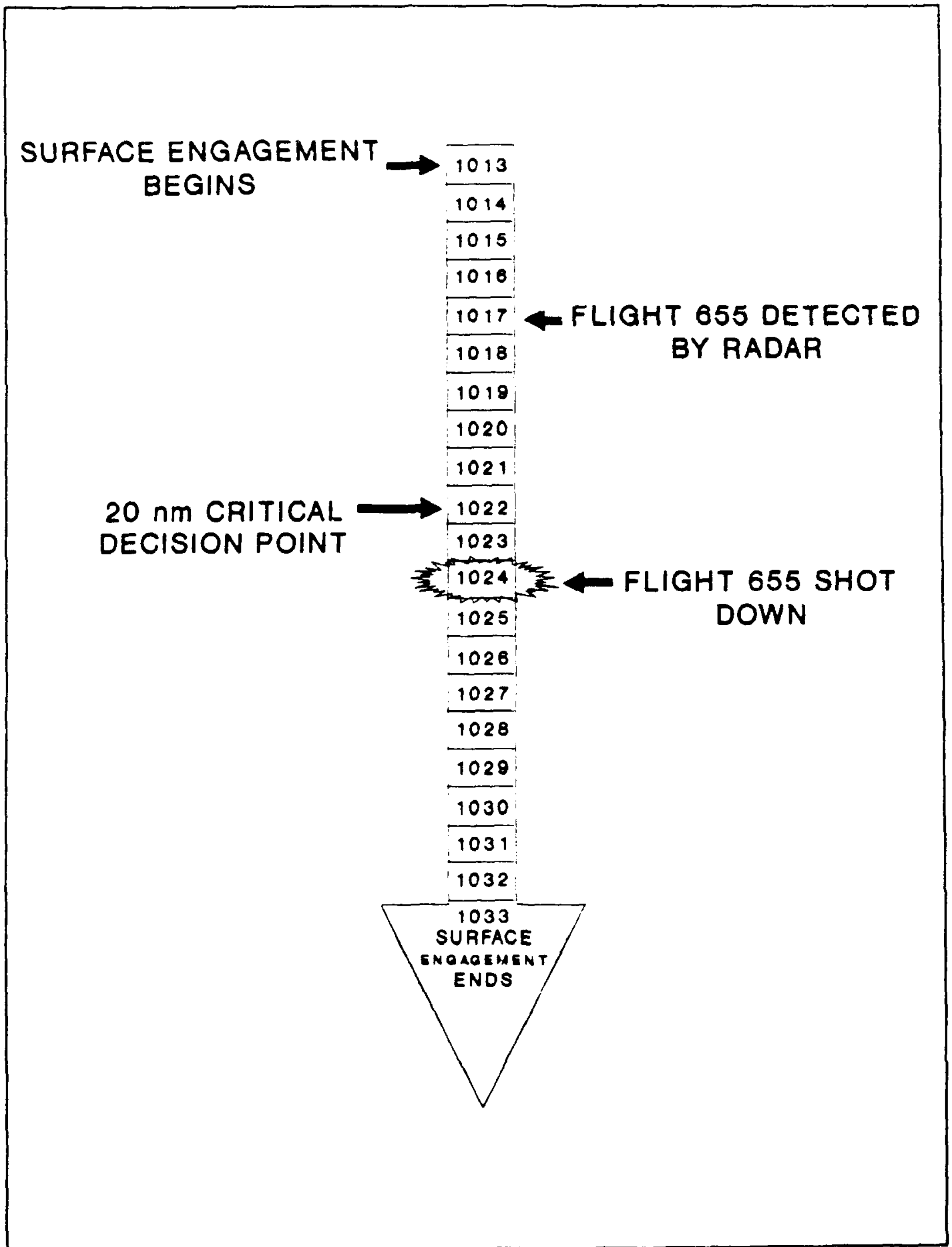


Figure II-8. Time Line of Air Engagement in Relation to the Surface Engagement

(A-59), which had a width of 20 NM and a center line at ten NM. The total length of the air route was 123 NM. Flight 655 remained within the airway squawking Mode III-6760 and made a route position report to Bandar Abbas departure control at approximately 1024L. The flight was ascending through 12,000 feet and was traveling at 380 knots (KTS) at the time of the position report radio call.

TABLE II-5

BANDAR ABBAS FLIGHT SCHEDULE FOR SUNDAY, 3 JULY 1988

FLT #	TO	DEPT TIME	ACFT TYPE
IR 655	Dubai	0950L	Airbus 300
IR 236	Bandarlengeh	1240L	737
IR 236	Shiraz	1240L	737
IR 236	Tehran	1240L	737
IR 452	Tehran	1340L	Airbus 300
IR 394	Isfahan	1400L	737
IR 394	Tehran	1400L	737
IR 134	Shiraz	2050L	737
IR 134	Tehran	2050L	737
IR 458	Tehran	2245L	Airbus 300

Source: Fogarty, 1988, p. 15

While immersed in the surface battle, the *Vincennes* suffered a foul bore on mount 51, in which a round of ammunition was chambered, but could not be fired. This equipment casualty occurred about 1020L. The foul bore necessitated the tactical action officer (TAO) to employ radical maneuvering, using 30 degrees rudder at 30 KTS ship's speed, in order to keep gun mount 52 pointed at the most threatening of the surface contacts. This high speed, large rudder angle turn caused books, publications and loose equipment to fall from desks and consoles in CIC. (Fogarty, 1988, p. 26)

A minute later at 1021L, the *Vincennes* was ordered to take tactical control of the USS *Sides* by Golf Sierra, (the area anti-surface warfare coordinator). Thirteen minutes later at approximately 1033L, the *Vincennes* and *Montgomery* "disengaged" when the remaining small boats turned away, no longer presenting a threat to U.S. warships. (Fogarty, 1988, pp. 26-27)

4. Air Engagement

The air engagement time sequence lasted seven minutes and eight seconds, from 1017L, when the Airbus was detected, until 1024L, when the contact was shot down by missiles from the *Vincennes* at an altitude of 13,500 feet, 3.35 NM to the west of the air corridor's centerline. (Fogarty, 1988, pp. 6, 14-17) Figure II-9 depicts the geographical location of Flight 655's debris. During this time, the *Vincennes* was actively involved in the surface skirmish with the IRGC boats, and the *Montgomery* was still under her tactical control. To simplify the complicated sequence of events during the air engagement, Tables II-6 through II-12 and accompanying narrative will outline the chronological sequence of the air engagement.

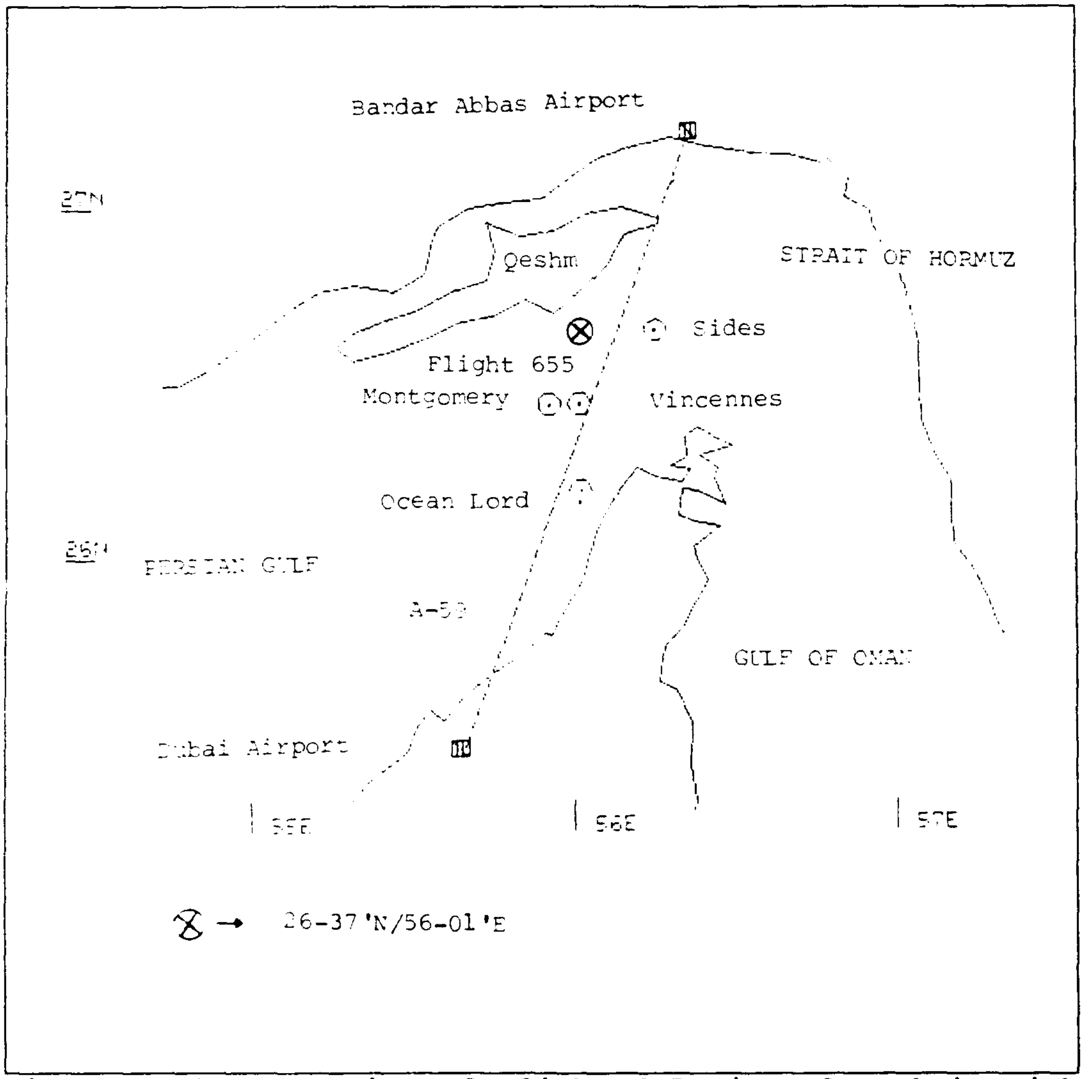


Figure II-9. Location of Flight 655 Aircraft Debris with Respect to Other Ships in the Area (not to scale)

TABLE II-6

AIR ENGAGEMENT SEQUENCE -- 1017L

EVENTS
P-3 62 NM west of *Vincennes*
SPY-1 radar detected Flt 655 BRG 025, RNG 47 NM at 900 ft
IDS broke Mode III as 6675 (C & D held 6760)
Announcement of F-14 heard by at least two watchstanders on internal net 15/16
ADT stated unidentified aircraft (Flt 655) was squawking Modes II and III
Source: Senate Hearing, 1988, p. 10

At 1017L, Iran Air Flight 655 departed the Bandar Abbas joint military/civilian airport. The *Vincennes'* SPY-1 radar detected Flight 655 at a bearing of 025 degrees true from the *Vincennes* at a range of 47 NM. In the meantime, an Iranian P-3, which was approaching the *Vincennes* from the west, was being closely monitored. The identification supervisor, IDS, saw an IFF Mode III squawk of 6675 as the aircraft departed the airport, while the Aegis system saw an IFF Mode III squawk of 6760. The SPS-49 air detect tracker, 49-ADT, saw both a Mode II and III squawk from Flight 655. It was at this time Identification Supervisor (IDS) reported over the internal net 15/16 that the approaching aircraft was an F-14. At least two other Combat Information Center (CIC) members heard this report over the net.

Flight 655 was also reported by the *Vincennes* over Link 11 as track number 4474 (TN 4474), while the *Sides* saw the same contact on her radar and identified it as TN 4131 over the link. (Senate Hearing, 1988, p. 10; Fogarty, 1988, pp. 29-30)

TABLE II-7

AIR ENGAGEMENT SEQUENCE -- 1018L

EVENTS
IDS reviewed commercial air schedule
Flt 655 BRG 025, RNG 44 NM, CSE 202, SPD 232, ALT 2500 ft by SPY-1 radar
Sides illuminated Flt 655 with fire control radar
Source: Senate Hearing, 1988, p. 10

A minute later at 1018L, the identification supervisor was consulting the commercial air schedule at his station. Because Flight 655 was 27 minutes late, he concluded that the contact of interest was not Flight 655. Meanwhile, the Aegis radar indicated that Flight 655 was on a constant bearing of 025 degrees true and at an altitude of 2,500 feet. Also, the tactical information coordinator, TIC, noted TN 4474 changed to TN 4131. (Senate Hearing, 1988, p. 10; Fogarty, 1988, p. 31.)

In the midst of this activity, the *Vincennes* challenged the Iranian P-3 over both the Military Air Distress (MAD) and International Air Distress (IAD) channels. The P-3 replied that he was on a search mission and would stand clear of the *Vincennes*. Concurrently, the tactical information coordinator recalled seeing Mode I and Mode II on the P-3, which was TN 4472. (Fogarty, 1988, p. 30)

The tactical action officer (TAO) aboard the *Sides*, which was 18 NM northeast of the *Vincennes*, directed his weapons control officer, WCO, to illuminate the contact with his fire control radar (Senate Hearing, 1988, p. 10). While the *Sides* was able to observe TN 4131 along with the *Vincennes*, the *Montgomery* never gained radar contact on TN 4131 (Fogarty, 1988, 30-31).

At 1019L, the anti-air warfare coordinator, AAWC, ordered TN 4131 be challenged over the MAD. The following MAD warning message was issued:

> 'Unidentified Iranian aircraft on course 203, speed 303, altitude 4000, this is U.S. naval warship, bearing 205, 40 miles from you. You are approaching U.S. naval warship operating in international waters. Request you state your intentions.' (Fogarty, 1988, p. 31)

At 1020L, the *Vincennes* issued the first of several IAD warnings to TN 4131:

> 'Unknown aircraft on course 206, speed 316 position 2702N/0561E, you are approaching U.S. naval warship, request you remain clear.' (Fogarty, 1988, p. 31)

TABLE II-8

AIR ENGAGEMENT SEQUENCE -- 1020L

EVENTS
Vincennes issued first warning on IAD to Flt 655
IDS saw Mode II 1100 on his RCI and reported possible F-14 over internal net 15/16 to all stations
Several people heard the F-14 call
GW reported inbound F-14 to GB BRG 025, RNG 32 NM
GW told GB that a warning was issued and ignored
OSDA tagged Flt 655 as F-14 on large screen displays in front of the CO, TAO, and GW
Source: Senate Hearing, 1988, p. 10

It was at 1020L that the air engagement decision process began. The identification supervisor, IDS, saw an IFF Mode II squawk of 1100 on his remote control indicator (RCI) and reported possible F-14 to all stations over internal net 15/16. Several CIC members heard the approaching aircraft identified as an F-14. The own ship display assistant, OSDA, having heard that the contact was identified as an F-14, tagged Flight 655 with an F-14 label on the screens in front of the commanding officer (CO), tactical action officer (TAO), and Golf Whiskey or the AAW TAO. (Senate Hearing, 1988, p. 11; Fogarty, 1988, p. 32)

The AAW TAO, "Golf Whiskey," proceeded to inform higher headquarters of this development. Here, the AAW TAO, who was the officer sitting next to the commanding officer and charged with overseeing the air picture, informed Golf Bravo (the call sign for Commander, Joint Task Force Middle East) that an F-14 was approaching the *Vincennes* at a bearing of 025 degrees and range of 32 NM. During this radio transmission, he told Golf Bravo that a warning was already issued to TN 4131 and that there was no response from the contact. (Senate Hearing, 1988, p. 11; Fogarty, 1988, p. 32)

Also, at 1020L, there were various accounts of Modes II and III having been seen by several watchstanders (IDS, AIC-3, AAWC and TIC); however, the *Vincennes'* system still held no IFF Mode II, only Mode III-6760 for TN 4131 (Fogarty, 1988, p. 32).

Additionally, Golf Sierra, who was aboard the USS *Hancock*, the area anti-surface warfare coordinator, ordered the *Vincennes* to take tactical control of the *Sides*. The *Montgomery* was already under the *Vincennes'* tactical control. (Fogarty, 1988, p. 32)

TABLE II-9

AIR ENGAGEMENT SEQUENCE -- 1021L

EVENTS
GW told GB his intention to engage F-14 at 20 NM
GB told GW to issue warning before engaging
AAWC directed continuous warnings (one MAD and one IAD warning issued)
Flt 655 BRG 025, RNG 30 NM, CSE 207, SPD 350, ALT 7000 ft by SPY-1 radar
CO acknowledged CICO's report that approaching aircraft was a possible commercial aircraft
Source: Senate Hearing, 1988, p. 11

As indicated earlier, Golf Whiskey or the AAW TAO informed Golf Bravo that the contact was identified as an Iranian F-14. However, Golf Bravo could not verify this information on TN 4131 due to time constraints. At 1021L, Golf Whiskey stated his intentions of engaging TN 4131 at 20 NM unless it turned away. He requested Golf Bravo's concurrence. Golf Bravo approved the request with one stipulation: The *Vincennes* must warn the aircraft first before firing. (Fogarty, 1988, p. 33)

A series of continuous warnings began. There was no response from Flight 655 as it remained on a constant bearing, now at 31 NM at 350 KTS climbing through an altitude of 7,000 feet. (Senate Hearing, 1988, p. 11; Fogarty, 1988, pp. 33-34)

Towards the end of this minute, "the combat information officer told the commanding officer that the approaching aircraft was possibly a commercial airliner," a comment acknowledged by the commanding officer (Senate Hearing, 1988, p. 11).

TABLE II-10

AIR ENGAGEMENT SEQUENCE -- 1022L

EVENTS
Radio warnings issued
Attempts to illuminate Flt 655 with fire control radar began
The "contact" was observed to be descending by various CIC members
Flt 655 at 9000 ft and ascending by SPY-1 radar
Source: Senate Hearing, 1988, p. 11

At 1022L, two minutes prior to firing, the *Vincennes* continued to issue warnings over both IAD and MAD channels. Still no response. The AAWC console operator attempted to illuminate the aircraft with fire control radar; however, due to a procedural error, the contact could not be illuminated until the actual time of engagement. (Senate Hearing, 1988, p. 11) The commanding officer inquired as to the status of TN 4474, not realizing that the track number had changed. The contact of interest had arrived at the critical 20 NM decision point, and an unidentified console operator reported the contact was descending from 12,000 feet at 459 KTS. (Rogers, 1992) Also during this minute, the first reports of descending altitude occurred. The air detect tracker, 49-ADT, observed an IFF Mode II appear on his remote control indicator, not on his character read out, which occurred at about the 20 NM point. He also noticed that the contact was descending in altitude. (Fogarty, 1988, p. 35) In addition, the identification supervisor and tactical information coordinator saw that the contact was descending and said it aloud over the net. Meanwhile, the Aegis system showed that an unidentified crew member manning the watch console of FC-1 "hooked" TN 4474 for five seconds, showing a range of 110 NM, a bearing of 139 degrees, altitude of 11,900 feet and speed of 448 KTS. It was not clear that this information was conveyed over the net. However, Flight 655 had been and always was ascending. (Senate Hearing, 1988, p. 11; Fogarty, 1988, p. 34)

Contrary to what was being seen in the *Vincennes'* CIC, the tactical action officer (TAO) on the *Sides* noticed that TN 4131 continued to ascend to 11,000 feet as it reached closest point of approach (CPA). Also, there was growing excitement and yelling in the *Sides'* CIC about the contact being a commercial aircraft. According to Captain Rogers, "When an attempt by the *Sides'* air tracker to get the TAO's attention was made, he was told to 'Shut up, you're making too much noise.'" (Rogers, 1 May 1992) The TAO on the *Sides* looked at the weapon control officer's IFF box, which read in the Mode III, 6700 block, indicating commercial air. The contact was at 11,000 feet and about 15 NM on a course paralleling the *Sides*. Meanwhile the commanding officer of the *Sides* evaluated the contact "as a non-threat based on CPA to USS *Sides*, F-14 ASUW capability, lack of ESM and precedent. He noted an altitude of 11,000 feet and shifted his attention to the P-3 to the west." (Fogarty, 1988, p. 36) This evaluation was not passed to the *Vincennes* (Rogers, 1 May 1992).

TABLE II-11

AIR ENGAGEMENT SEQUENCE -- 1023L

EVENTS
No radar emissions detected from Flt 655
Flt 655 BRG 018, RNG 16 NM, SPD 371 KTS, ALT 11230 ft by SPY-1 radar
TIC began to update range of Flt 655 at every open spot on internal net 15/16
By SPY-1 radar, Flt 655 RNG 14 NM, ALT 12000 ft, SPD 382 KTS
Source: Senate Hearing, 1988, p. 11

At 1023L, the contact was within the 20 NM critical decision point. The commanding officer of the *Vincennes* continued to hold his fire while searching for any kind of electronic emission that might help identify the "unknown-assumed hostile" contact that was steadily closing in range. Flight 655 was at 16 NM, bearing 018 degrees, and climbing through an altitude of 11,000 feet at 371 KTS. (Senate Hearing, 1988, p. 12)

Concerned that the aircraft continued to close despite repeated warnings, the tactical information coordinator, TIC, began to update the aircraft's range at every opportunity on the internal net 15/16. (Senate Hearing, 1988, p. 12; Fogarty, 1988, p. 36) In reality, at 14 NM from the *Vincennes*, Flight 655 was climbing through 12,000 feet at a speed of 382 KTS a minute prior to missile impact. However, the international air distress operator (IAD) recalled the contact being at a height of 7,700 traveling at a speed of 450 KTS. Golf Whiskey or the AAW TAO indicated that he "heard continuous reports of declining altitude." (Fogarty, 1988, p. 36)

TABLE II-12

AIR ENGAGEMENT SEQUENCE -- 1024L

EVENTS
IDS observed Flt 655 at 7800 ft at 455 KTS descending
Spy-1 radar held Flt 655 at 12000 ft ascending at 380 KTS
Firing key turned
AAWC recalled altitude of 6000-7000 ft
14 seconds after firing key was turned, MSS started launch sequence
Three seconds later the first missile was launched followed by the second missile
Two missiles intercepted Flt 655 BRG 001, RNG 8 NM at 13500 ft at 383 KTS
Source: Senate Hearing, 1988, p. 12

At the beginning of this minute, (1024) the *Vincennes*' system data indicated TN 4131 was at a range of 12 NM, speed of 380 knots, and was climbing through an altitude of 12,000 feet. The identification supervisor, IDS, observed TN 4131 at 445 KTS and descending at 7,800 feet. (Senate Hearing, 1988, 12; Fogarty, 1988, p. 37)

The commanding officer turned the firing key, initiating the Standard missile launch sequence. The anti-air warfare coordinator, AAWC, recalled seeing an altitude of 6,000-7,000 feet at engagement, while the air intercept coordinator, AIC-3, recalled TN 4131 at an altitude of 7,000-8,000 feet at missile launch. Meanwhile, the international air distress operator, IAD, was in the process of issuing another challenge over the IAD when the missiles were launched. By the end of this minute, both missiles struck the aircraft, eight NM from the *Vincennes* at 13,500 feet. (Senate Hearing, 1988, p. 12; Fogarty, 1988, p. 38)

NOTES

1. The mechanics for citing references is in accordance with the Naval Postgraduate School Thesis Manual and is as follows: If a cited reference, (author, date, page), refers to only the sentence, the period comes after the cited reference. If the cite refers to the paragraph, the cited reference is placed after the period. If the cite follows material in quotes, the cited reference follows the period and closing quotation mark.

2. Tables II-1 & 2 were found in "Gulf Ops," by Ronald O'Rourke in the U.S. Naval Institute Proceedings, Naval Review 1989 edition, page 43. O'Rourke's sources included The Washington Post, 13 October 1987, p. 12, The New York Times, 10 January 1988, p. E3, and the Center for Defense Information, 6 July 1988 and 13 January 1989. In Table II-2, separate figures for July and August were not available. Also, the Iran-Iraq War lasted nearly eight years, starting in 1980, and on 20 August 1988, a United Nations sponsored cease fire went into effect. (O'Rourke, 1989, p. 42)

3. Operation PRAYING MANTIS was the largest battle fought at sea since World War II. PRAYING MANTIS' significance was that it showed that the Standard missile can be used in a surface-to-surface engagement as a "quick-draw, supersonic, anti-ship missile" and verified the reliability and effectiveness of several other modern weapon systems. (O'Rourke, 1989, p. 44) For more information regarding air and surface engagements during Operation PRAYING MANTIS, see "Operation PRAYING MANTIS," U.S. Naval Institute Proceedings, May 1989, pp. 54-70.

4. Carlucci made the following announcement:

> Aid will be provided to friendly, innocent, neutral vessels flying a non-belligerent flag outside declared war-exclusion zones that are not carrying contraband or resisting legitimate visit and search by a Gulf belligerent. Following a request from a vessel under attack, assistance will be rendered by a U.S. warship or aircraft if this unit is in the vicinity and its mission permits rendering such assistance. (O'Rourke, 1989, p. 47)

5. Also, commercial aircraft usually did not carry radar homing and warning (RHAW) equipment, which meant that civilian aircraft would be unaware and could not reply if locked on by a fire control radar aboard a military platform. (Fogarty, 1988, p. 16)

6. In general, IFF systems consist of interrogator and transponder equipment, which are used to determine the identity of a radar contact. Upon interrogation by a coded signal, an aircraft's transponder will electronically respond with a particular mode and code, such as Mode III-XXXX. The four digit number after the mode is merely a numeric code of numbers further identifying the aircraft. Normally, this information is filed on a flight

plan and processed through air traffic control channels prior to the aircraft's departure. Basically, the aircraft can be electronically interrogated by anyone having an IFF system tuned to the appropriate frequency. (Friedman, 1989, p. 73) For simplicity purposes in this case, Mode II will be considered an Iranian military aircraft while a Mode III reply would be considered a commercial aircraft.

7. All times are in local time based on a 24 hour clock. To convert Zulu time to Iranian local time, add three hours and thirty minutes, not four hours, to Zulu time i.e., 0647Z equals 1017L. Tehran is 11 1/2 hours ahead of California time.

8. Evaluations as to exactly how well the *Vincennes* performed in the training exercises were not available. Results were not entirely outlined in the unclassified report of the naval investigation. However, according to an interview with Captain Rogers (U.S. Navy retired) on 8 April 1992, the *Vincennes* received high ratings regarding her performance in preparing for the Persian Gulf mission.

9. The word "gulf" as in the Persian Gulf refers to a body of water. However, in the military phonetic alphabet, which is primarily used for clarity in radio communications when referring to the English alphabet, the phonetic pronunciation for "G" is "golf" and is spelled accordingly. The words "gulf" and "golf" have two separate meanings and are spelled differently. Throughout this thesis, other phonetic alphabet references are made such as:

"GW" -- "G": Golf
"W": Whiskey

"GB" -- "G": Golf
"B": Bravo

"GS" -- "G": Golf
"S": Sierra

"GE" -- "G": Golf
"E": Echo

"AW" -- "A": Alpha
"W": Whiskey

"AS" -- "A": Alpha
"S": Sierra

10. Under the Composite Warfare Commander (CWC) concept of operations involving an aircraft carrier, the Persian Gulf's "Golf Whiskey" was equivalent to an "Alpha Whiskey," who was the air advisor, and "Golf Sierra" was the same as an "Alpha Sierra," the surface advisor. The *Vincennes* was also Golf Echo, or the Electronic Warfare advisor to Golf Bravo as well, but "GE" was not depicted on the Persian Gulf command organization diagram, Figure II-4.

11. There are five condition codes on-board Navy vessels:

> Condition One is General Quarters with all crewmen manning battle stations and all non-combat oriented activities, such as the mess, halted. Condition Two is applied when a ship has been operating at General Quarters for a long period, and it is necessary to take some crewmen off their battle stations in order to provide food or essential repairs. Condition Three puts one-third of the crew at battle stations at all times. It is the normal wartime operating state. Condition Four is used for routine steaming from port to assignment or in untroubled waters. Condition Five applies when a vessel is in port and only partly manned. (Staff Investigation, 1987, p. 12)

12. According to the Siletzky and Campbell Masters Thesis entitled, Comparison of Electromagnetic Propagation Predictions from IREPS and RPO Across a Coastal Transition, the following excerpt and Figures II-10 and II-11 describe ducting:

> Electromagnetic waves are refracted, or bent, as they propagate through the atmosphere. Strong refraction can produce anomalous EM propagation. While refraction occurs at all frequencies, it is particularly important at frequencies from 30 MHz to 30 GHz, which includes the VHF, UHF, and RADAR bands... [where] the majority of RADARs and communication links utilize this portion of the spectrum.... Trapping refers to the refraction of an EM wave for which the wave's radius is less than that of the radius of the curvature of the earth. The EM wave is then refracted back towards the surface of the earth; if it is then reflected off the surface, it will again be refracted back to the earth. This produces ducting, which is the channelling of radio or RADAR waves. The EM energy is thus confined to a vertical region, instead of spreading normally.(1992, pp. 5 and 7)

As shown in the following figures, ducting can be categorized into three basic types: Evaporation, surface, and elevated duct with various duct thicknesses (1992, p. 10).

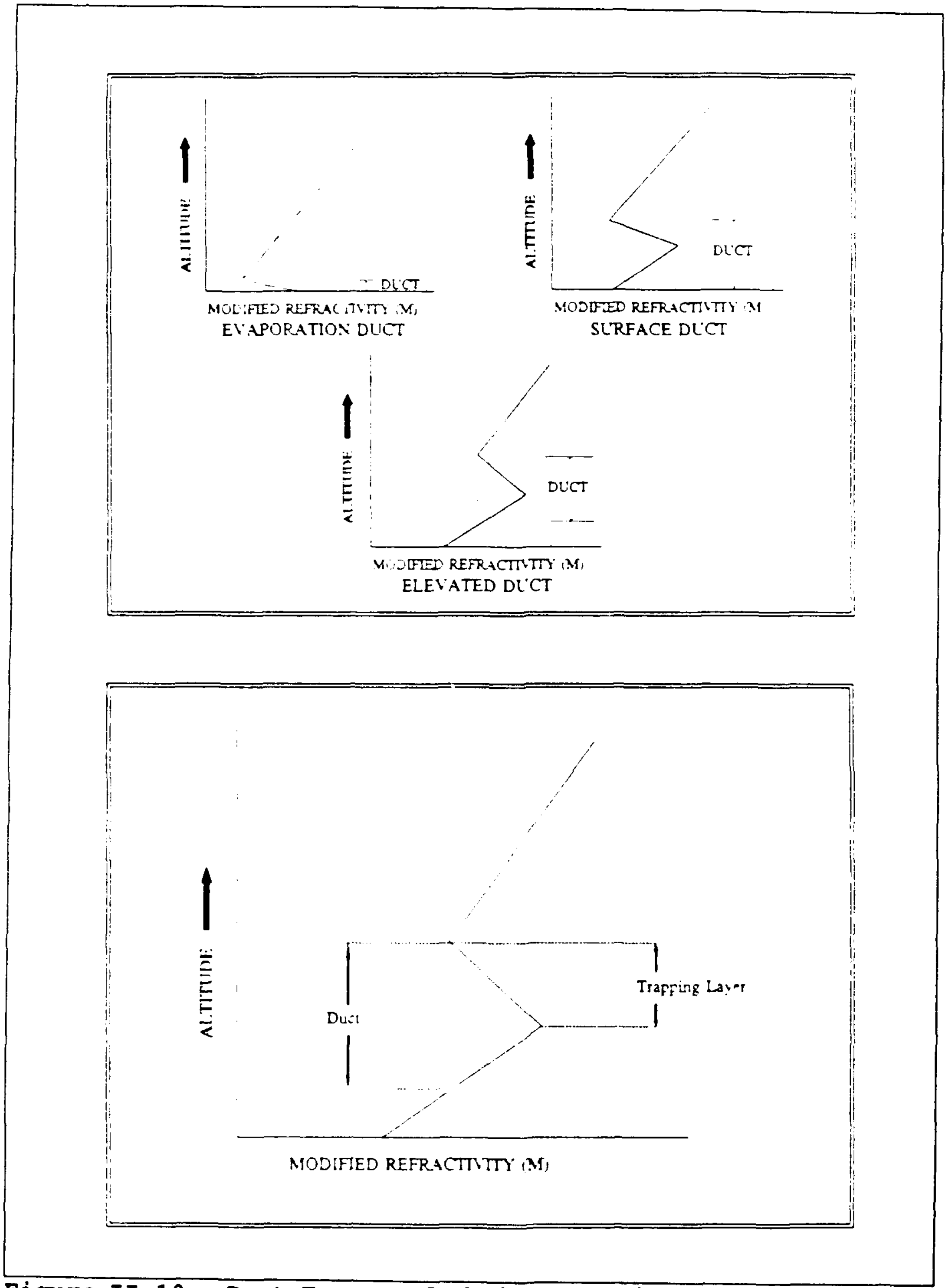


Figure II-10. Duct Types and Their Determination of Thickness (Campbell and Siletzky, 1992, pp. 9 and 10)

III. ANALYSIS AND INTERPRETATION

A. ADMIRAL FOGARTY'S ANALYSIS AND INTERPRETATION

By order of General George B. Crist, U.S. Marine Corps, Commander in Chief, U.S. Central Command, Rear Admiral William M. Fogarty, U.S. Navy, Director, Policy and Plans (J-5), U.S. Central Command, was appointed to conduct the formal investigation into the circumstances surrounding the downing of a commercial airliner by the *Vincennes*. Because of the divergence between recorded data on the system tapes and the recollection of the witnesses concerning what they saw and when, Admiral Fogarty requested a psychiatrist and a psychologist from the U.S. Navy Medical Corps to come to Bahrain and augment the seven member investigation team to help "determine whether the dynamics of the situation, which confronted the crew of the USS *Vincennes* impacted on their ability to perceive and relay the data that was available to them." (Fogarty, 1988, pp. 1 and 2)

There were two categories of data that were employed in the Fogarty report pertaining to the air engagement (1988, pp. 28-29):

- System or "actual" data that was extracted from the data tapes of the Aegis Command and Decision (C & D) system;
- Recollected or "perceived" data based on witness recall of events as gathered from witness statements and testimony.

Since there were no voice tape recordings that recorded the crew members' dialogue over the *Vincennes'* internal net 15/16 (Rogers, April 1992), the investigation team had to literally reconstruct the sequence of events based on both the data extracted from the system tapes and witnesses' recollection as to what they "saw" and when they saw it.[1] Because of the short time window involved with the air engagement, both types of information were used by the team to assess what happened and when. (Fogarty, 1988, p. 2)

The findings of the Fogarty report[2] can be summarized as follows:

In general, the *Vincennes* did not intend to shoot down an Iranian commercial airliner, but rather it engaged an aircraft the commanding officer (CO) believed to be hostile and a threat to his ship. "Based on the information used by the CO, the short time frame in which to make his decision, and his personal belief that his ship and the *Montgomery* were being threatened, he acted in a prudent manner." (1988, p. 42) Also, based on the information available to Commander, Joint Task Force Middle East (CJTFME) or "Golf Bravo," his confidence in Captain Rogers and the capabilities of the *Vincennes*, his concurrence to engage TN 4131 was correct. Essentially, the shoot down of Flight 655 was not the result of any negligent or culpable conduct by any Navy personnel. (1988, pp. 42-43)

More specifically, however, time compression played a significant role. From the time the CO first became aware that the contact was a possible threat until he made his decision to engage, the elapsed time was about three minutes and 40 seconds. Most of the CO's time was devoted to the ensuing surface engagement against Iranian gun boats, which left very little time for him to personally verify the information that was being provided to him. (1988, p. 43)

Captain Rogers had great confidence in his Combat Information Center (CIC) team's abilities. The Fogarty investigation also felt that the "fog of war and those human elements which affect each individual differently--not the least of which was the thought of the *Stark* incident--were factors that must be considered." (1988, p. 43)

The Aegis weapon system functioned as designed. Had the CO used the information generated by his Command and Decision (C & D) system[3] as the sole source of his tactical information, he might not have engaged TN 4131. Also, the digital data extracted from the data recording tapes were valid, providing invaluable insights to include the evaluation of individual CIC console operator actions. (1988, p. 43)

According to the investigation team's interpretation, Captain Rogers based his decision to engage TN 4131 on the following: The aircraft took off from a joint military/civilian airfield in Iran, heading directly towards his ship at a relatively low altitude that was lower than what the *Vincennes* observed commercial flights to fly previously. Also, the contact was not flying exactly on the airway center line. Not only did TN 4131 appear to veer towards the *Montgomery* upon fire control radar illumination, but it was reported to be increasing in speed, decreasing in altitude and closing range. These characteristics signified that the aircraft was maneuvering into an attack position. No radar transmission was detected from track 4131, and the aircraft was not responding to verbal warnings over the Military Air Distress (MAD) and International Air Distress (IAD) channels. Personnel aboard the *Vincennes* reported the aircraft to be squawking

Mode II-1100, which was historically correlated to Iranian F-14's. Iranian fighter aircraft had flown coincident with the surface hostilities between U.S. and Iranian forces as demonstrated on 18 April 1988 during Operation PRAYING MANTIS. There were no combat air control aircraft in the area to provide a visual identification. Also, an Iranian P-3 was airborne to the west of the *Vincennes* had turned inbound. Warnings from intelligence cautioned U.S. forces to prepare for increased hostile activity over the 4th of July weekend. Other factors included the *Stark* incident that had occurred a year prior, and the possibility of the aircraft contact being on a suicide mission. And lastly, Iranian F-14s had an air-to-surface weapons capability. (1988, pp. 43-44) Captain Rogers' decision to delay engagement until the aircraft was within 15 NM demonstrated an appreciation for the consequences of his actions, which was balanced with his responsibility to defend his ship. (1988, p. 45)

The *Vincennes* was adequately trained to perform her mission as a unit in the Joint task Force Middle East. She properly applied the rules of engagement (ROE) to both surface and air engagements. With the exception of the AAWC position, the *Vincennes*' Anti-Air Warfare (AAW) watch organization was experienced and qualified. Regarding the rest of the watch organization, "Golf Whiskey" was considered by the CO as his primary force and ship air warfare advisor. The Fogarty investigation team made the following observations:

> The Persian Gulf modifications to the *Vincennes*' CIC organization moved the ship's AAW coordination function away from AAWC and left him acting largely as a console operator. Assignment of 'GW' to Force AAW, Ship AAW, and [deleted] talker for surface and air [Situation Reports] SITREPS degraded his ability

to independently assess the actual profile and [identification] ID of TN 4131. (1988, p. 46)

The ensuing surface engagement was a significant factor that increased the tension within the CIC as well as the foul bore on mount 51. The subsequent high speed maneuvering of the ship to keep Mount 52 in a position to engage the gunboats complicated the situation and prevented the CO from devoting full attention to TN 4131. (1988, p. 47)

The Fogarty team indicated that the information made available to the CO conflicted in some cases with the data available in the Aegis Command and Decision (C & D) system. This conflict involved two areas: The C & D system contained no Mode II IFF information on TN 4131; yet, operators in the CIC used Mode II as a means of declaring TN 4131 as an Iranian F-14. Also, the C & D system showed TN 4131 continuously ascending, while the CO received reports of descending altitude prior to enabling the firing key. (1988, p. 44)

Regarding the air engagement, at no time did Flight 655 descend in altitude prior to engagement. It was on a normal climb-out from Bandar Abbas and was flying within an established air route, albeit 3.37 NM west of the centerline. It was still in the assigned airway, but not exactly on the centerline. Additionally, Flight 655 was not squawking Mode II-1100, but Mode III-6760 during the entire flight. Although IFF codes were not absolute determinants for engagement, Mode III was the least reliable, because all aircraft were capable of squawking Mode III. (1988, p. 47-48) Regarding this IFF issue, the Fogarty investigation concluded the following:

> The IDS mis-correlated a [Remote Control Indicator] RCI readout of Mode II-1100 with TN 4131. This occurred, according to analysis of data, when the IDS hooked TN 4131 as it departed Bandar Abbas and left it hooked for almost 90 seconds. This meant that as the hooked symbol moved toward the USS *Vincennes*, the read-gate for the RCI remained near Bandar Abbas. A Mode II transmission from an aircraft on the ground in Bandar Abbas would then be displayed in his RCI if the signal could get to the ship. The un-correlated IFF Mode II-1100 obtained by IDS could have been generated by a military aircraft (C-130, F-4, F-14) located on the ground at Bandar Abbas. This was supported by his IDS' RCI set up and the [radio frequency] RF ducting condition in effect on 3 July 1988. Therefore, any number of military aircraft present at the airfield could have responded to a Mode II IFF interrogation by USS *Vincennes* due to the ducting conditions prevalent that day. (1988, p. 48)

Incidentally, TN 4133, which was an Iranian C-130 (Senate Hearing, 1988, p. 53), departed Bandar Abbas simultaneously with the *Vincennes*' missile launch squawking Mode I-11. This could have been a potential source of confusion between Mode I-11 and Mode II-1100 on IDS and AAWC's RCI. (1988, p. 48)

Another source of confusion could be attributed to the impending engagement. It is entirely possible that decreasing altitude passed over the net by TIC after the 15 NM point could have occurred if TIC passed range values only. These range values could have been interpreted as altitude values. Another possibility could be that the TIC misread his character read out (CRO) and interchanged altitude and range. (1988, p. 48)

The investigation team indicated that the ship's air controller supervisor's (ACS) recollection of 7800 feet at six NM was actually the altitude of TN 4131 33 seconds after missile intercept. This individual was essentially recollecting the planes' altitude as it plummeted to the water. In addition, the team also attributed the recollection of Mode III IFF responses other than 6760 for TN 4131 were caused by imperfect recall by the IDS, ACS, AAWC console operators as well as the post incident situation report writer. And lastly, the range and altitude information passed to the CO on Net 15 was correct until TN 4131 reached approximately 15 NM--approximate time 1023L. (1988, p. 48)

Regarding commercial aircraft, the investigation team felt that current verbal warnings and challenges were not specific enough, for they did not clearly identify to pilots which aircraft the ship was attempting to contact. Also, there were a limited number of very high frequency (VHF) radios on surface units that seriously limited their capability to simultaneously monitor the IAD frequency and communicate with civilian air traffic control towers. Although the warnings could be transmitted over the IAD and MAD and be heard by other ships in the area, it is not clear to the ship issuing the warning whether a particular aircraft has heard a particular challenge, unless it replies or turns away. (1988, pp. 48-49)

And finally, the Fogarty team assessed CJTFME involvement as the following: The CJTFME's confidence in Captain Rogers, the Aegis weapon system, and the information available to him from the Flag Plot were factors that led to his concurrence with the *Vincennes'* decision to engage. The CJTFME exercised good judgement in directing the *Vincennes* to warn the aircraft before firing. However, due to the fact that the CJTFME did not have a real time data link, he could not have independently verified the data regarding TN 4131. (1988, pp. 49-50)

In summary, Admiral Fogarty indicated that his investigation team was "unsuccessful in satisfactorily reconciling the conclusion that the contact was descending when in fact the Aegis weapon system showed the aircraft always to be climbing."

(Senate Hearing, 1988, p. 16) The investigation team felt there were some psychological factors involved with the incident. As they discovered disparities between the C & D system data tapes and what various CIC members believed they saw, Admiral Fogarty requested the professional advice of the USN Medical Corps who were experts in the area of combat stress. The Medical Corps' opinion was reflected in the Fogarty report:

> Stress, task fixation, an unconscious distortion of data may have played a major role in this incident. [Tactical Information Coordinator] TIC and [Identification Supervisor] IDS became convinced track 4131 was an Iranian F-14 after receiving the IDS report of a momentary Mode II. After this report of the Mode II, TIC appear[ed] to have distorted data flow in an unconscious attempt to make available evidence fit a preconceived scenario. ('Scenario fulfillment') TIC's perception that there was an inexperienced, weak leader in the [Anti-Air Warfare Coordinator] AAWC position led to the emergence of TIC in a leadership role. TIC's reports were accepted by all and could have influenced the final decision to launch missiles. (1988, p. 45)

By primarily attributing this divergence to "...the misreading of altitude" (Senate Hearing, 1988, p. 16) due to "...combat induced stress on personnel" (Fogarty, 1988, p. 51), Admiral Fogarty recommended that the Chief of Naval Operations direct further study concerning the impact of stress factors on personnel aboard naval ships with highly technological and sophisticated command, control, communications, and intelligence (C3I) systems as well as address the possibility of establishing a psychological profile for personnel who must function in this type of environment. (Fogarty, 1988, p. 51). The Fogarty investigation team could not account for the divergence between system and recollected data, and it still remained a puzzle at the time of the Senate Hearing before the Committee on Armed Services. Essentially, the Fogarty interpretation considered this disparity as a result of stress.

B. CAPTAIN ROGERS' ANALYSIS AND INTERPRETATION

1. Introduction

Captain Rogers' account corresponds with the Fogarty version, except for two aspects: His analysis and interpretation points to a confusion over track numbers and the existence of a second aircraft. The information obtained in this section was derived from several meetings starting from a classroom presentation at the Naval Postgraduate School in Monterey, California, by Captain Will Rogers, III, to C3 students held on 9 August 1990 and a series of personal interviews on 9 October 1991, 13 February 1992 and 8 & 9 April 1992. *During the interviews with Captain* Rogers, he specifically emphasized that the track number issue was just one piece of the puzzle. Additionally, Captain Rogers indicated that the remarks made by Senator John Glenn succinctly summarized "six fundamental considerations" that he had to consider prior to his decision to engage. According to Senator Glenn, in a statement submitted at the Senate Hearing, the following remarks were made:

> It has been said that there were six critical fundamental considerations to the incident that the CO of the *Vincennes* could neither control nor discount: *Vincennes* was engaged in intense surface action with Iranian gunboats. The unidentified assumed hostile contact had taken off from an airfield used by military aircraft. The flight was heading directly at *Vincennes* and its range was relentlessly closing. The unknown aircraft radiated no definitive radar emissions. *Vincennes'* warnings went unacknowledged and unanswered. The compression of time gave him an extremely short decision window, less than 5 minutes. Additionally, it was only prudent for Captain Rogers to assume that the contact was related to his engagement with the Iranian boats until proven otherwise--the proof never came. (Senate Hearing, 1988, p. 56)

2. Naval Tactical Data System

The air engagement was a complicated sequencing of events. One of the most difficult aspects of this sequence was to understand how the track number issue fit in. The following description, written in coordination with Captain Rogers', was deliberately simplified to give the reader a flavor of what happened without getting swamped with detail.[4]

The Naval Tactical Data System's Link 11 allows tactical data to be transmitted and received between various ships and aircraft in a battle group. The link is a real time data transfer, which allows all participating units to share an expanded picture. This sharing of information enlarges the tactical picture available to the battle group. (Rogers 1992)

In general, when a contact is detected by radar, the link input operator will acquire the target and designate it to the system which assigns the track a four digit track number. Each ship or aircraft is assigned a block of numbers that is specific to that ship or aircraft. The track numbers from this block of numbers are used to identify the contact. Once the contact is identified by track number, information regarding the contact's kinematics such as speed, range, course, altitude and IFF, is continuously updated by the entering participating unit (PU), unless the contact is dropped from the link. These track numbers allow all units to track the same contact using the same common reference number. Within this system, a link controller manages the link, and a protocol of written and machine based "dos and don'ts" is utilized to control system operation. (Rogers, 1992)

3. Aegis Command and Decision System

In the case of the Aegis Command and Decision (C & D) system, the operator can obtain kinematic information on the contact of interest (COI) by either "hooking"[5] the contact by rolling the ball tab to the COI and depressing the "hook" button or by entering the track number on the digital display entry unit key pad. An overview of the OJ-194 PPI display console is presented in Appendix C. By either method, kinematic information will be displayed in an alpha numeric manner on the character read out (CRO). This detailed information does not reflect on the large screen display (LSD). (Rogers, 1992; Mosher[6], 1992)

The *Vincennes* is equipped with a state of the art weapon system called Aegis, which is capable of rapidly developing track data for several hundred contacts virtually simultaneously. Because of the speed with which the track file is built, a feature was designed into the system that automatically correlates link track numbers entered by other units and compares these with its "own ship" information. If its "own ship" track can be correlated, the track number assigned by Aegis is retrieved and returned to track stores. This feature allows track management of numbers of contacts greater than the size of the assigned track block. This track number correlation and management is accomplished automatically. However, there is no alerting mechanism that calls the operator's attention to the fact that an auto-correlation had taken place on a contact. (Rogers, 1992)

Another aspect of the Aegis system is that once a contact is generated, the computer will assign an internal number called a control track storage number (CTSL) to that track. The CTSL is transparent to the operator. In the *Vincennes*' case, the CTSL assigned to the contact that got shot down remained the same from the time the aircraft was detected to missile impact. On the other hand, the common track number changed three times during the detect to engage sequence as will be described. (Rogers, 1992)

4. Track Number Sequence

The USS *Vincennes* was assigned track block 4400-4576. The USS *Sides* was assigned block 3400-3576, while the British ship, HMS *Manchester*, was assigned 6400-6576. As discussed, these numbers allow all units in the link to call up and display which participating unit entered the track. (Rogers, 1992; Rogers, 1990)

At about 1017L, the *Vincennes* and the *Sides* detected the same contact originating from Bandar Abbas practically simultaneously. The *Vincennes* assigned the contact TN 4474, and the *Sides* assigned it TN 4130 over the link using a track number from the wrong block. The *Sides* was in the link for a short period, but briefly dropped from the link. Upon the *Sides*' rejoining the link, she re-reported the contact, this time as TN 4131, which was another link protocol violation. Meanwhile, the *Vincennes* had identified this contact as TN 4474. The Aegis system auto-correlated this information and adopted TN 4131 as the new common track number. Again, this correlation was done automatically by the system, not by the operator, which was a standard operating procedure inherent in the Aegis system. Track number 4474 was assigned initially by the Aegis system and was the number later used when the track information was requested by the commanding officer. So, TN 4474 went back into the system as an unused track number. (Rogers, 1992)

In the Gulf of Oman, there were three ships that came into play: the USS *Spruance*, a destroyer, the USS *Forrestal*, an aircraft carrier, and a British ship, HMS *Manchester*, which was over 100 NM southeast of the *Vincennes* in the Gulf of Oman. When TN 4131 was nearing the 20 NM critical decision point as to whether to engage the contact or not, an A-6 was flying a surface combat air patrol (SUCAP) mission and was checking in with the E-2 from the *Forrestal*. At this time, the A-6 was descending and accelerating during check in. The A-6's track number was issued by the *Spruance* and was designated, coincidentally, as TN 4474. In the meantime, the HMS *Manchester*, which was just entering the Southern Persian Gulf link (that was comprised of the *Vincennes*, *Sides* and *Montgomery*) included the *Spruance's* track of 4474 in her reported track file. The kinematics of TN 4474, now, once again, in the *Vincennes*' tactical picture indicated high speed (459 KTS) and descent from an altitude of 12,000 feet. This track number (TN 4474) re-entered the link at about the time the actual contact of interest (TN 4131) was at the critical 20 NM decision point, at which point the Commanding Officer of the *Vincennes* asked the question, "What is 4474 doing?" An unidentified console operator entered the numbers 4-4-7-4 onto the remote control indicator key pad rather than "ball tab and hooking" the contact of interest on the console scope. Neither the operator nor the captain were aware at that moment that the track number had changed from TN 4474 to TN 4131. When the key pad was utilized to input the numbers, the system brought up the kinematics of the A-6 contact associated with TN 4474. Consequently, reports to the command console that the contact was descending from 12,000 feet at 459 KTS were generated. This information was conveyed over internal net

15/16. Throughout the remaining minute, more reports from other console stations indicated that the contact was in fact descending and closing. (Rogers, 1992) At ten NM the missiles were launched, with the first missile intercepting TN 4131 at a range of eight NM, speed of 383 KTS and altitude of 13,500 feet. (Fogarty, 1988, p. 39)

5. Summary

In sum, Captain Rogers offered a different interpretation of the incident, in which he introduced the confusion in track numbers as well as the existence of two aircraft. Not that the track number issue was an overriding contribution to the airliner shoot down, it was but one small piece of a complex puzzle that was compounded by other equally as important contributing factors.

C. AUTHOR'S ANALYSIS AND INTERPRETATION

1. Introduction

Considering both the Fogarty and Rogers' interpretations of the incident, the divergence between system and recollected data still remains a problematic issue in that the system data showed the aircraft always to be ascending, while recollected accounts from witnesses indicated the aircraft was descending. To address this issue, relationships between range, altitude, time, speed, and track number variables as obtained from the Fogarty investigation report are presented and compared. The driving force behind this analysis was to determine whether there were two aircraft involved in the *Vincennes* incident or not.

2. System Data

The first step taken in performing the analysis was to construct scatter plots of the data presented in the Fogarty report regarding the air engagement, in which a comprehensive data set listing is comprised in Appendix D. Each (x,y) entry represents a point plotted on a two dimensional coordinate system. The plots were then analyzed for trends regarding their clustering tendency or lack thereof and for any other pattern that emerged. Also, Appendix E presents a correlation coefficient summary of all scatter plots and Appendix F contains regression equations for all graphs having a linear fit line drawn through the data.

The information presented in Table III-1 is a composite of all system data entries that were presented in the air engagement "Time Line" section of the Fogarty report (1988, pp. 28-39). System data entries were extracted from the text and compiled in tabular form. The system data as presented in the Fogarty report were originally obtained from the *Vincennes'* data reduction tapes, depicting a second-by-second account of the position, kinematics, Identification Friend or Foe (IFF) information and Link 11 message flow of all contacts held by the *Vincennes'* Aegis weapon system. Furthermore, the data enabled the reconstruction of all "button actions" by the Command and Decision (C & D) console operators and the information available to them on their console read outs. (Fogarty, 1988, pp. 8-9) Table III-1 is a summary of all information that could be reasonably assimilated from the Fogarty report, regarding the above relationships.

TABLE III-1

SYSTEM DATA WITH RANGE, ALTITUDE, TIME, SPEED AND TRACK NUMBER VARIABLES

RANGE	ALTITUDE	TIME	SPEED	TN
47	900[a]	1017	---	4474
44	2500	1018	232	4474[b]
40	4000	1019	303	4131
34	6160	1020	334	4131
29	7000	1021	350	4131
25	8400	1022	---	4131
22	9200	1022	---	4131
20	10000	1022	360	4131
110	11900	1022	448	4474[c]
16	11230	1023	371	4131
15	11000	1023	---	4131
14	12000	1023	382	4131
12	12370	1024	380	4131
10	12950	1024	385	4131
8	13500	1024	383	4131

a. Altitude obtained from Senate Hearing, 1988, p. 10.
b. Aegis auto-correlated the *Vincennes'* track number of 4474 and the *Sides'* track number of 4131, resulting in TN 4131 as the new track number for the air contact originating from Bandar Abbas.
c. FC-1 hooked TN 4474.

As displayed in Table III-1 and as confirmed in Admiral Fogarty's report:

> The data from the USS *Vincennes'* tapes, information from USS *Sides* and reliable intelligence information, corroborates the fact that TN 4131 was on a normal commercial air flight plan profile, in the assigned airway, squawking Mode III 6760, on a continuous ascent in altitude from takeoff at Bandar Abbas to shoot down. (1988, p. 8)

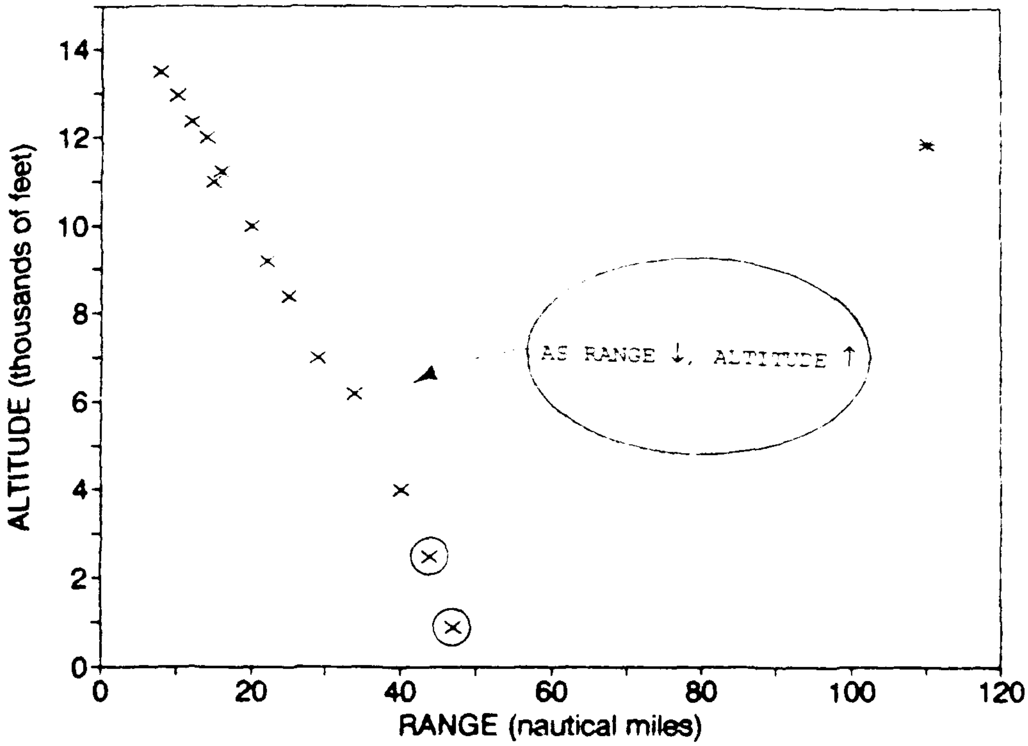
Therefore, based on the above assessment regarding the system data, the flight profile as represented by the "X" symbol is actually Iran Air Flight 655 in Figures III-1 through III-4.[7]

The system data in the above table shows that the TN 4474 data point at 1022L is not consistent with the other data points representing Flight 655. There are several interesting observations that stand out just by scanning the table: First, the labelling of the track number as TN 4474 is not consistent with the other labels of TN 4131 between 1019L and 1024L. Secondly, the track number label of TN 4474 is the same as the track number of the contact when it was originally detected by the *Vincennes* at 1017L. Thirdly, the speed of the TN 4474 data point at 1022L is 63 knots faster than the highest speed reached by TN 4131 at that time. Also, the range is not even close to the furthest point at which the contact was originally detected at 47 NM. And, lastly, the altitude is nearly 2,000 feet higher than the highest point reached by TN 4131 at 1022L. Not shown on the table is bearing. The FC-1 hook of TN 4474 at 1022L indicated a bearing of 139 degrees, while the rest of the data indicated TN 4131 was maintaining a constant bearing of 025 degrees.

In sum, the system data as presented in Table III-1 suggests the existence of two aircraft, which will be further demonstrated graphically.

a. Altitude versus Range

Three scatter plots were created from the system data to illustrate the relationships between altitude versus range, altitude versus time, and range versus time. In Figure III-1, altitude entries ranged from a height of 900 feet to 13,500 feet (y-axis), while the range entries were in nautical miles (x-axis). These altitude and range entries include the FC-1 data point as extracted from the system tapes and is designated with the following symbol, "*", on the scatter plot. Overall, the negative slope as depicted by the



LEGEND

* -- *TN 4474 hooked by FC-1 at 1022L for 5 seconds with RNG 110 NM, BRG 139, ALT 11,900, SPD 448 (Fogarty, 1988, p. 34).*

X -- Flight 655 with TN 4131 label

(X) -- Flight 655 with TN 4474 label

Slope: Positive

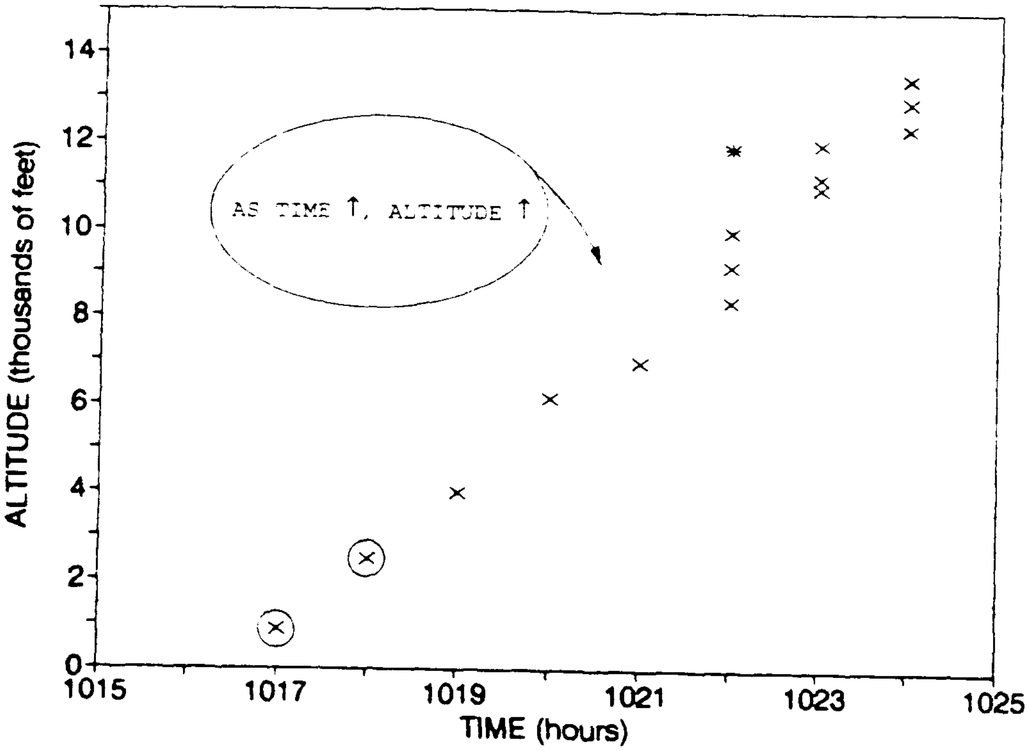
Correlation Coefficient: +.979

Figure III-1. System Data--Altitude versus Range

"X" symbol indicates the aircraft was ascending: As the range decreased or as the contact got closer to the *Vincennes*, the contact was continuously climbing. However, the correlation coefficient, -.293, was weak. It appears FC-1 data point of TN 4474 had an adverse influence on the degree of linear relationship among the variables. To assess the extent of this influence, the correlation coefficient was re-computed without the FC-1 hook of TN 4474, and a strong linear relationship was realized as shown by a coefficient of -.997. (Refer to Appendix E, Correlation Coefficient Summary, *Groups 1 and 3 for* a comparison of correlation coefficients.) This magnitude of change from a weak to a strong linear relationship suggests the FC-1 hook of TN 4474 is not related to the remaining data. Its removal strengthened the linear relationship among the rest of the data points, which happen to be data points from Flight 655's flight profile.

b. Altitude versus Time

Altitude entries were depicted height in feet (y-axis) while time increments were based on a 24 hour clock spaced at minute intervals (x-axis). A total of 15 observations were provided by system data. The "*" symbol in Figure III-2 represents the TN 4474 data point at 1022L, 11,900 feet, as identified in Table III-1. The positive slope represents a rate in feet per minute that Flight 655 was ascending. As time progressed, the contact continuously gained in altitude as it approached the *Vincennes*. This trend is also revealed by the correlation coefficient of +.979, which shows a strong



LEGEND

* -- *TN 4474 hooked by FC-1 at 1022L for 5 seconds with RNG 110 NM, BRG 139, ALT 11,900, SPD 440 (Fogarty, 1988, p. 34).*

X -- *Flight 655 with TN 4131 label*

(X) -- *Flight 655 with TN 4474 label*

Slope: Negative

Correlation Coefficient: -.293

Figure III-2. System Data--Altitude versus Time tendency of the data to reflect a linear relationship. Without the FC-1 hook of TN 4474, there is an even stronger linear relationship.

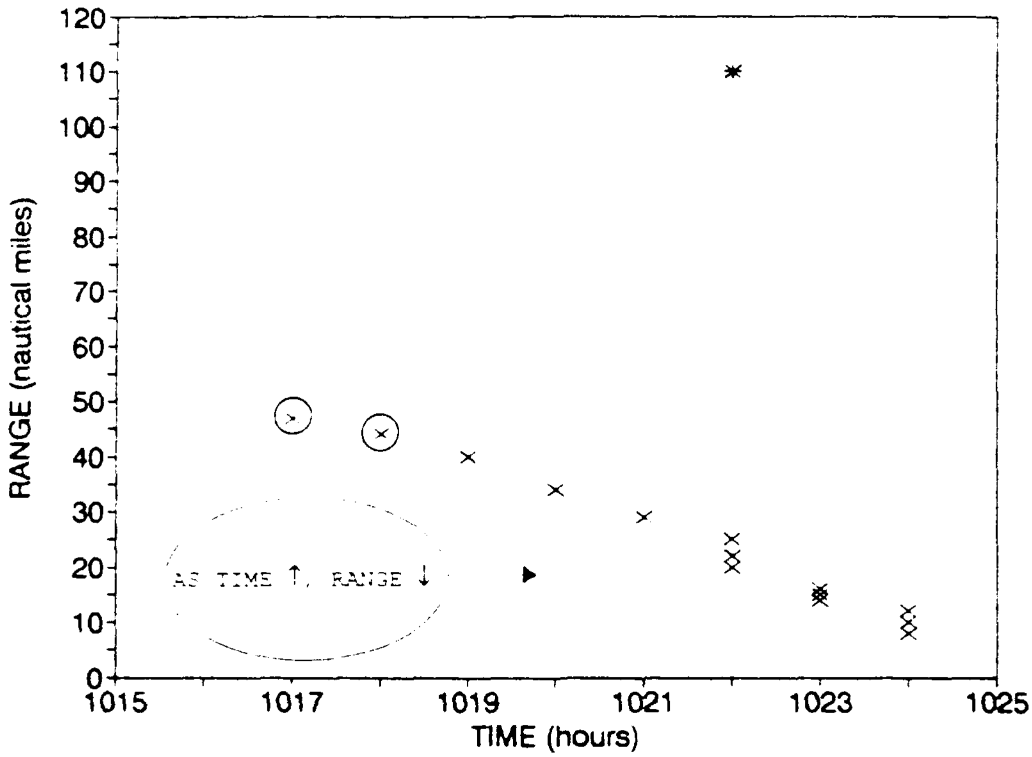
Also, the data points tended to cluster at the time of 1022L, which is a significant time period in the air engagement. At this time, the TN 4474 data point was nearly 2,000 feet higher than the rest of the data points for that minute. Regarding Rogers' interview data, he asked, "What is 4474 doing?" at the 20 NM point, which correlates to the time frame of 1022L. An unidentified console operator stated the contact was at 12,000 feet and descending, which was only 100 feet higher than the altitude obtained by the hook of TN 4474 by the FC-1 at 1022L.

c. *Range versus Time*

The last plot in this series involves range in nautical miles (y-axis) versus time based on a 24 hour clock in minute increments (x-axis). The significance of Figure III-3 is not necessarily the fact that as time progressed, range decreased, but the lack of relationship between the FC-1 hook of TN 4474 and the rest of the data points signifying Flight 655. The FC-1 data point was at a range of 110 NM, while the next most extreme range value at 1022L was at 25 NM.

d. *Summary of System Data*

When comparing all three graphs as consolidated in Figure III-4 and the system data as provided in Table III-1, it is evident that the FC-1 hook of TN 4474 at 1022L is not congruent with the rest of the data. On the other hand, there is congruence between the variables of time and their track number designation exists between the FC-1



LEGEND

• -- *TN 4474 hooked by FC-1 at 1022L for 5 seconds with RNG 110 NM, BRG 139, ALT 11,900, SPD 448 (Fogarty, 1988, p. 34).*

X -- *Flight 655 with TN 4131 label*

(X) -- *Flight 655 with TN 4474 label*

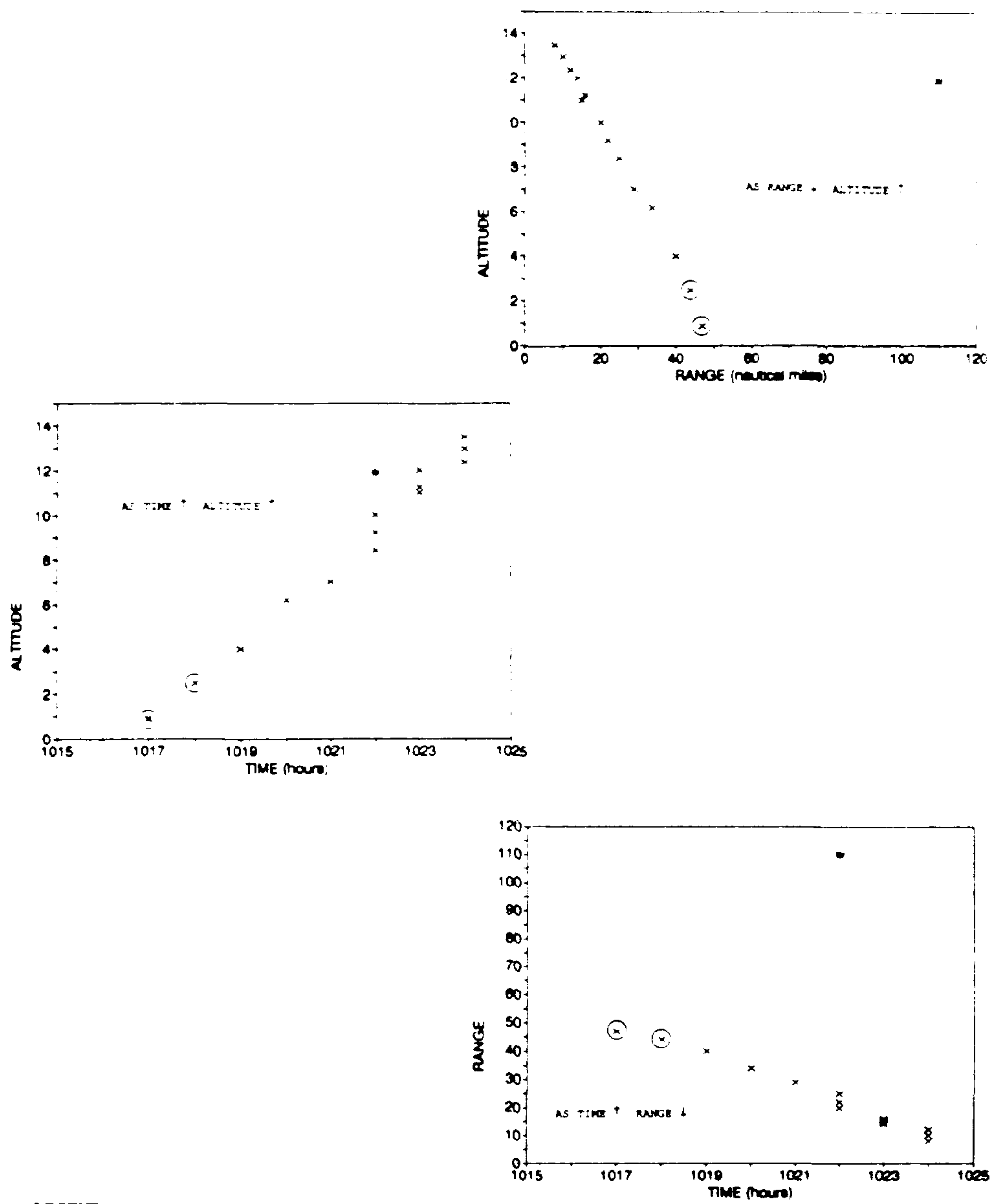
Slope: **Negative**

Correlation Coefficient: -.440

Figure III-3. System Data--Range versus Time hook of TN 4474 at 1022L, the remaining system data points, and Rogers' interpretation. The nature of this congruence is outlined in the following:

- TN 4474 was the *Vincennes*' original track number designating Flight 655 and was labelled as "unknown-assumed enemy."
- The Aegis system automatically correlated the track numbers from TN 4474 to TN 4131.
- The *Spruance* coincidentally designated TN 4474 to an A-6.
- At 1022L, Rogers inquired at to the status of TN 4474, and an unidentified operator responded with kinematic information characteristic of an attack profile.
- The *Manchester* entered into the Southern Persian Gulf link bringing with it the *Spruances*' track of 4474.
- And, kinematics associated with the hook of TN 4474 by an unidentified watchstander manning the FC-1 console are not congruent with the Flight 655 profile.

Even though range seems to be problematic in Figure III-3 with the FC-1 data point, it really serves to strengthen the argument that Aegis operators were obtaining information about the A-6 that was over 100 NM away, and that the A-6 kinematics were already in the system even though the duration of the FC-1 hook lasted five seconds. At first glance at the graphs, the TN 4474 hook by the FC-1 seems as if it was an anomaly and that it should be "thrown out" from the "good" data. But, in actuality, it is a lynch pin that helps to ascertain why crew members were reporting descending altitude readings and increasing speed, when the contact of interest was ascending. This relationship will be further discussed in recollected data section. Based on Captain Rogers' interview data and the kinematics of the FC-1 hook of TN 4474 as shown by the system data, the



LEGEND

* -- *TN 4474 hooked by FC-1 at 1022L for 5 seconds with RNG 110 NM, BRG 139, ALT 11,900, SPD 448 (Fogarty, 1988, p. 34).*

X -- *Flight 655 with TN 4131 label*

(X) -- *Flight 655 with TN 4474 label*

Figure III-4. System Data--Altitude versus Range, Altitude versus Time, and Range versus Time following pattern emerges: The kinematics of the FC-1 hook is not related to the system data, but is related to Captain Rogers' interview data. There is a strong possibility that the kinematics associated with the FC-1 hook of TN 4474 was the kinematics associated with the A-6 in the Gulf of Oman.

3. Recollected Data

A second data set was created based on recollected data by witnesses as extracted from the text in the Fogarty report (1988, pp. 29-39). There were 18 different observations that were detailed enough to plot on a graph. Before delving into the graphical analysis, it should be noted that there may be some bias inherent in the data by virtue of the type of data that it is--recollections from witnesses. This bias involves the extent of witness recall and how accurate the recollection was. Another source of bias resides in the investigation team as they placed the events in sequential order based on their interpretation of what the witnesses said through statements and testimony.

The Fogarty report did not state in all instances where Combat Information Center (CIC) members were obtaining this information. Typical dialogue in the report was "AIC-3 recalled an altitude of 9000 feet at 20 NM" (Fogarty, 1988, p. 20), but did not indicate where or from what instrument he was obtaining this information. Some entries contain more detailed information than others, which again goes back to the accuracy of the testimony and witness statements and their interpretation by the investigation team.

Despite these apparent limitations, it is assumed that the witnesses' recollections were reasonable and that the information in the report was comprehensive.

Also, it is assumed that the investigation team integrated witness accounts with that of the data tapes to reconstruct the sequence of events with minimal deviation from reality.

As shown by Table III-2, the recollected or "perceived" data from witness accounts are presented in composite form; however, it should be noted that there was no recollected data provided in the Fogarty report by the crew member manning the FC-1 console (FC-1) stating what he believed he saw. Since there was no witness testimony from that individual available, there was no data that could be entered into Table III-2 from FC-1. As already shown with the system data, TN 4474 was hooked by FC-1. The FC-1 hook is a system data point extracted from the data reduction tapes, not a data point based on witness recall.

TABLE III-2

RECOLLECTED DATA BY WITNESSES WITH RANGE, ALTITUDE, TIME, SPEED AND TRACK NUMBER VARIABLES

WHO	RANGE	ALTITUDE	TIME	SPEED	TN
GW	$ 39	9800	1020	---	4131
AIC-3	30	9000	1021	---	4131
AAWC	30	$ 8500	1021	---	----
OSDA	29	8000	1021	---	4131
49 ADT	25	12000	1022	---	4131
CSC	22	10300	1022	---	4131
IAD	20	10500	1022	---	4131
AIC-3	20	9000	1022	---	----
TIC	15	11000	1023	---	----
AIC-3	15	7700	1023	---	4131
IAD	$ 15	7800	1023	450	----
RSC	12	$ 5500	1024	---	----
IDS	$ 11	7800	1024	445	4131
49 ADT	10	7800	1024	---	4131
TIC	10	10000	1024	---	4131
AAWC	% 8	$ 6500	1024	---	----
MSS	6	7000	1024	---	----
UBS	6	7000	1024	---	----

$ -- Several witness accounts were provided in the form of ranges. These ranges were averaged to obtain a single value in order to plot the data point.
% -- "At engagement" estimated by the author to mean 8 NM.

a. Altitude versus Time

The recollected data as depicted with the hourglass symbol was derived using all "perceived" altitude versus time entries regarding the crew's recollection of "Flight 655." In Figure III-5, altitude is in feet (y-axis), and time is in minutes based on a 24 hour clock, (x-axis). The negative slope suggests that as time progressed,

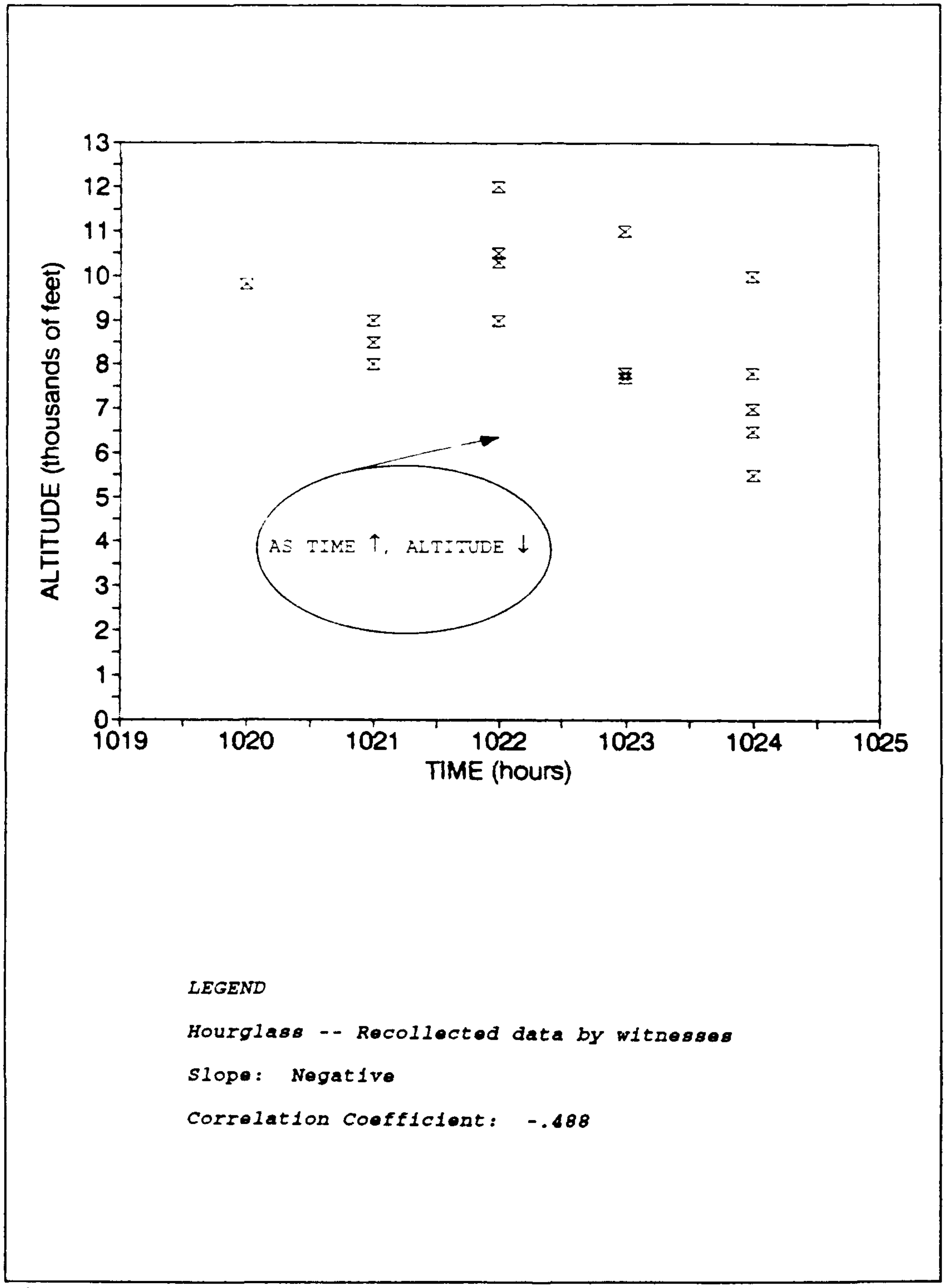


Figure III-5. Recollected Data by Witnesses--Altitude versus Time the contact descended as it approached the *Vincennes*. However, the clustering tendency of this data is not strong, but in the weak to moderate range as revealed by the correlation coefficient, -.488 as shown in Appendix E, Group 2, Correlation Coefficient Summary.

b. Altitude versus Range

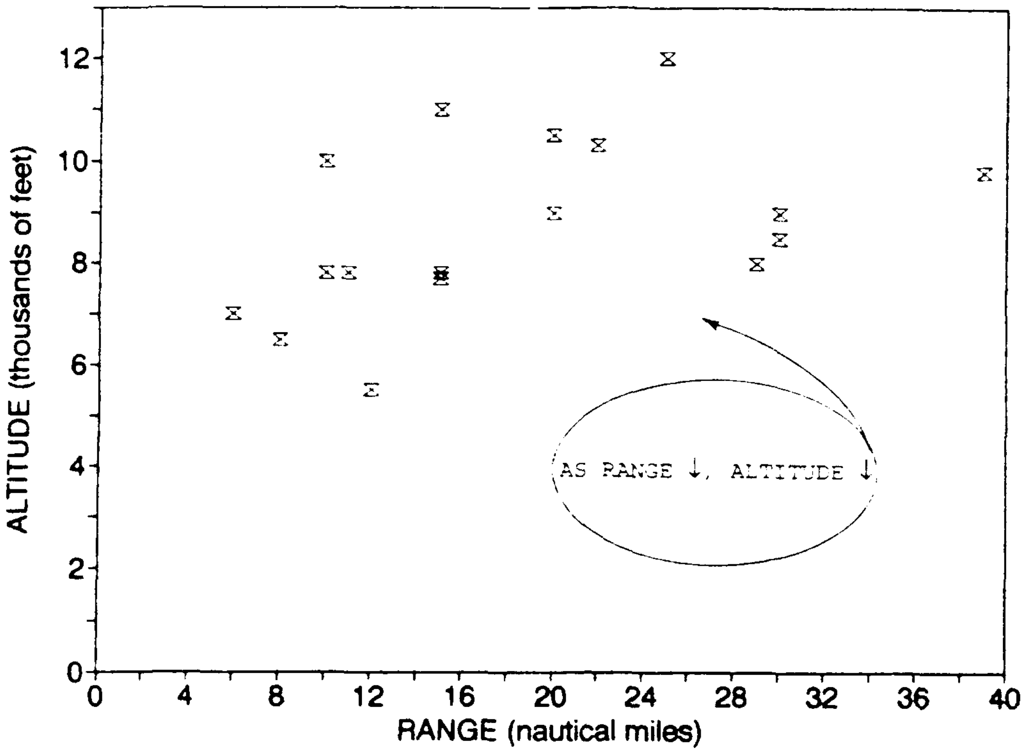
The next graphical presentation, Figure III-6, contains recollected altitude versus range entries regarding the perceived flight of "Iran Air Flight 655" by various *Vincennes* crew members. The altitude is in feet (y-axis), while range is in nautical miles (x-axis). The correlation coefficient is +.483, which is in the weak to moderate range. The slope is positive, indicating that the contact was decreasing in as it approached the *Vincennes*.

c. Summary of Recollected Data

Overall, the recollected data suggests the existence of one aircraft. The trends emerging from the data show a weak-to-moderate clustering tendency and that the contact was descending in altitude. The weak-to-moderate clustering tendency of the recollected data sparked further inquiry.

4. Comparative Analysis between System and Recollected Data

Before continuing with more graphical analysis, a comparison was made between system data and recollected data as shown in Table III-3, using the following question as a guide: How much disparity was there between actual and perceived data entries? Data points in the recollected data set that were reasonably close to actual data entries were those entries with a 2,000 foot maximum disparity in altitude and three NM



LEGEND

Hourglass -- Recollected data by witnesses

Slope: Positive

Correlation Coefficient: +.483

Figure III-6. Recollected Data by Witnesses--Altitude versus Range maximum disparity in range. All other entries outside this "disparity range" were considered highly disparate entries.

There were minimal disparities between the variables of time and range. However, the disparities in altitude ranged from no disparity, 0 feet, to a maximum disparity of 7,000 feet between system and recollected data. Hence, the last column consists of altitude disparities, since it was the largest source of disparity of the variables analyzed. Interestingly, over time, the disparity between actual and perceived data altitude entries tended to increase.

TABLE III-3

VARIANCE TABLE BETWEEN ACTUAL AND PERCEIVED DATA

CIC Member	A range / P range	A altitude / P altitude	A time / P time	Disparity
?? GW	40/39	4000/9800	1019/1020	5800 ft
* AIC-3	29/30	7000/9000	1021/1021	2000 ft
* AAWC	29/30	7000/8500	1021/1021	1500 ft
* OSDA	29/29	7000/8000	1021/1021	1000 ft
? 49 ADT	25/25	8400/12000	1022/1022	3600 ft
* CSC	22/22	9200/10300	1022/1022	1100 ft
* IAD	20/20	10000/10500	1022/1022	500 ft
* AIC-3	20/20	10000/9000	1022/1022	1000 ft
* TIC	15/15	11000/11000	1023/1023	0 ft
? AIC-3	15/15	11000/7700	1023/1023	3300 ft
? IAD	15/15	11000/7800	1023/1023	3200 ft
? RSC	12/12	12370/5500	1024/1024	6870 ft
? IDS	12/11	12370/7800	1024/1024	4570 ft
? 49 ADT	10/10	12950/7800	1024/1024	5150 ft
?? TIC	10/10	12950/10000	1024/1024	2950 ft
? AAWC	8/8	13500/6500	1024/1024	7000 ft
? MSS	8/6	13500/7000	1024/1024	6500 ft
? UBS	8/6	13500/7000	1024/1024	6500 ft

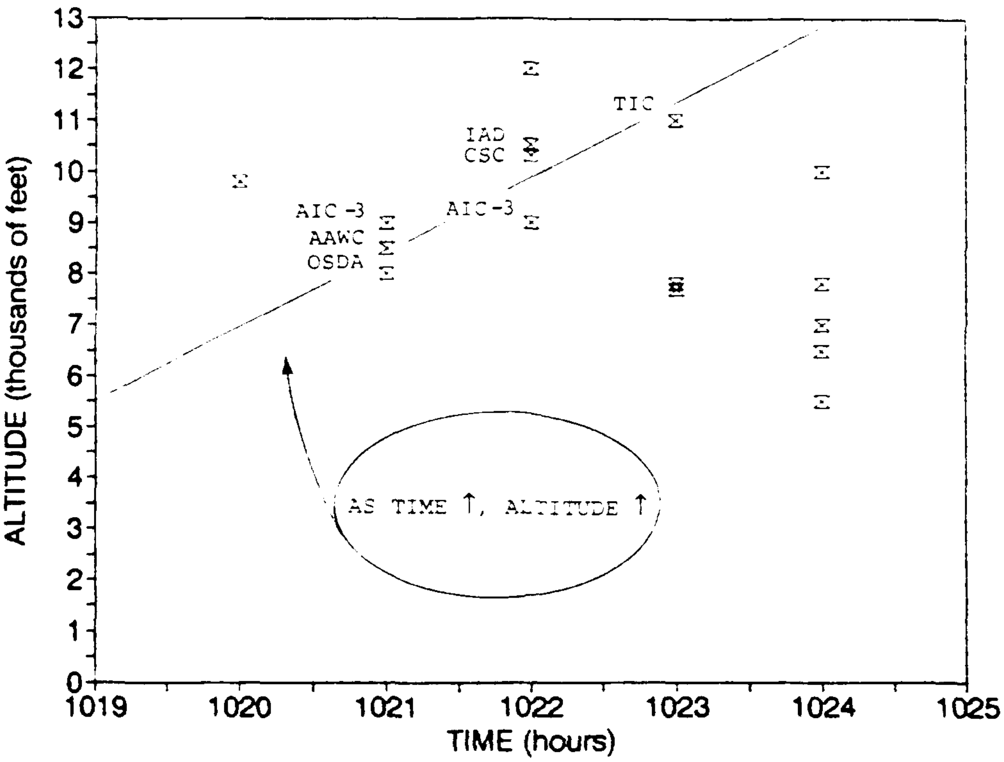
?? - Data entries that appeared out of place with both recollected and system data.
* - Recollected data entries that were reasonably close to actual data entries--within 2000 feet and 3 NM
? - Highly disparate entries from actual data entries--in excess of 2000 feet and 3 NM
"A" - Actual or system data entries
"P" - Perceived or recollected data entries by witnesses

a. *Comparative Scatter Plots within Recollected Data*

(1) *Altitude versus Time*

There were 18 different observations regarding altitude versus time from 12 CIC members who were the following: GW, AIC-3, AAWC, OSDA, 49 ADT, CSC, IAD, TIC, RSC, IDS, MSS and UBS. Multiple observations were provided by AIC-3 consisting of three entries, and two entries each from the AAWC, 49 ADT, TIC and IAD. On several graphs these multiple entries will be connected by a dashed line to show their trend.

Figure III-7 shows a scatter plot of all "perceived" or recollected data entries, with data points in close proximity to system data entries being labelled. These data entries were tagged with a "*" symbol in Table III-3. The following trend was revealed: At 1021L, the AAWC, OSDA and AIC-3 entries were "reasonably close," within 2,000 feet, to entries from the actual system data tapes. The data points as provided by the CSC, IAD, AIC-3 were also reasonably close at 1022L. The TIC's input at 1023L indicated no disparity with the system data. Just by focusing on the labelled entries, a pattern emerges as demonstrated by the linear fit drawn through the labelled data points, which shows as time progressed, the altitude increased. This trend was commensurate with what the real Flight 655 was doing. Appendix F contains the regression equation for this and all subsequent linear fits drawn. However, when analyzing the recollected data points labelled in Figure III-8, which represent the highly disparate entries as designated with a "?" symbol on Table III-3, another linear



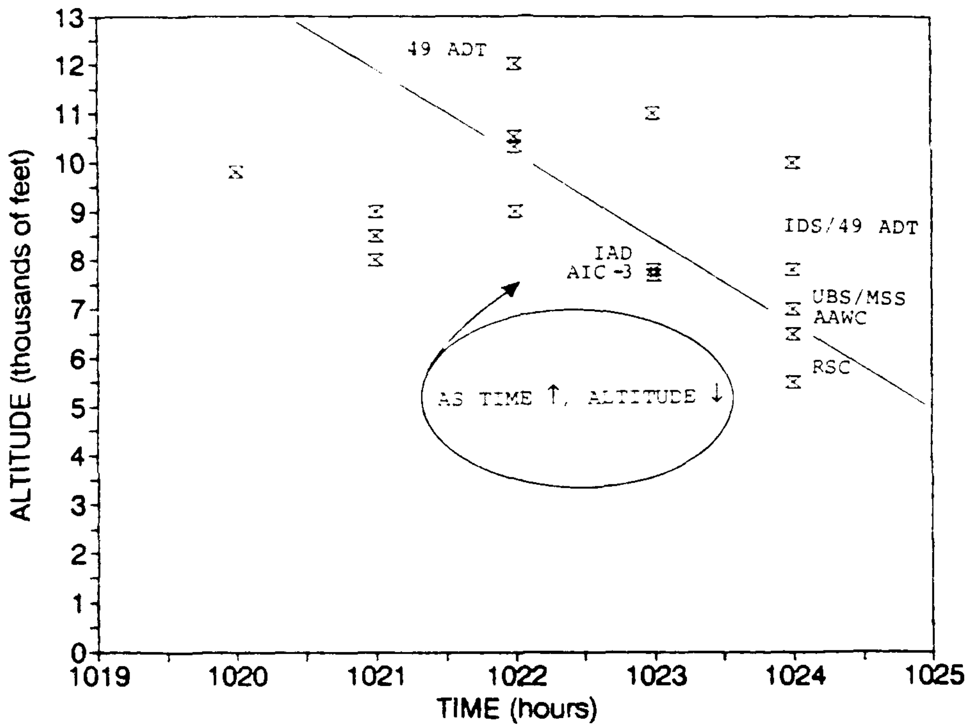
LEGEND

Hourglass with operator label -- Recollected data by witnesses in close agreement with system data. Corresponds to "" symbol in Table III-3.*

Hourglass without operator label -- Remaining recollected data

Figure III-7. Recollected Data by Witnesses--Altitude versus Time with "Reasonable" Entries Labelled relationship appears. The scatter plot in Figure III-8 illustrates that as time progressed, especially after 1022L, the altitude of the contact decreased. A more descriptive picture is presented when Figures III-7 and III-8 are consolidated on one graph, Figure III-9. Here, another pattern emerges within the recollected by witnesses data set: Both ascending and descending observations were made by crew members as shown by the empty and solid hourglass symbols, respectively. Up until 1023L, most of the recollected data entries were matching system data entries. In fact, at 1023L, the TIC's observation matched exactly with the system data. As shown in Figure III-9, the 49 ADT recollected that the contact was at 12,000 feet at 1022L--an unusually high altitude. It was also at this time that the system data indicated the FC-1 hooked TN 4474 having an altitude of 11,900 feet. At 1023L and 1024L the IAD, AIC-3, RSC, AAWC, UBS, MSS, IDS and 49-ADT were all recalling entries that were over 2,000 feet below system data entries. The majority of these low altitude readings occurred at 1024L, the minute of missile impact. Additionally, at 1022L, Captain Rogers asked, "What is 4474 doing?" The response he received was that the contact was at 12,000 feet and descending at 459 knots (Rogers, 1992). It is entirely plausible, due to the track number issue and the reentry of TN 4474 into the *Vincennes'* tactical picture, that personnel were still thinking TN 4474 was still a valid track. Consequently, eight individuals could very well have been seeing kinematic information regarding the A-6 i 'he Gulf of Oman on their character read out displays.

However, when the recollected data set is analyzed in aggregate, with no labelling, the overall tendency for this data set shows a negative slope, suggesting

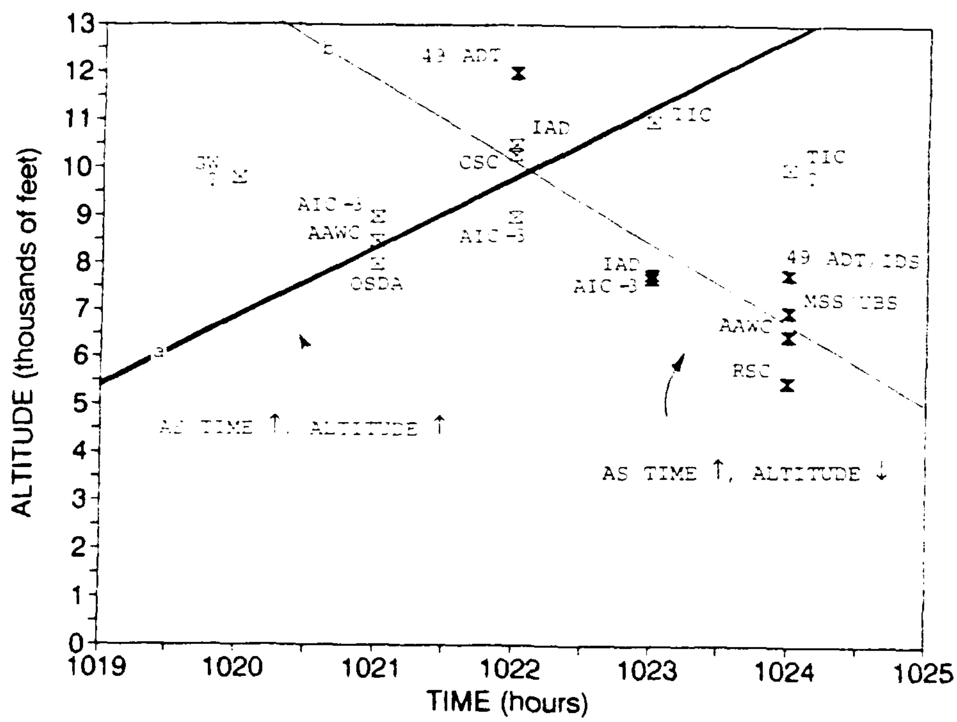


LEGEND

Hourglass with operator label** -- **Recollected data by witnesses not in close agreement with system data. Corresponds to "?" symbol in Table III-3 representing highly disparate entries.

Hourglass without operator label** -- **Remaining recollected data

Figure III-8. Recollected Data by Witnesses--Altitude versus Time with Highly Disparate Entries Labelled



LEGEND

Solid hourglass -- Recollected data by witnesses not in close agreement with system data. Corresponds to "?" symbol in Table III-3 representing highly disparate entries.

Empty hourglass -- Recollected data by witnesses in close agreement with system data. Corresponds to "" symbol in Table III-3.*

Hourglass with "?" next to operator label -- Data points that were not in agreement with either system or recollected data entries.

Figure III-9. Recollected Data by Witnesses--Altitude versus Time with all Data Entries Labelled that there was one aircraft that was descending in altitude. But, upon further analysis and labelling, the existence of two aircraft become apparent. Consequently, this divergence among the recollected data points probably accounts for the weak to moderate correlation coefficient of -.488.

To recap, patterns in the altitude versus time recollected data scatter plot show the existence of two aircraft. It was only until the data points were physically labelled and a disparity comparison was accomplished did this data set finally reveal some significant patterns. The first pattern as shown in Figure III-7 indicated that the contact was climbing. These data entries were within 2,000 feet of the system data set. The second pattern emerged in Figure III-8, where the highly disparate entries from Table III-3 were physically labelled on the graph. These entries were in excess of 2,000 feet of the system data, showing that as time passed, the contact was descending. Figure III-9 is a composite of Figures III-7 and III-8. Essentially, line "a" designates the flight path of Flight 655, which was climbing, and line "b" designates a descending flight profile.

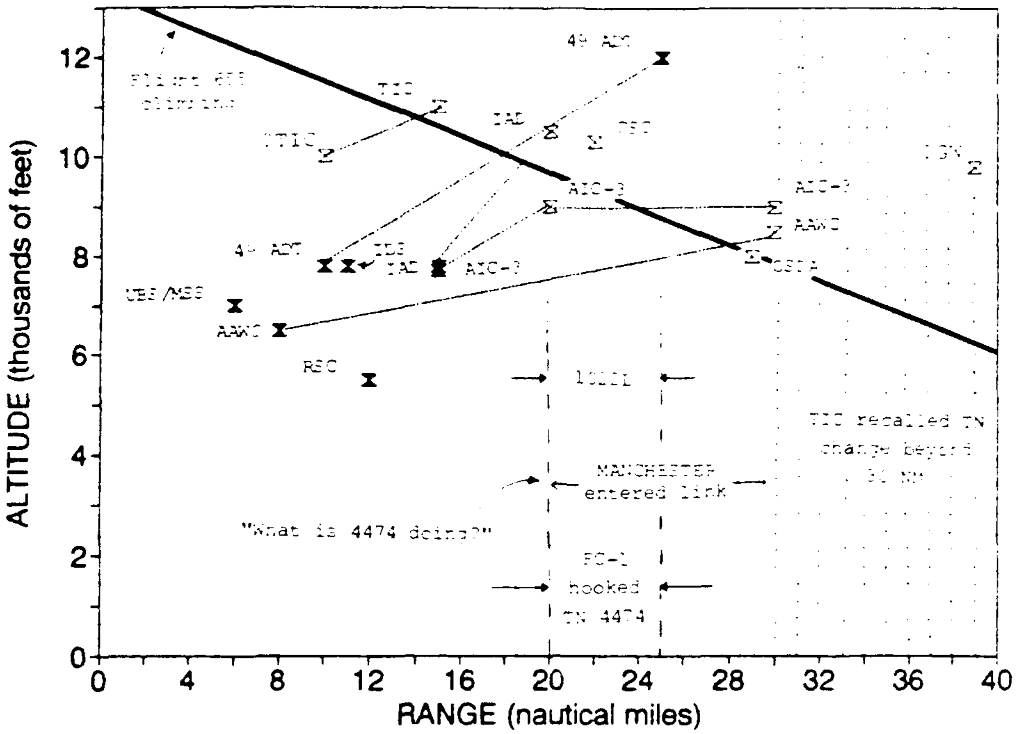
(2) Altitude verses Range

The next scatter plot, Figure III-10, involves another in depth analysis of recollected data. The empty hourglass symbols are those data points where crew member observations were in reasonable proximity to that of the system data on Flight 655 as extracted from the Aegis system data tapes. The entries with the solid hourglass symbol represent those data points, that when compared to the system data entries there is a large disparity as summarized in Table III-3. In Figure III-10, several crew members were within reasonable proximity to the data tape entries. However, as Flight 655 neared the *Vincennes* at about the 15 to 20 NM point, increased observations indicating that the aircraft was descending were noted. This tendency was particularly evident by the dashed lines among CIC members with multiple observations, which was directly contrary to what was happening in with Flight 655.

As depicted in Figure III-10, the TIC recalled that TN 4474 was changed to TN 4131 "somewhere beyond 30 NM." (Fogarty, 1988, p. 31) However, it is not clear whether he communicated this information over the net. It is interesting to note that CIC members were matching system data entries up until 1022L. After 1022L, their entries diverged from system data. Five CIC personnel who had double or triple entries all observed decreases from previous observations made a minute or two earlier as shown on Figure III-9.

It has been mentioned several times that 1022L was a critical time. It was critical for several reasons:

- *Vincennes* entered into the 20 NM weapons envelope for air-to-surface missiles.
- Captain Roger's asked, "What is 4474 doing?" He was not aware of the track number change. (Rogers, 1992)
- HMS *Manchester* entered into the Southern Persian Gulf link at or slightly before 1022L, bringing with it kinematics from an A-6 on a surface air combat patrol mission in the Gulf of Oman. The A-6 was coincidentally assigned a track number of TN 4474 by the *Spruance*. The track kinematics indicated high speed, 459 knots, and descending from 12,000 feet as the A-6 reported in to an E-2. (Rogers, 1992)



LEGEND

Solid hourglass symbol with operator label -- Recollected data by witnesses not in close agreementwith system data. Corresponds to "?" symbol in Table III-3 representing highly disparate entries.

Empty hourglass symbol with operator label -- Recollected data by witnesses in close agreement with system data. Corresponds to "" symbol in Table III-3.*

Empty hourglass symbol with "?" next to operator label -- Data points that were not in agreement with either system or recollected data entries.

Solid thick line depicts Flight 655 climbing in altitude.

Thin line between operator labels demonstrates trend.

Area between dashed line approximates the minute of 1022L which is based on system range entries correlating to the time of 1022L, which is the range between 25 to 20 NM. See Table III-1.

Dotted area beyond 30 NM corresponds to TIC remarks recalling the track number change to TN 4131 having occurred "somewhere beyond 30 NM." (Fogarty, 1988, p. 31)

At 20 NM, CO asked: "What is 4474 doing?" (Rogers, 1992)

UBS/MSS depicts two entries at the same (x,y) coordinate location.

Figure III-10. Recollected Data by Witnesses--Altitude versus Range Descriptive Scatter Plot

Additionally, according to the data as presented, the minute encompassing the time of 1022L is comprised of a nautical mile range of about 20 to 25 NM as illustrated in Figure III-10. The 49 ADT entry, the first of the highly disparate data entries, occurred at the 25 NM point at 1022L. He recalled an altitude of 12,000 feet, which is 3,600 feet higher than system data. According to Captain Rogers' recollection, reports were conveyed to the command console that the contact was descending from 12,000 feet at 459 knots. It was also at this time, as shown in Table III-1, FC-1 hooked TN 4474 at an altitude of 11,900 feet, range of 110 NM and speed of 448 knots. It should also be noted that the FC-1 hook of TN 4474 was only 100 feet lower than the 49 ADT altitude data point, which occurred in the 1022L time frame.

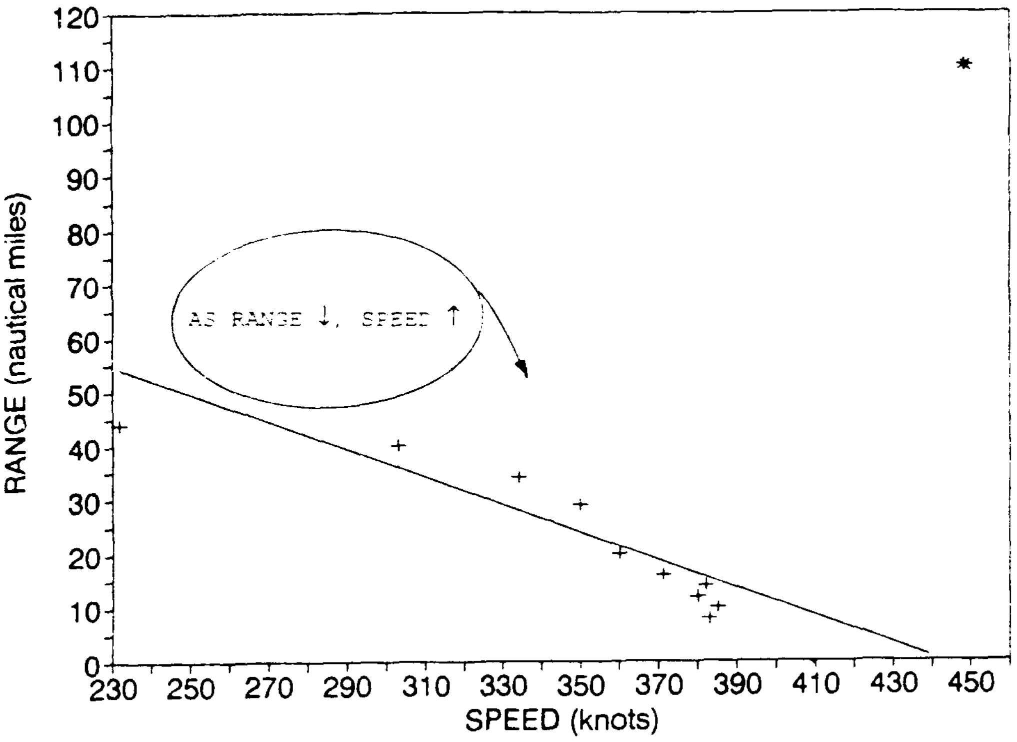
(3) Summary

To summarize, the scatter plots demonstrate the existence of two aircraft within the recollected data set. Comparisons were made between the recollected data entries and Captain Rogers' interview data as well as the FC-1 hook of TN 4474 from the system data set. These comparisons strongly suggest that the second aircraft was the A-6 in the Gulf of Oman. Further evidence supporting this statement will be presented when the speed variable is analyzed in the following section.

b. Comparative Scatter Plots between System and Recollected Data

(1) Speed Variable

Another relationship that has not yet been discussed involves speed, which is the fourth variable of interest. The system data in Figure III-11 shows



LEGEND

** -- TN 4474 hooked by FC-1 at 1022L for 5 seconds with RNG 110 NM, BRG 139, ALT 11,900, SPD 448 (Fogarty, 1988, p. 34).*

+ -- Flight 655

Figure III-11. System Data--Range versus Speed the following relationship: As the range decreased between the *Vincennes* and Flight 655 as indicated by the "+" symbol, the aircraft's speed was increasing steadily. Flight 655's lowest speed recorded by system tapes was at 232 knots at a range of 44 NMs. The highest speed that Flight 655 achieved was at 385 knots, ten miles from the *Vincennes* and two nautical miles prior to its shoot down. Meanwhile, the FC-1 hook of TN 4474, was traveling at a speed of 448 knots.

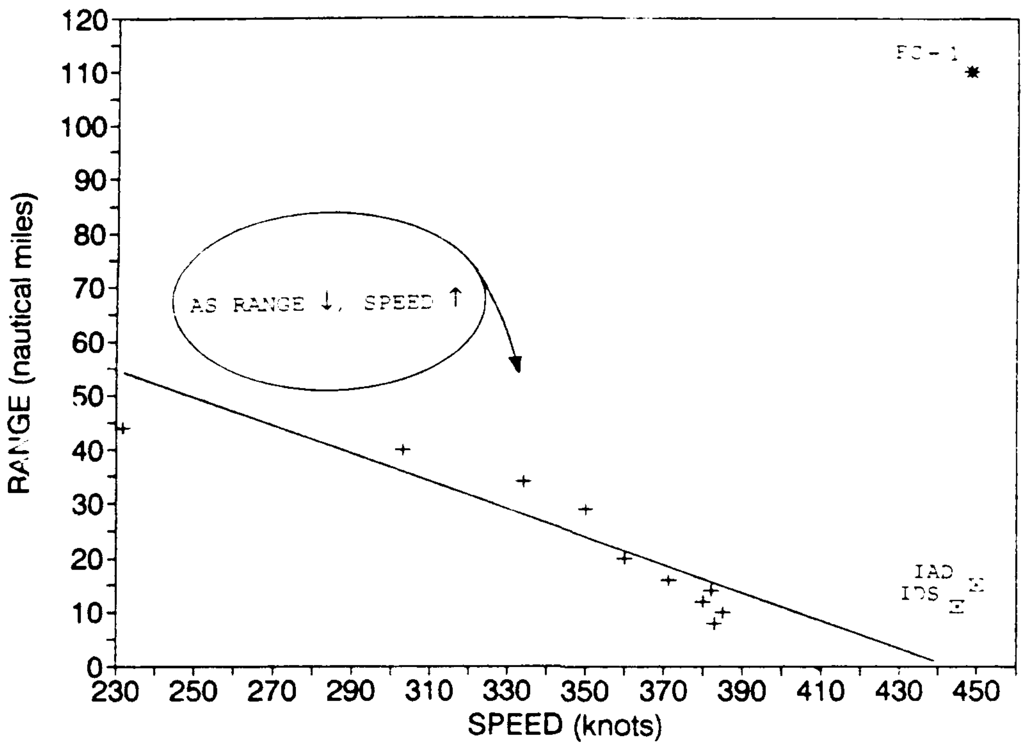
In addition to the above information, the speed recollected by the IDS and IAD were 450 and 445 knots, respectively. The FC-1 hook of TN 4474 data point along with the IDS and IAD entries are summarized in Table III-4. The speed values between all three entries are within five knots of the lowest and highest values and are depicted in aggregate in Figure III-12, which shows a close relationship among speed values, but the range of the FC-1 data point is at a 110 NM. However, when

TABLE III-4

SPEED SUMMARY

WHO	SPEED	ALTITUDE	RANGE
IAD	450	7800	15
IDS	445	7800	11
FC-1	448	11900	110

system data is plotted against the recollected speed data entries regarding speed and time, Figure III-13 reveals a near horizontal pattern between the IDS, IAD and FC-1 data



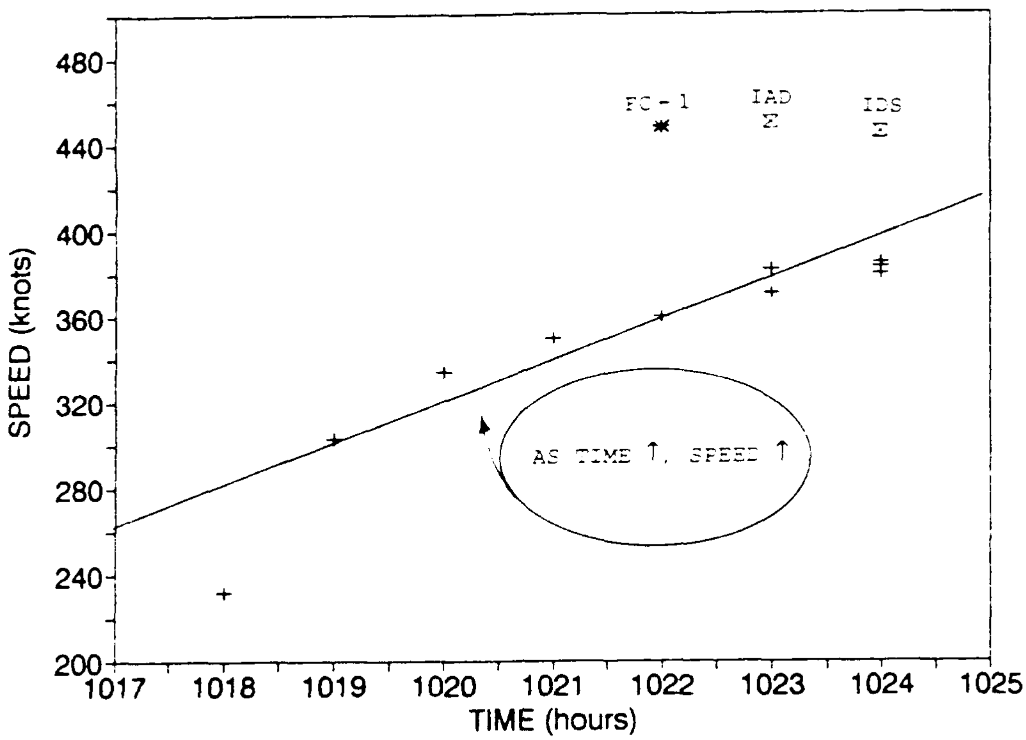
LEGEND

** -- TN 4474 hooked by FC-1 at 1022L for 5 seconds with RNG 110 NM, BRG 139, ALT 11,900, SPD 448 (Fogarty, 1988, p. 34).*

+ -- Flight 655

Hourglass symbol -- Recollected data points

Figure III-12. System and Recollected Data Combined--Range versus Speed



LEGEND

* -- *TN 4474 hooked by FC-1 at 1022L for 5 seconds with RNG 110 NM, BRG 139, ALT 11,900, SPD 448 (Fogarty, 1988, p. 34).*

+ -- *Flight 655*

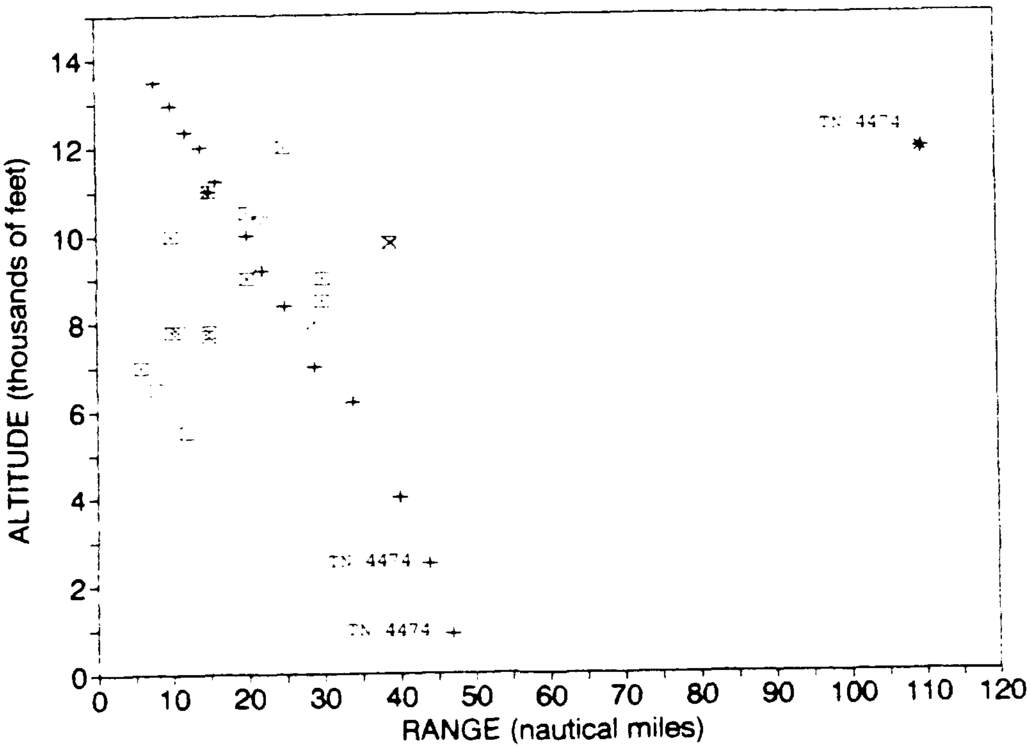
Hourglass symbol -- Recollected data points

Figure III-13. System and Recollected Data Combined--Speed versus Time entries. In addition to the preceding information, Captain Rogers indicated that at the 20 NM point, he asked, "What is 4474 doing?" In reply to his question, he stated that an unidentified console operator reported the contact was at 12,000 feet and descending at 459 knots. (Rogers, 1992) This speed value Captain Rogers recalled fits well with the speed values obtained from the FC-1 hook of TN 4474 and the IAD and IDS observations. Based on the graphical analysis along with Captain Rogers' account regarding the A-6 aircraft, the IAD, IDS, and the FC-1 hook entry of TN 4474 appear to be related.

(2) Altitude versus Range

A comparative graphical analysis between system and recollected data was accomplished using the variables of altitude and range. Figures III-14a and III-14b demonstrate an interesting trend using all "raw" data points as provided in Tables III-1 and III-2. In both graphs, the "+" symbol represents Flight 655, while the hour glass symbol represents recollected data points. The "*" symbol represents the FC-1 hook of TN 4474, which is a system data entry. As shown by the linear fit in Figure III-14b, the range decreased as the Flight 655's altitude increased. Also, a line was fitted through the recollected data points, which shows that as the range decreased, the altitude also decreased.

In addition, a further distinction between system data and recollected data is demonstrated in Figure III-14b, where the empty hourglass symbol means reasonable recollected data entries and a solid hourglass symbol means highly disparate recollected data entries. The empty hour glass symbology shows that CIC



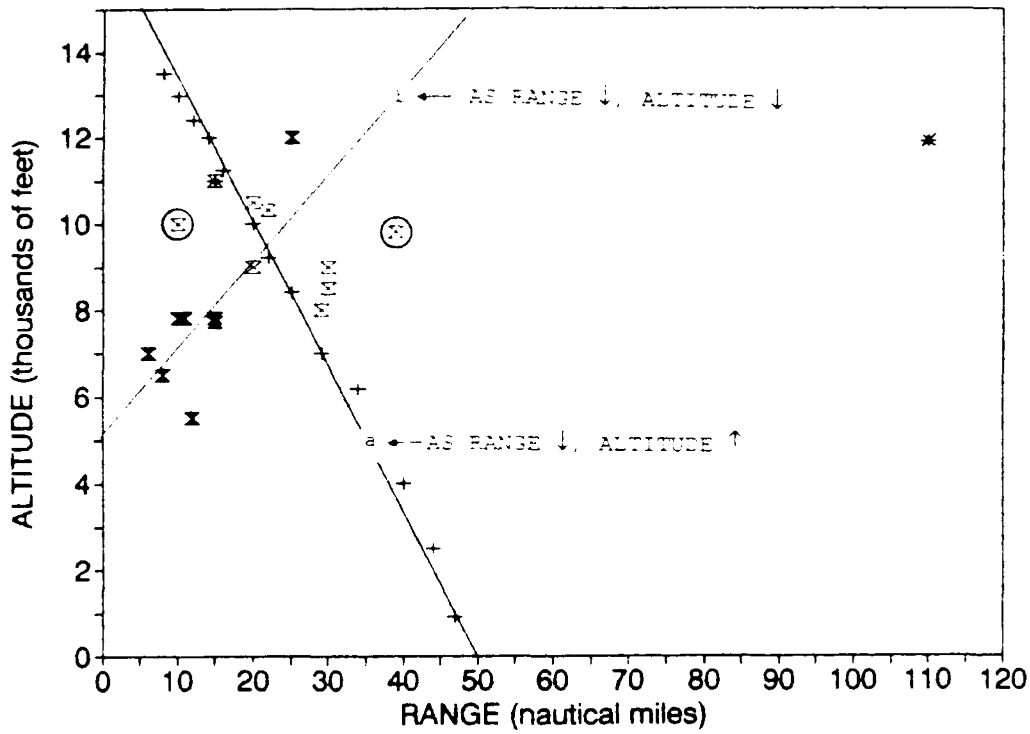
LEGEND

** -- TN 4474 hooked by FC-1 at 1022L for 5 seconds with RNG 110 NM, BRG 139, ALT 11,900, SPD 448 (Fogarty, 1988, p. 34).*

+ -- Flight 655

Hourglass symbol -- Recollected data points

Figure III-14a. System and Recollected Data Combined--Altitude versus Range



LEGEND

** -- TN 4474 hooked by FC-1 at 1022L for 5 seconds with RNG 110 NM, BRG 139, ALT 11,900, SPD 448 (Fogarty, 1988, p. 34).*

+ -- Flight 655

Hourglass symbol -- Recollected data points

Solid hourglass symbol -- Recollected data by witnesses not in close agreement with system data. Corresponds to "?" symbol in Table III-3 representing highly disparate entries.

Empty hourglass symbol -- Recollected data by witnesses in close agreement with system data. Corresponds to "" symbol in Table III-3.*

Empty hourglass symbol with circle -- Data points that were not in agreement with either system or recollected data entries.

Figure III-14b. System and Recollected Data Combined--Altitude versus Range

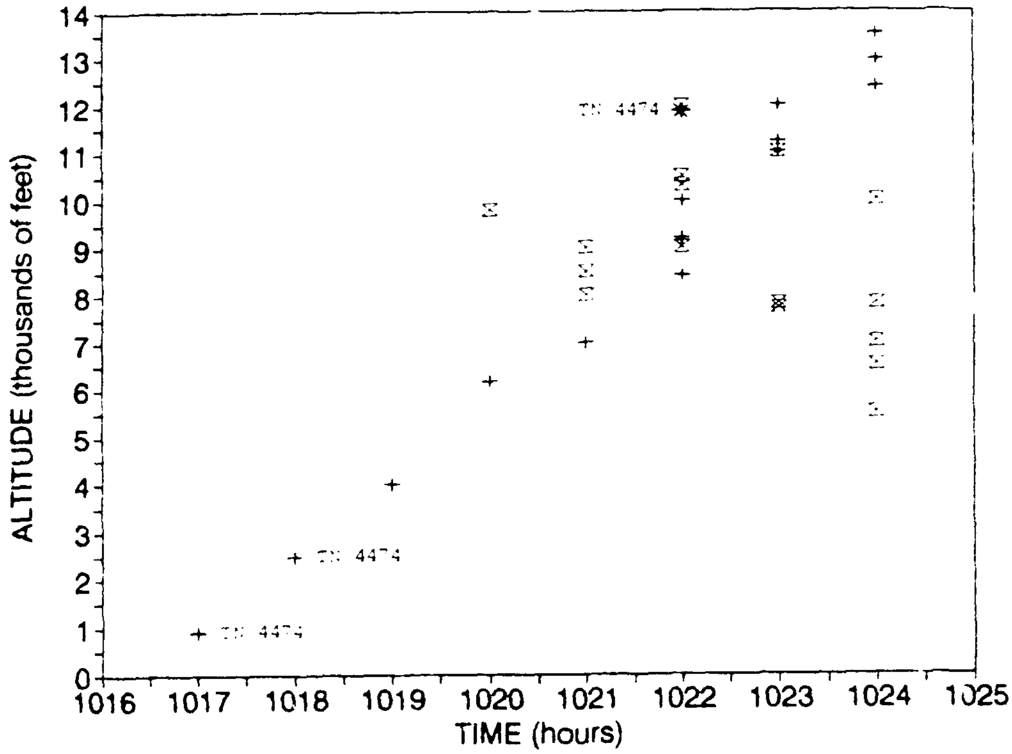
personnel were in agreement with system data, while the solid hourglass symbology demonstrates that CIC crew members were seeing the contact descend. As shown by the comparative scatter plots, an aircraft cannot be simultaneously ascending and descending, which is a paradox and further confirms the existence of a second aircraft. The next section provides further analysis of this seemingly contradictory event.

(3) Altitude versus Time

A comparative graphical analysis is conducted between system data entries from Table III-1 and recollected data entries from Table III-2 and are depicted in Figures III-15a and III-15b using altitude and time variables. At 1022L, there is an intersection and subsequent divergence between actual and recollected data entries. This type of divergence was observed within the recollected data set itself (Figure III-9) in that up until about 1022L, crew members' observations were congruent with the system data. After 1022L, the witness data points became progressively less congruent with system data entries.

Upon viewing these figures, it is also pertinent to note that at 1022L, 49 ADT recalled Flight 655 at 12,000 feet, which was an exceptionally high data point when compared with the other altitude entries, both actual and perceived, with the exception of the FC-1 hook entry. The FC-1 data entry reflected the kinematics of an aircraft associated with a track of 4474. Its altitude is practically the same as the 49 ADT observation. This also coincides with Captain Roger's account regarding altitude.

In Figure III-15b, the system data, "+" symbol, shows that Flight 655 was ascending over time while the perceived data entries, the solid hourglass symbol,



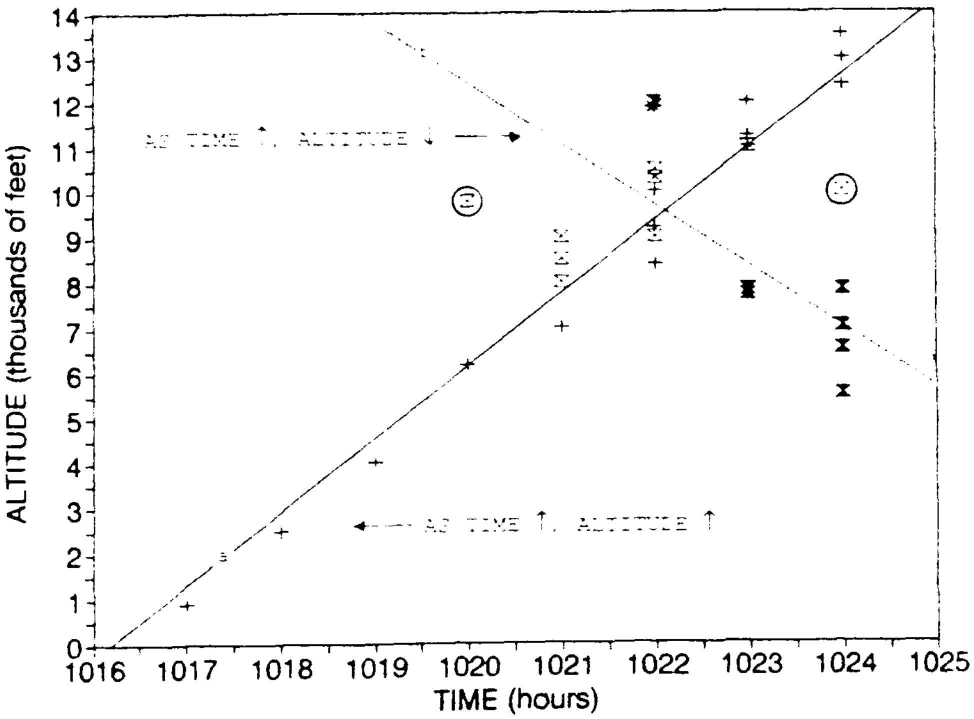
LEGEND

** -- TN 4474 hooked by FC-1 at 1022L for 5 seconds with RNG 110 NM, BRG 139, ALT 11,900, SPD 448 (Fogarty, 1988, p. 34).*

+ -- Flight 655

Hourglass symbol -- Recollected data points

Figure III-15a. System and Recollected Data Combined--Altitude versus Time



LEGEND

** -- TN 4474 hooked by FC-1 at 1022L for 5 seconds with RNG 110 NM, BRG 139, ALT 11,900, SPD 448 (Fogarty, 1988, p. 34).*

+ -- Flight 655

Hourglass symbol -- Recollected data points

Solid hourglass symbol -- Recollected data by witnesses not in close agreement with system data. Corresponds to "?" symbol in Table III-3 representing highly disparate entries.

Empty hourglass symbol -- Recollected data by witnesses in close agreement with system data. Corresponds to "" symbol in Table III-3.*

Empty hourglass symbol with circle -- Data points that were not in agreement with either system or recollected data entries.

Figure III-15b. System and Recollected Data Combined--Altitude versus Time indicates that the contact was descending over time. The "*" symbol represents the FC-1 hook of track 4474, which is practically superimposed over the 49 ADT data entry. Kinematic information concerning TN 4474 from the *Manchester* was already in the system in order for the FC-1 to hook TN 4474 and actually obtain kinematic information. Otherwise, TN 4474 would have still been in track number storage. The next question is whether the FC-1 hook of TN 4474 data point, 49 ADT, IDS, IAD, RSC, AAWC, TIC, AIC-3, MSS, and UBS entries are related or not. How do they compare with Captain Rogers' account? To answer these questions, some refinement of data had to be accomplished. This is the topic of discussion for the next section.

c. Summary

In summary, the comparative analysis between system and recollected data show a strong indication that CIC personnel were actually seeing kinematics from another aircraft having the same track number as the *Vincennes'* original track number initially designating Flight 655 departing Bandar Abbas at 1017L. The inclusion of the speed variable augments this assessment when compared with the FC-1 hook of TN 4474 and is further corroborated with the interview data from Captain Rogers.

5. Further Refinement of Recollected Data

When analyzing the data, it appeared that there was latitude for further refinement, particularly in the recollected data set. This assessment was based on the degree of disparity between actual and perceived data entries as shown in Table III-3.

(See Appendices D and E, Groups 7 and 8, for the refined data set listing and correlation coefficient summary and Appendix F for regression analysis.)

Basically, the refinement process resulted in the removal of several data points. First the GW and TIC entries that seemed "off" or out of place were removed, for they lacked synchronization with the both the recollected and system data. This could possibly be due to GW and TIC's unclear recollection or could be the result of the investigation team having difficulty in estimating chronologically when and where these observations occurred in conjunction with other events going on at the same time. These entries were designated with a "??" in Table III-3.

Secondly, the data points in the recollected data set that seemed reasonably close (within 2000 feet or 3 NM) to the actual entries as extracted from the system data tapes were also removed. This included various entries from AIC-3, AAWC, OSDA, CSC, IAD and TIC all designated by an asterisk "*" in Table III-3. The rationale behind this action was to assess the linearity of the perceived data that was highly disparate with the system data obtained from the Aegis data reduction tapes as designated with a "?" symbol in Table III-3. In other words, the six reasonable entries were distorting the "highly disparate" perceived data entries. The data that were out of place (GW and TIC entries) and the data that matched what was going on in the real ascent of Flight 655 were removed, leaving behind a "filtered" data set of recollected observations of the perceived Flight 655. This was accomplished to assess the remaining recollected data's linearity and compare it with the actual flight path based on the system data tape entries. As can be seen in Appendix E, Correlation Coefficient Summary, all coefficient values from Group 7, Refined Recollected Data from Witnesses data set, indicate a strong correlation between, altitude versus range, altitude versus time and range versus time. This is especially apparent when compared to the correlation coefficients in the recollected data by witnesses, Group 2, data set.

Figure III-16 shows the refined recollected data in a scatter plot. Again, altitude is provided in feet (y-axis), while time is in minutes and based on a 24 hour clock (x-axis). The negative slope indicates that as time progressed, the aircraft's height was descending. The correlation coefficient is -.842, indicating a strong linear tendency. Essentially, these data appear related.

This refinement was taken one step further by adding the system data outlier, FC-1 hook of TN 4474, to the reconstructed recollected data as shown in Figure III-17. The negative slope indicates that as time progressed, the altitude decreased, which means that the contact was descending. The correlation coefficient is strong at -.899 as visually evidenced by the scatter plot.

In summary, the refined recollected data shows an even tighter relationship among the data points. These graphs also display an aircraft as seen by eight crew members descending in altitude, which is contrary to the flight path of Flight 655. The FC-1 hook of TN 4474 fits well with the refined recollected data, and a strong relationship among the data points is also realized. Essentially, the data point associated with the FC-1 hook of TN 4474 that appeared to be an anomaly in system data "bridges the gap" between system and recollected data regarding the existence of two aircraft. Although the FC-1 data point is not related to the system data, it is related to the refined

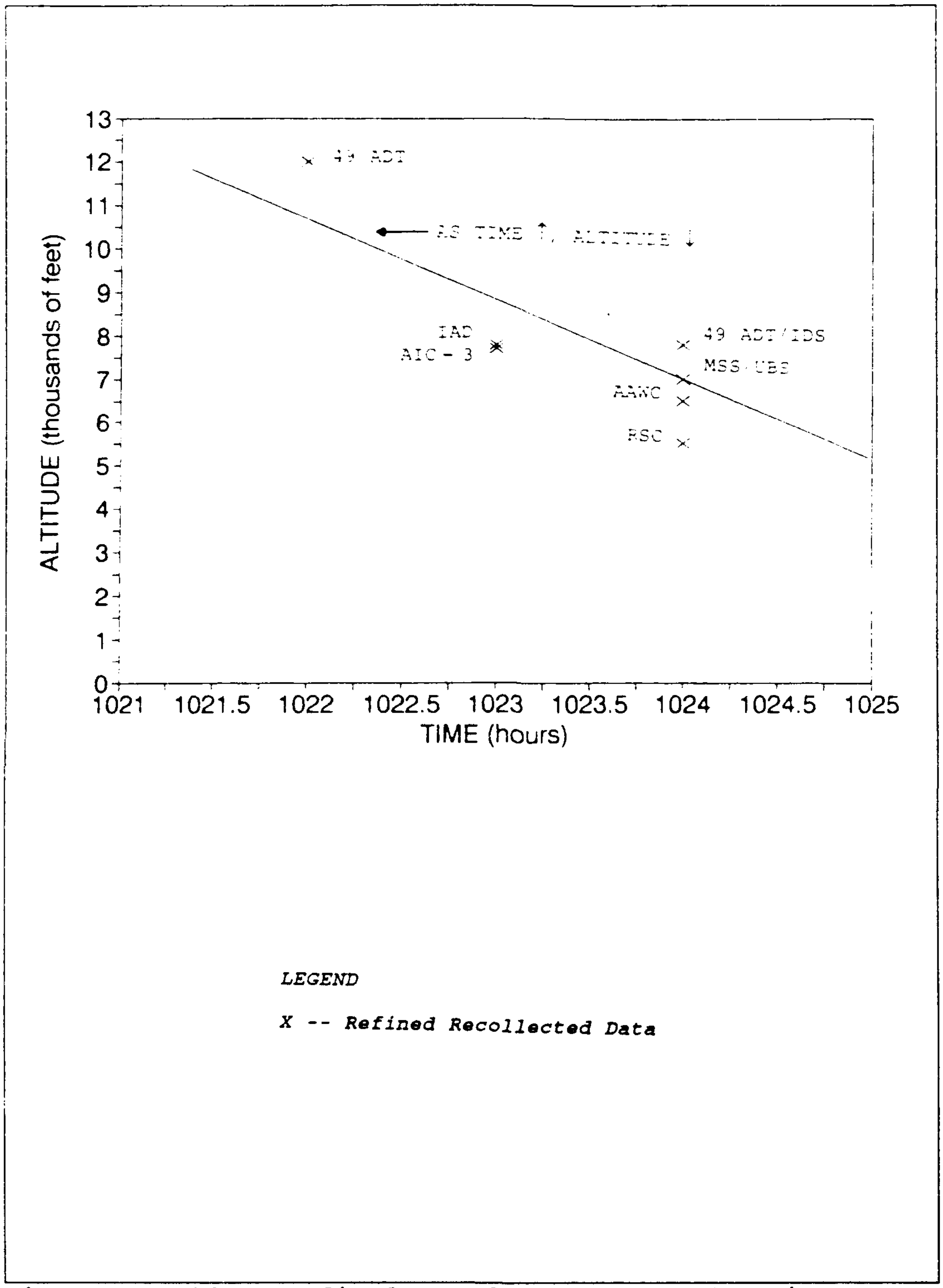
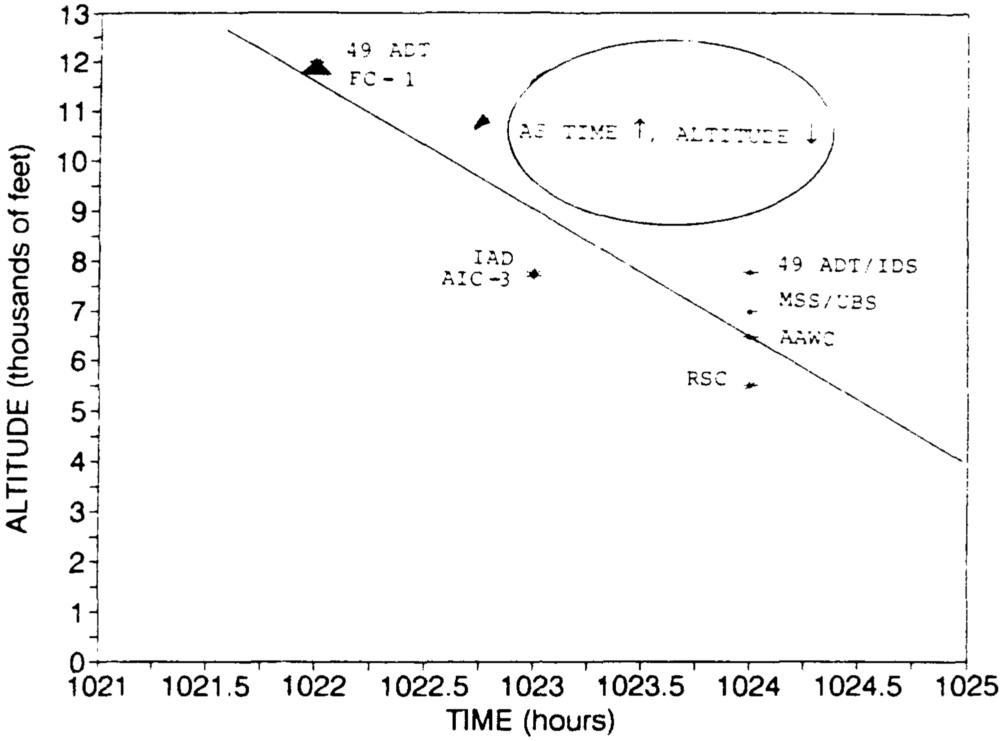


Figure III-16. Refined Recollected Data by Witnesses--Altitude versus Time



LEGEND

** -- Refined Recollected Data*

Solid triangle -- FC-1 hook of TN 4474

Figure III-17. Refined Recollected Data with the FC-1 Hook of TN 4474--Altitude versus Time

recollected data. This indicates that the second aircraft's kinematics were in the Aegis system. Coupling this information with Captain Rogers' interview data, the crew members were probably seeing kinematics from the A-6 that happened to be assigned a track of 4474, which was the *Vincennes'* original track designation of the "unknown-assumed enemy" contact from Bandar Abbas. All these relationships and their interrelationships with each other emphatically demonstrate that the other aircraft was the A-6 in the Gulf of Oman. This is explicitly shown in the next section.

6. Comparison between System and Refined Recollected Data

A comparison between system and refined recollected data, altitude versus range data points, is illustrated in Figure III-18. Line "a" shows that as the range decreased, the altitude increased, delineating the flight pattern of Flight 655 ("+" symbol). As signified by line "b," as range decreased, the A-6 ("X" symbol) decreased as well. The "*" entry is the FC-1 hook of TN 4474. The majority of witnesses recalled Flight 655 as descending, starting at 15 NM, which also corresponds with general exclamations being made within the CIC that the aircraft was descending.

Altitude versus time entries from system data and reconstructed recollected data were merged as shown in the following scatter plot, Figure III-19. Again, another distinct pattern emerges, showing a clear linear ascent on one hand, and on the other, a clear linear descent. The kinematic information and the analysis provided so far indicates that two separate aircraft were being tracked, one that was climbing, which in reality was Flight 655, and another that was diving, which was the A-6 in the Gulf of Oman.

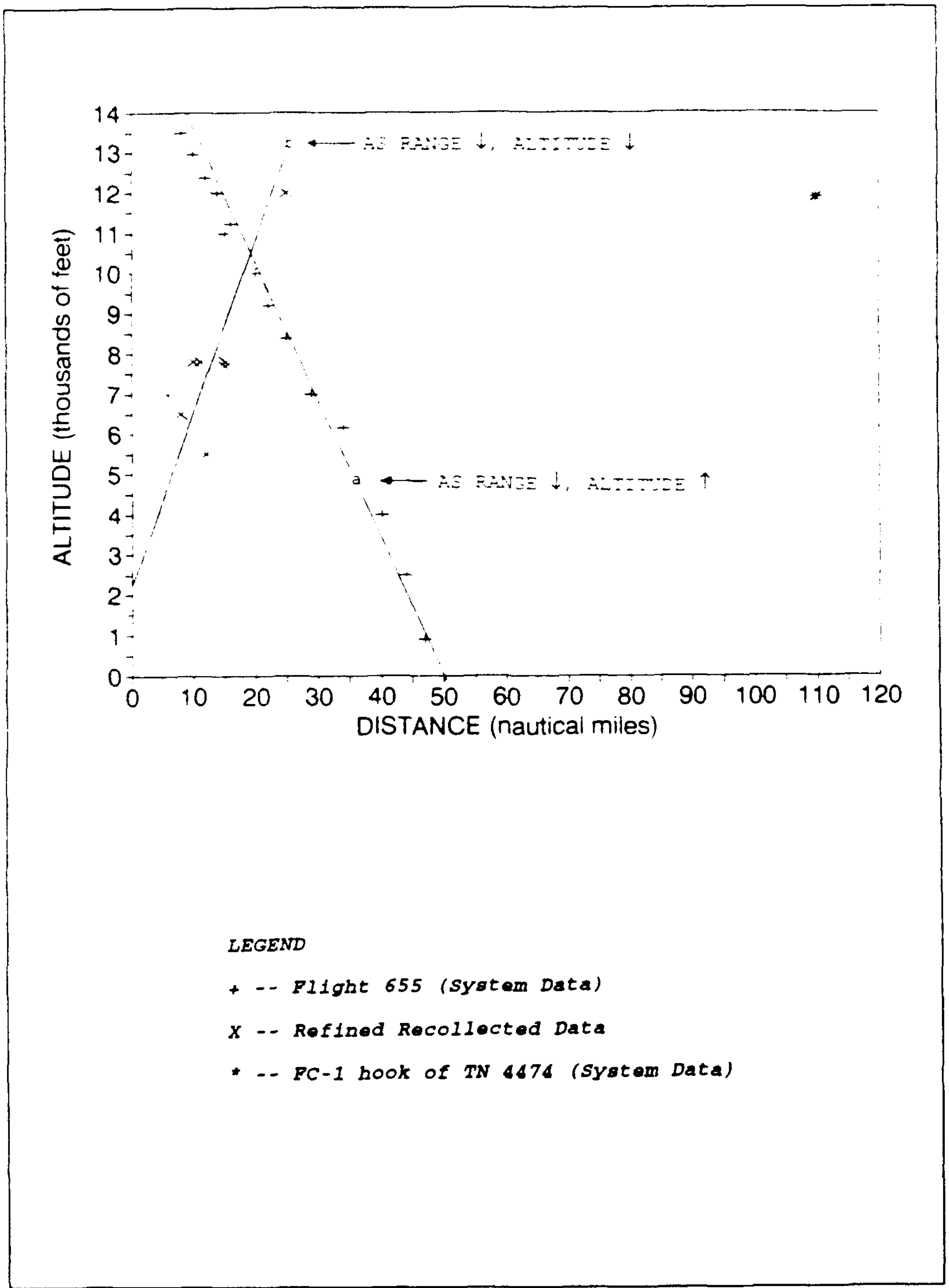


Figure III-18. Comparison between Refined Recollected, System, and FC-1 Hook of TN 4474 Data Entries--Altitude versus Distance

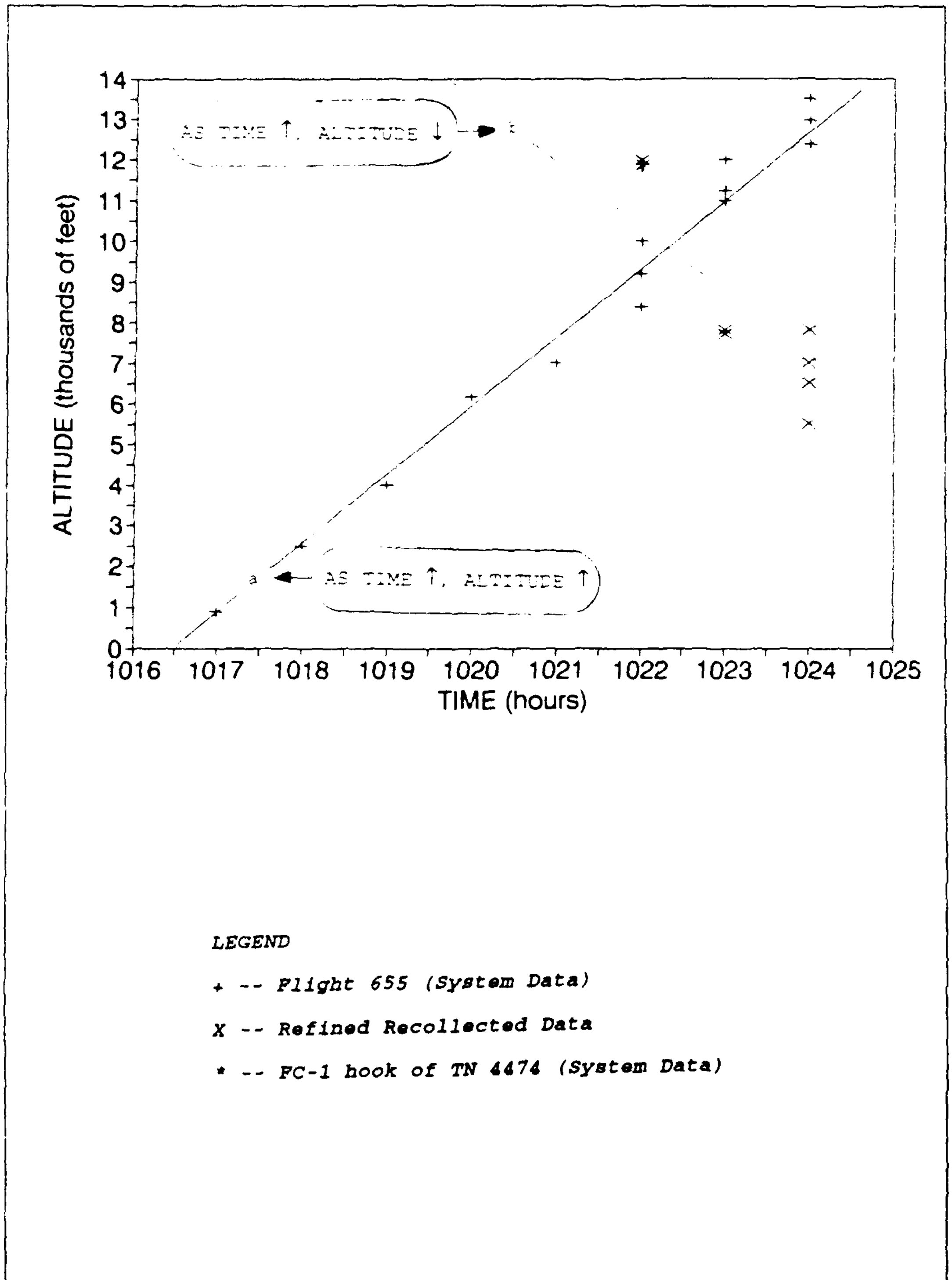


Figure III-19. Comparison between Refined Recollected, System, and FC-1 Hook of TN 4474 Data Entries--Altitude versus Time

7. Conclusion

In summary, system data show Flight 655 continuously climbing and suggests the existence of two aircraft. Although recollected data show the contact to be descending and points to the existence of only one aircraft, further analysis on the recollected data by witnesses data set again suggests the existence of two aircraft.

Up until 1022L various CIC crew members matched system data entries, indicating a climbing profile; but, after 1022L, they progressively diverged from the system data entries, indicating a descending flight profile. This finding called for further comparative analysis between system and recollected data. This additional analysis clearly demonstrated the existence of two aircraft, especially when the speed variable was included in the analysis.

Because of the disparity between system and recollected data, additional refinement of the recollected data was needed. The highly disparate data points were analyzed and compared with the FC-1 hook of TN 4474 data point. The results of this comparison show a distinctly descending flight profile and a strong linear relationship. And, lastly, the system data were compared with the refined recollected data and an even more definitive set of trends emerges showing the existence of two aircraft.

The question as to the other aircraft's identity is inferred when compared to Captain Rogers' interview data. Namely, it is probable that various crew members aboard the *Vincennes* were detecting kinematic information from a second aircraft, an A-6, having the same track number as was originally designated to the unknown-assumed enemy contact of interest initially detected from Bandar Abbas. Even without Captain

Rogers' interview data to serve as an avenue of comparison, the graphs still indicate the existence of a second aircraft, but its identity may not have been known.

Additionally, the above graphical analysis and conclusion also supports Captain Rogers' account regarding the track number sequence as presented earlier in this chapter. Although the FC-1 hook entry of TN 4474 appeared as an anomaly throughout Chapters II and III, in reality it was not. The same goes for the 49 ADT, AIC-3, IAD, RSC, IDS, AAWC, UBS and MSS observations. It is the opinion of this author that the eight CIC members listed above were not in all instances "misreading altitude" (Senate Hearing, 1988, p. 16) due to "stress" and "scenario fulfillment", which were originally identified as being primary causes for this divergence between recollected and system data entries (Fogarty, 1988, p. 45). The relationships are too consistent. The cause of this divergence and subsequent chain of events is attributed to the CIC's inability to identify and detect that there were two aircraft involved, which is one part of an overall systemic problem to be discussed in detail in the Chapter IV.

NOTES

1. As a result of the integration of these two categories of data to produce a chronology, there may be inconsistencies in the sequencing of events--they may not be an exact replication of what happened.

2. Recommendations from the Fogarty report also included:

No disciplinary of administrative action should be taken

Send a message to Iran recommending aircraft fly at an altitude of 25,000 feet to minimize the risk of another accidental shoot down

No change to existing Rules of Engagement

Urge the International Civilian Aviation Organization to issue an immediate NOTAM

Revise voice warnings to be more specific to include geographical positional references and IFF mode

Strengthen the Middle East Force "inchop briefs" to include an in depth review of the unique problems associated with the commercial air picture for that region

Continue the liaison efforts with Air Traffic Control agencies and American Embassies to resolve commercial air problems

Strengthen the AAWC position in the CIC organization

Incorporate the CIC organization modification required by Persian Gulf operations into the existing Battle Doctrine. Golf Whiskey should not be given the responsibility as a radio telephone talker

Determine cause of net 15/16 degradation due to loading

Redesign Aegis large screen display (LSD) to allow for altitude to be directly displayed on the LSD

Devise a means to slave the Remote Control Indicator (RCI) challenge gate to a hooked track

Train in a low intensity environment, real or simulated

Develop a fleet wide identification matrix for dense air traffic environments

Conduct exercises that challenge the deconfliction capabilities of surface ships with and without VID

Review Aegis IFF operator training procedures and ensure operator familiarity of pros and cons of various RCI selective modes (1988, pp. 51-53)

3. C & D System from page 4. The following information concerning the Aegis Command and Decision System is extracted from the Configuration Definition Document for Aegis Guided Missile Cruiser Combat System (CG 65-73), Second Issue, CG 47 Class CDRL J016, November 1991, as prepared by the Government Electronic Systems Division, General Electric Company:

The Command and Decision (C & D) System performs control and integration functions for the Aegis Combat System. It is the focal point for the collection, correlation, analysis, and presentation of tactical data required to effectively employ the Aegis Weapon System. C & D integrates sensor data, data link information, threat data, operator inputs, and weapons status in a manner responsive to battle management and task force defense requirements. Figure III-20 is a schematic of the Aegis Combat System.

More specifically, C & D collects and correlates sensor data from ship sensors and data links, and disseminates these data to the appropriate console operators. C & D manages the track file, performs track identification, issues automatic engagement orders when authorized by doctrine, and provides weapon assignment recommendations to the console operators to aid them in making efficient use of sensor data and the weapon systems. Figure III-21 is a schematic of the C & D System.

4. The air engagement was a complicated sequencing of events. One of the most difficult aspects of this sequence was to understand how the track numbers fit in. Not that the track numbers were an overriding contribution to the airliner shoot down, they were but one small piece of a complex puzzle that was compounded by other equally as important contributing factors. The description was deliberately simplistic to give the reader a flavor of what happened without getting swamped with detail. This description does not insinuate that the NTDS Link 11 or Aegis weapon system are trivial.

5. When the terms "hooked" or "in close control" were used in conjunction with a track number, it means that the operator has the track number, identification (ID), grid coordinates, course, speed, altitude, ID amplifying information, Mode I/II/III IFF received, tracking quality, bearing and range. A characteristic that could not be displayed nor discerned on the *Vincennes'* radar console was the size of the contact, regardless of aspect angle (Fogarty, 1988, p. 29).

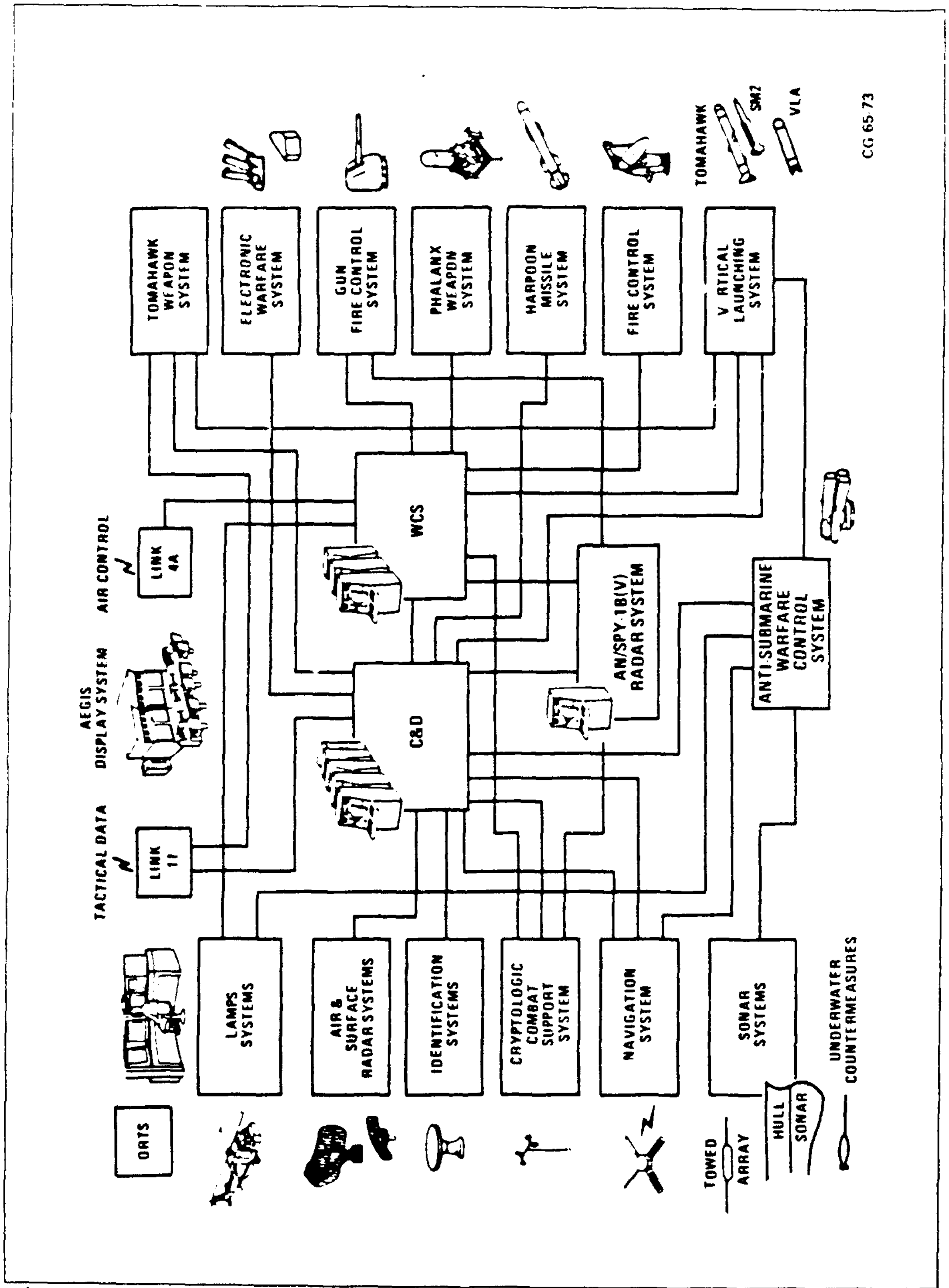


Figure III-20. Aegis Combat System Pictorial Diagram (Government Electronic Systems Division, 1991, p. 2-3)

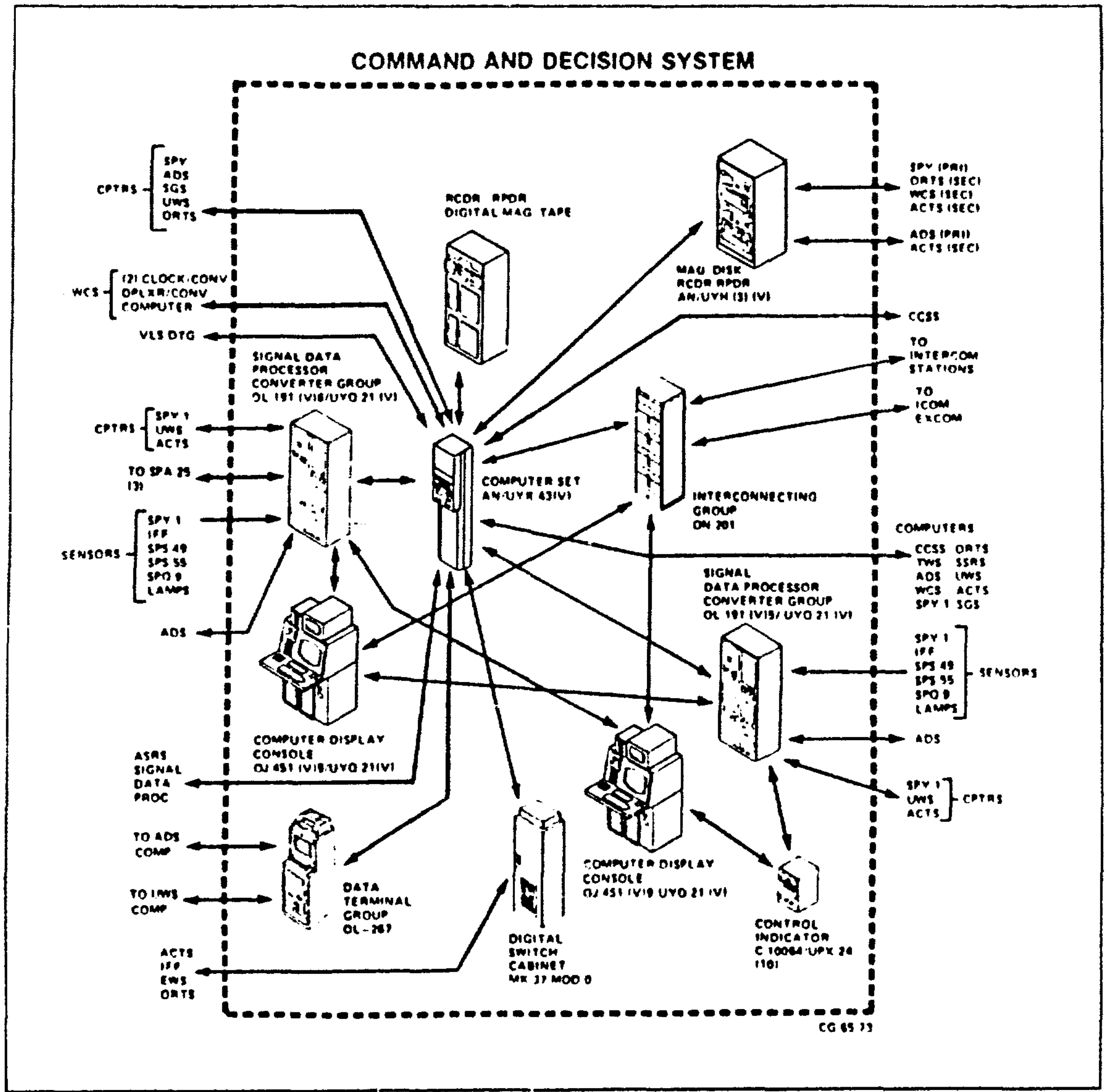


Figure III-21. Command and Decision System Pictorial Diagram (Government Electronic Systems Division, 1991, p. 3.2-2)

6. Also, another interview was held on 14 April 1992 with Lieutenant Terry Mosher, who served aboard an Aegis cruiser, the USS *Mobile Bay* (CG 53), in his previous assignment as Fire Control Officer, to help clarify some of the technical issues. Additionally, both the case, Chapter II, and the "Rogers' Interpretation" section of Chapter III were personally reviewed by Captain Rogers himself on 1 May 1992 to ensure accuracy.

7. Read graph legend carefully, "x" and "+" symbols will be used interchangeably, especially on the different comparative graphs.

IV. "CAUSAL FACTORS"

A. INTRODUCTION

In Chapter III, Analysis and Interpretation, the primary goal was to identify "the problem" in a quantifiable way. Based on both system and recollected data from witnesses as well as interview data from Captain Rogers, the data strongly suggested the existence of two aircraft, which led to the following question: How was it that the *Vincennes* could not identify and differentiate between two aircraft and consequently shoot down a commercial airliner, Iran Air Flight 655? To address this research question, Chapter IV is divided into three major sections. The first section primarily focuses on an event analysis of the *Vincennes'* air engagement; the second section, using a modified version of the Harvard Business School group dynamics model, takes a systemic approach to an analysis of the incident; and the third section develops a cybernetic model of the same events based on the concept of mutual causality.

B. IDENTIFICATION OF "CAUSAL FACTORS" USING AN EVENTS PATH MODEL

1. Introduction

Figure IV-1, Events Path Model of the *Vincennes'* Air Engagement, depicts a series of events/factors[1] that are arranged in chronological sequence from 1017L, the time that the contact was first detected by the *Vincennes*, to 1024L, the time when the contact was shot down. This linear model is broken down into external contextual and internal factors. External contextual factors were external to the *Vincennes* and are labelled **alphabetically**, while internal factors occurred within the *Vincennes*' Combat Information Center (CIC) and are labelled **numerically**. Additionally, it is assumed that some factors/events had a direct influence on others, such as, X brings Y into being, or makes Y smaller or larger, while other factors/events had an inverse effect.

2. Narrative

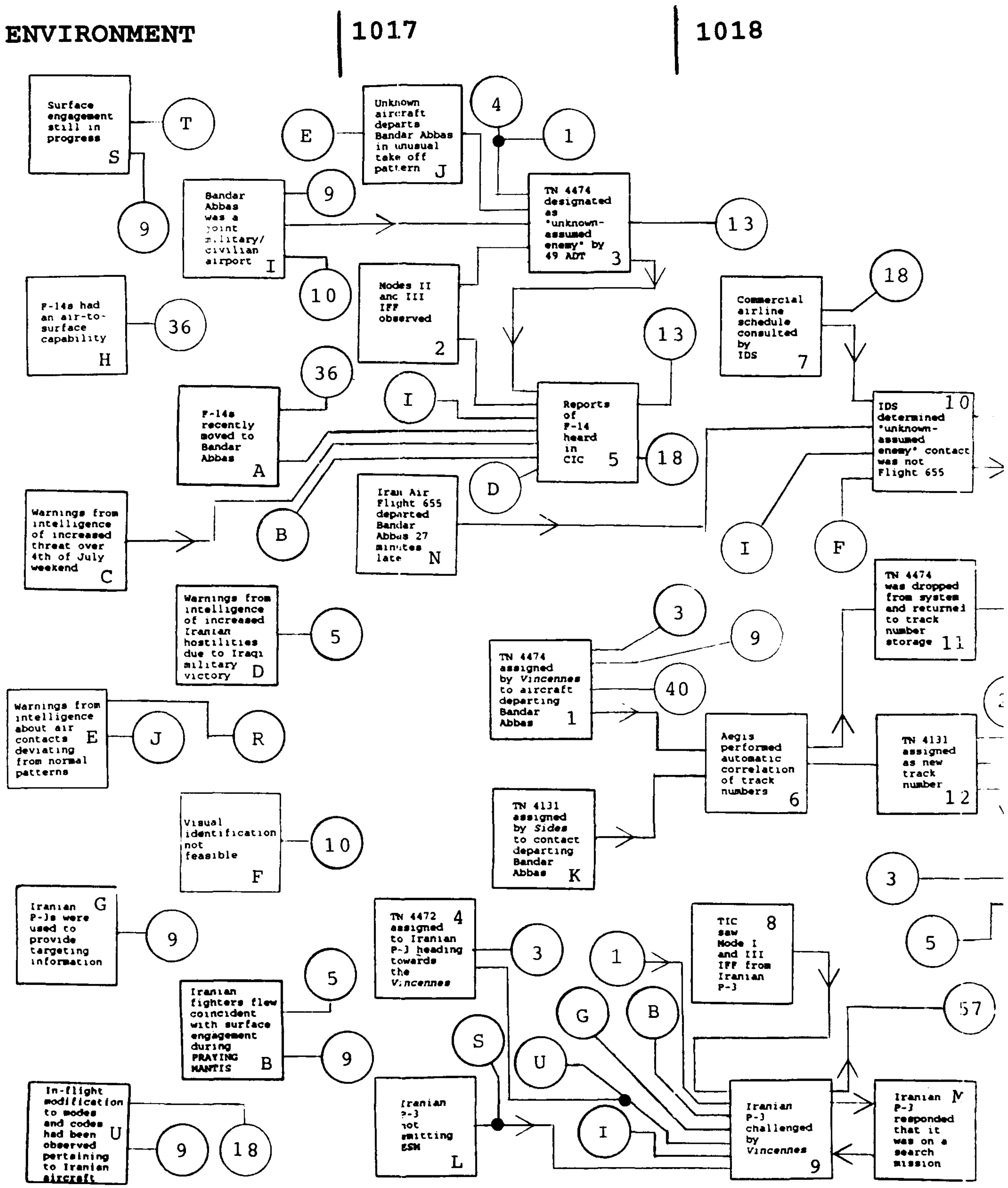
The main external contextual factors as recalled by Captain Rogers included the following environmental conditions: Intelligence warned of a possible Iranian retaliation for recent Iraqi victories **(D)** and of an increased threat over the Fourth of July weekend **(C)**. Intelligence briefings prior to the *Vincennes*' transfer to the Middle East Force specifically cautioned about aircraft not following normal, established patterns **(E)**. Iranian F-14s were recently deployed to Bandar Abbas **(A)** having an air-to-surface missile capability **(H)**. During Operation PRAYING MANTIS on 18 April 1988, Iranian fighters flew in conjunction with the surface engagement **(B)**, and Iranian P-3s were known to provide targeting information to third party forces during hostile activities **(G)**. Also, during this time, U.S. carriers remained outside the Persian Gulf, leaving no immediate means for visual identification to positively confirm aircraft identity **(F)**. Basically, this highly uncertain and potentially volatile environment was the local context within which the *Vincennes* was operating. (Fogarty, 1988, pp. 40-41)

As described, the external contextual factors serve as an overall backdrop for the subsequent set of internal factors with which the CIC organization had to contend.

Naturally, the simultaneity between internal and external factors and the impact that they had upon each other demonstrate the complexity inherent with a low intensity conflict[2] (LIC) combat situation as already shown pictorially and as will be reinforced through a narrative account outlining these causal relations.

Before proceeding further, it is essential to note that time is a contextual factor in and of itself, regarding the sequencing of events and the short time window within which Captain Rogers had to act. The most critical time of the air engagement occurred during the last 189 seconds, which was compounded by the 20 NM critical decision point at 1022L. It must be emphasized that Captain Rogers was under tight time constraints to synthesize a large amount of ambiguous, disjointed information and to make a decision as to whether to engage the aircraft or not. There was no time for information verification. (Rogers, 1992; 1990)

Before focusing on the air engagement, the surface engagement will be briefly discussed. As can be discerned from the Figure IV-1, the surface engagement was already in progress **(S)** when the air engagement sequence started and was still progressing after the contact was shot dov . In actuality, the surface engagement was Captain Rogers' primary concern due to the danger to personnel and equipment resulting from massed attacks by highly maneuverable gun boats. Gunfire between the *Vincennes* and Iranian Revolutionary Guard Corp (IRGC) forces was being exchanged, when at 1021L, gun mount 51 aboard the *Vincennes* malfunctioned **(T)**, which led the TAO to conduct radical maneuvers at high speed and large rudder angle to counter the threat **(20)**. This caused books, loose equipment and publications to fall from consoles and desks


ENVIRONMENT
1017
1018
Surface engagement still in progress S
T
9
Unknown aircraft departs Bandar Abbas in unusual take off pattern J
E
4
1
Bandar Abbas was a joint military/ civilian airport I
9
10
TN 4474 designated as "unknown-assumed enemy" by 49 ADT 3
13
Modes II and III IFF observed 2
Commercial airline schedule consulted by IDS 7
18
F-14s had an air-to-surface capability H
36
36
13
F-14s recently moved to Bandar Abbas A
I
Reports of F-14 heard in CIC 5
18
IDS determined "unknown-assumed enemy" contact was not Flight 655 10
D
Iran Air Flight 655 departed Bandar Abbas 27 minutes late N
Warnings from intelligence of increased threat over 4th of July weekend C
B
I
F
Warnings from intelligence of increased Iranian hostilities due to Iraqi military victory D
5
3
9
TN 4474 was dropped from system and returned to track number storage 11
TN 4474 assigned by Vincennes to aircraft departing Bandar Abbas 1
40
Warnings from intelligence about air contacts deviating from normal patterns E
J
R
Aegis performed automatic correlation of track numbers 6
TN 4131 assigned as new track number 12
TN 4131 assigned by Sides to contact departing Bandar Abbas K
Visual identification not feasible F
10
3
Iranian P-3s were used to provide targeting information G
9
TN 4472 assigned to Iranian P-3 heading towards the Vincennes 4
3
1
TIC saw Mode I and III IFF from Iranian P-3 8
5
Iranian fighters flew coincident with surface engagement during PRAYING MANTIS B
5
9
G
B
57
S
U
Iranian P-3 not emitting ESM L
I
Iranian P-3 challenged by Vincennes 9
Iranian P-3 responded that it was on a search mission M
In-flight modification to modes and codes had been observed pertaining to Iranian aircraft U
9
18

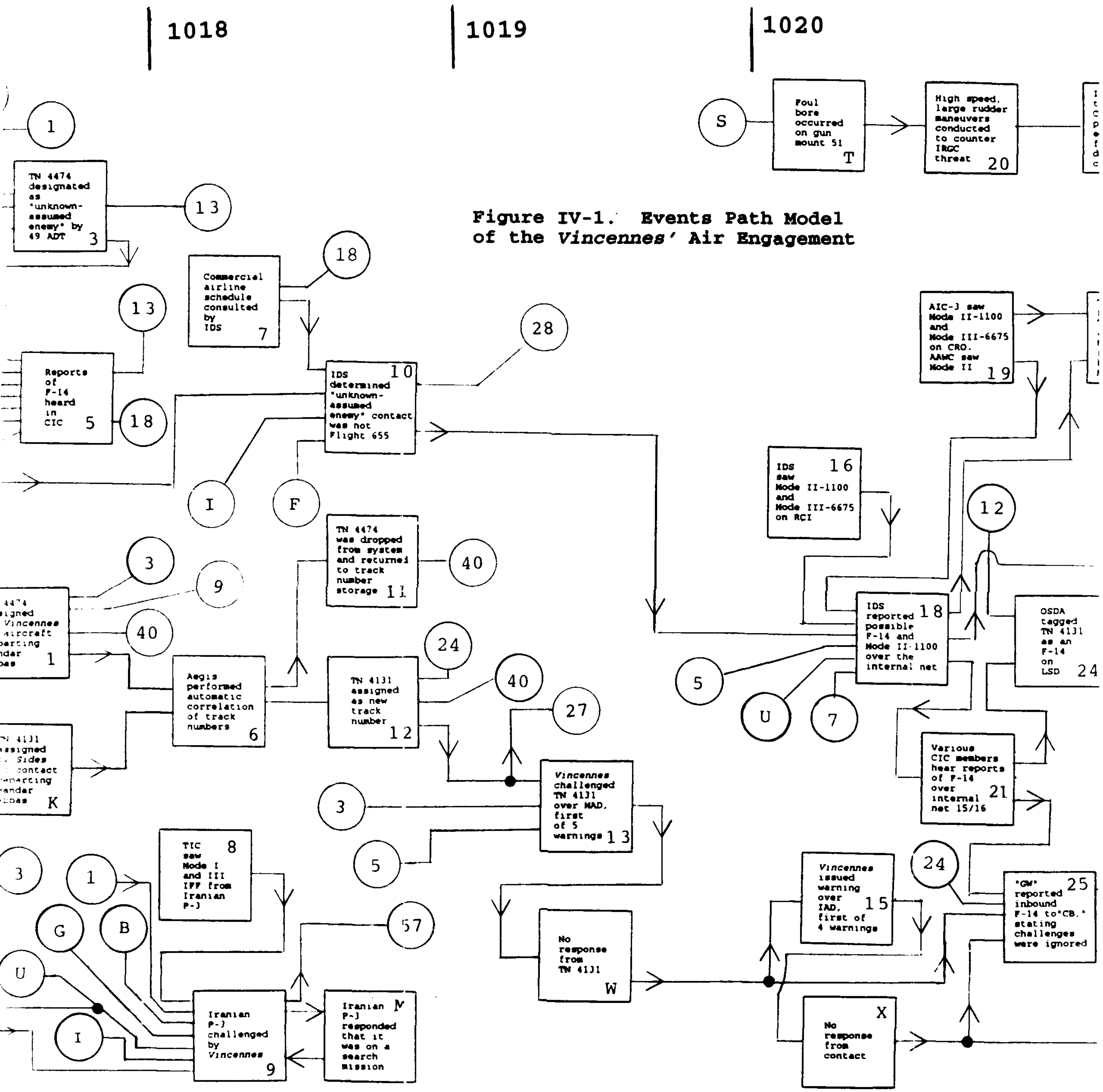
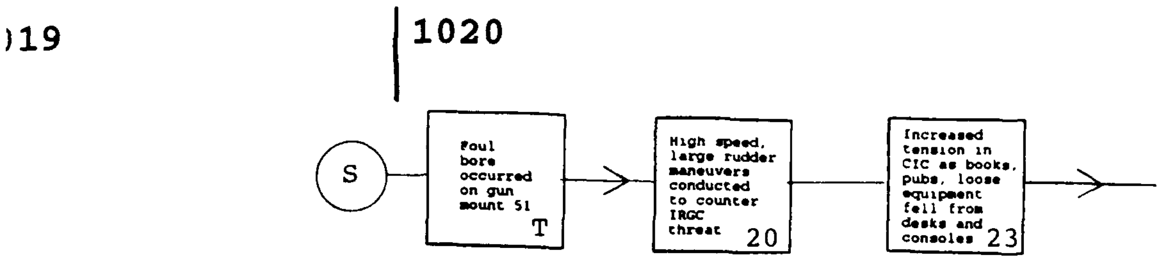


Figure IV-1. Events Path Model of the *Vincennes'* Air Engagement



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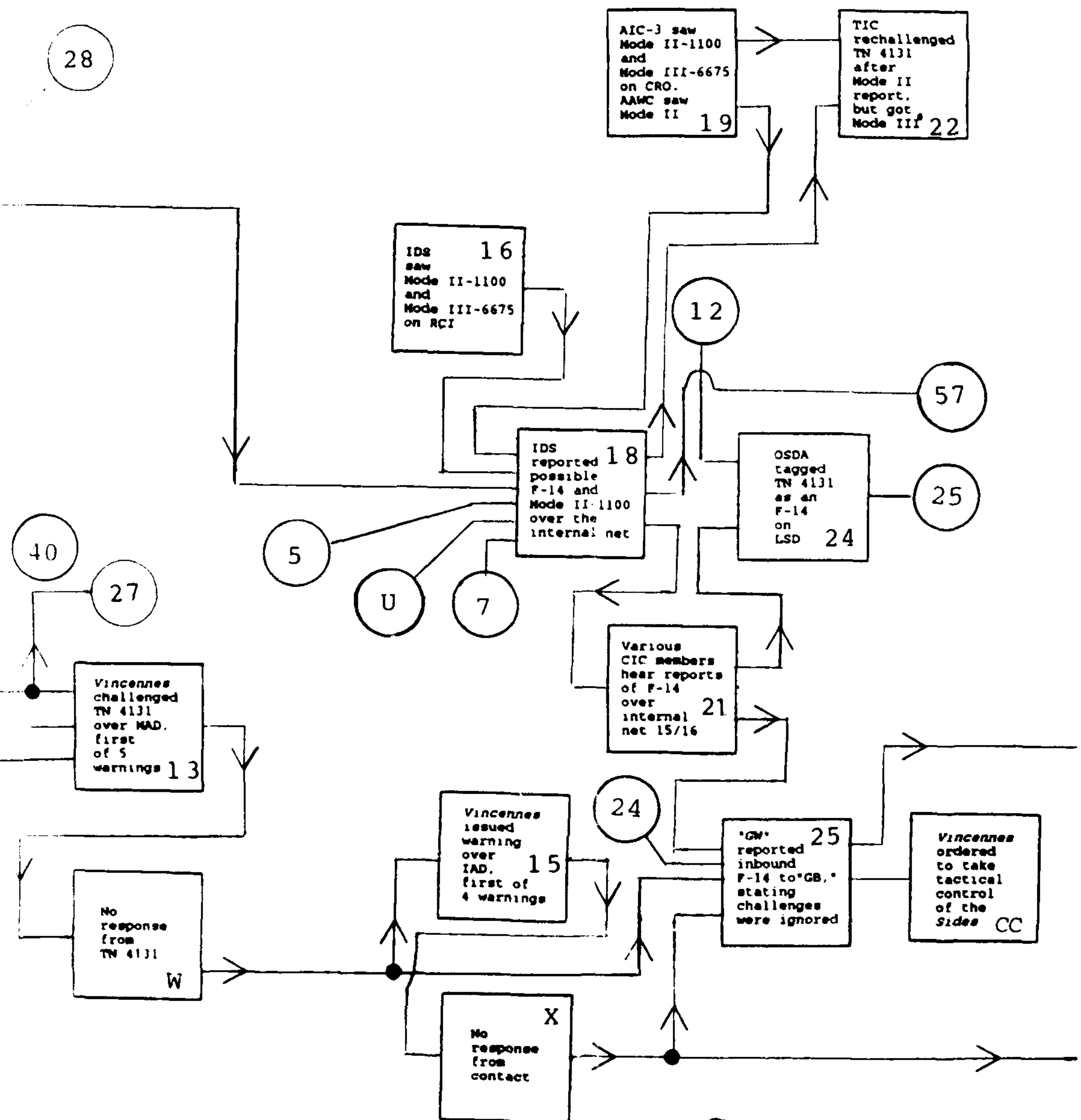


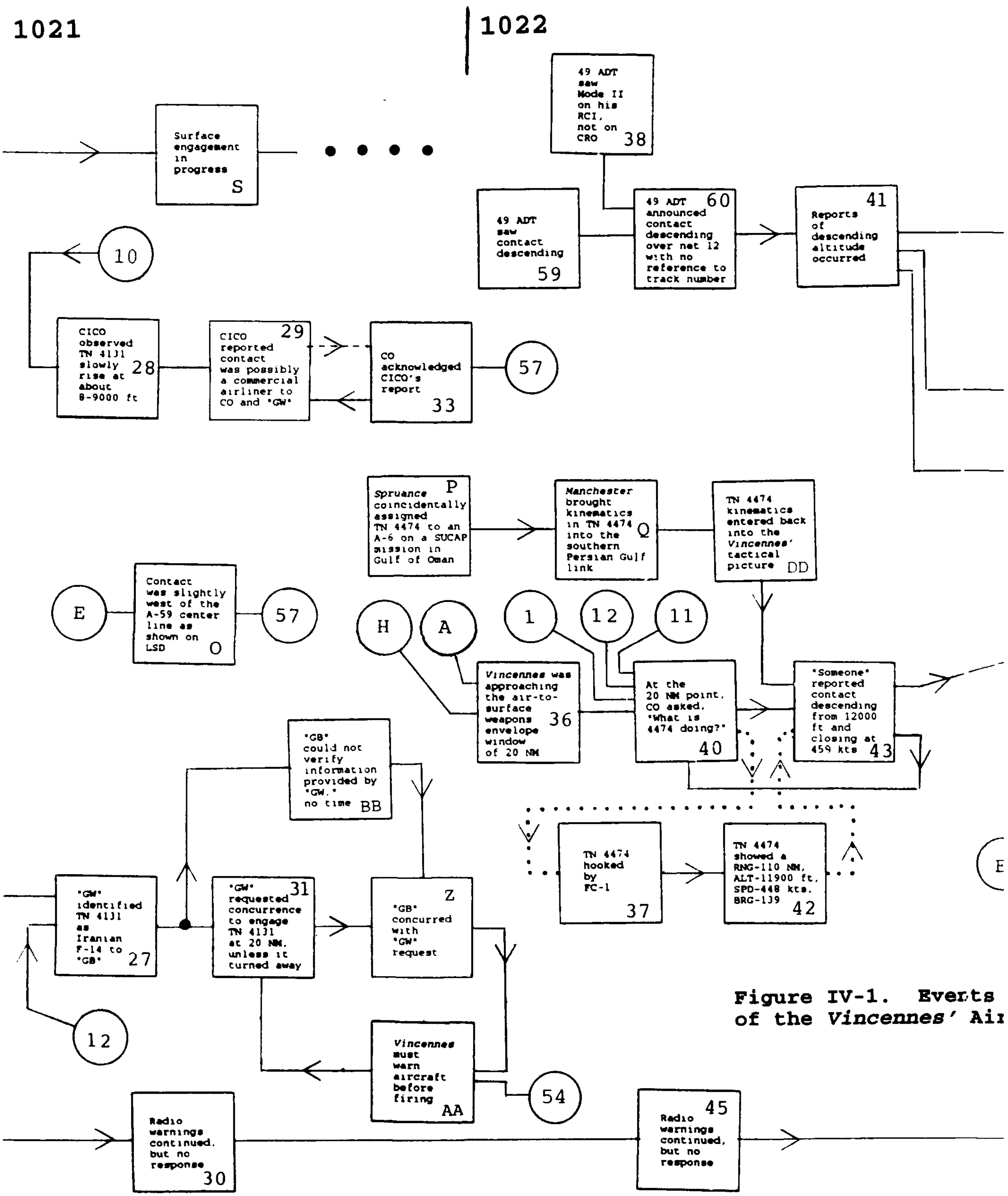


Figure IV-1. Everts
of the *Vincennes'* Ai

1

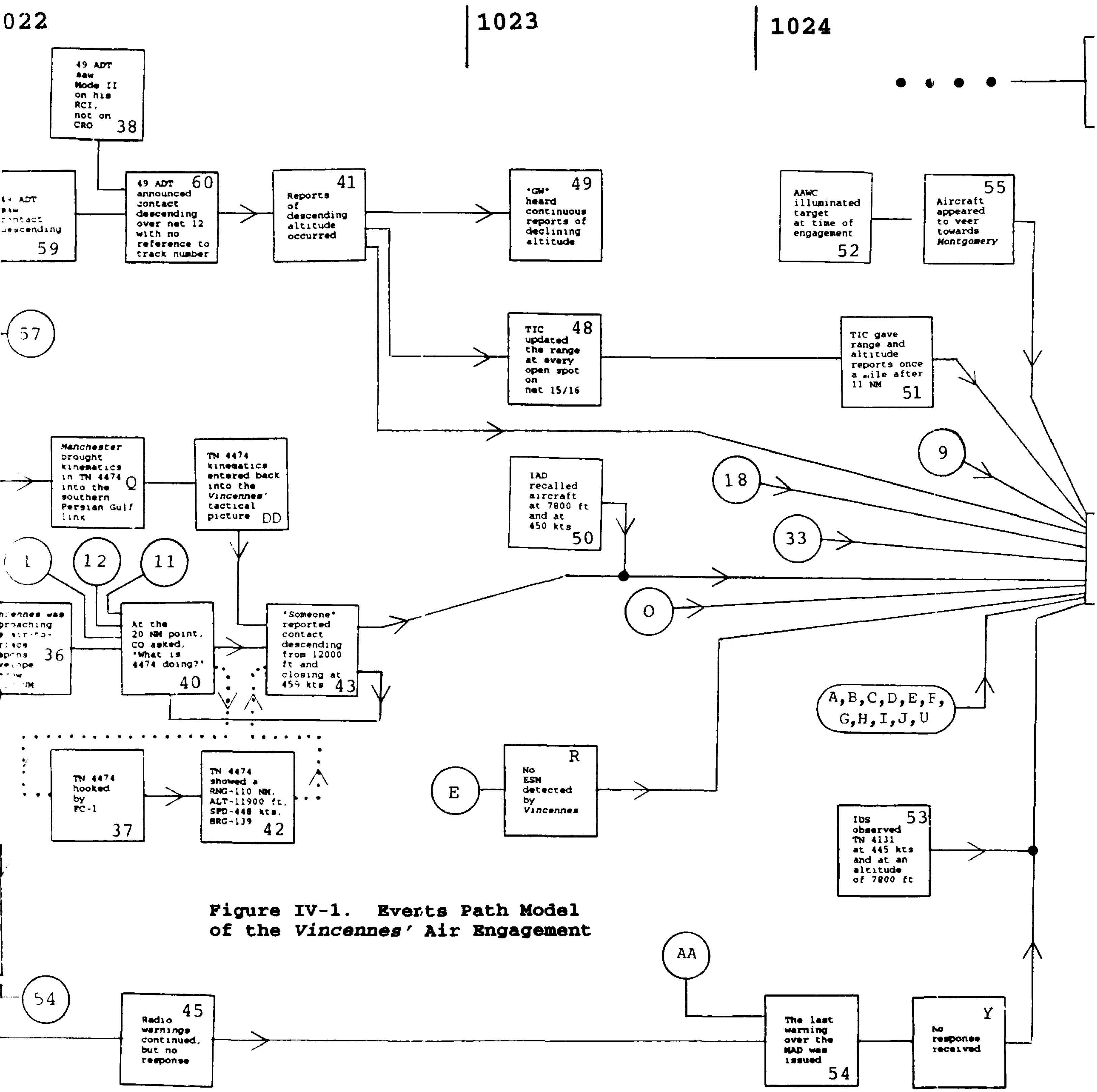
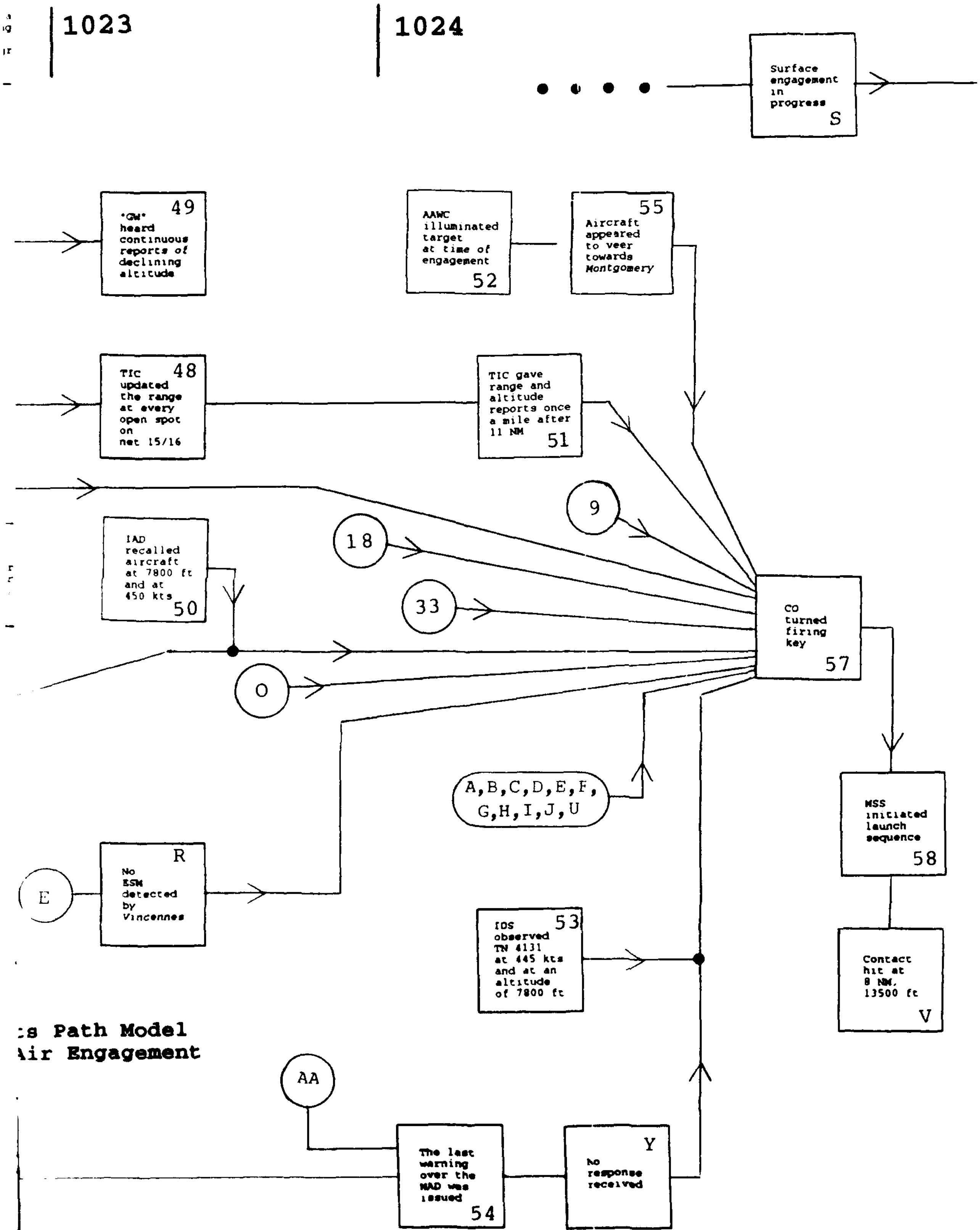


Figure IV-1. Events Path Model of the *Vincennes'* Air Engagement

2



:s Path Model
:ir Engagement

3

within the CIC (**23**). The significance of this event was that it was a disruptive factor that momentarily distracted personnel in the performance of their combat duties, which created a more intense atmosphere within CIC (**23**). Also, this event occurred at a key point in the air engagement sequence where reports of possible F-14 activity were being heard (**21, 24, & 25**). To further amplify the gravity of the tactical situation, there was an indirect connection between the Iranian P-3 that was detected 62 NM west flying towards the *Vincennes* and the surface engagement regarding targeting (**4 & G**), and the fact that there was an "unknown-assumed enemy" contact that had lifted off from Bandar Abbas (**B, I & 3**).

At 1017L, an aircraft departed the Bandar Abbas joint military/civilian airport on a southerly route (**I**). As it took off from the airport, its lift-off pattern deviated from previously observed commercial flights (**J**). Identification Friend or Foe (IFF) Modes II and III were also observed by members (49 ADT, UBS and AIC-3) within the CIC (**2**). These factors (**2, J & I**) combined with the intelligence warning (**E**), led the 49 ADT to designate the contact as "unknown-assumed enemy" (**3**). In the meantime, the *Vincennes* assigned TN 4474 to the contact that departed from Bandar Abbas (**1**).

As stated earlier, a surface engagement was in progress (**S**), and the *Vincennes* detected an Iranian P-3 with a heading of 085 and assigned it a track number of 4472 (**4**). The P-3 was not emitting any radar emissions (**L**), and the TIC saw Modes I and III IFF from the P-3 (**8**). These conditions (**S, L, 4 & 8**) led the *Vincennes* to challenge the P-3 (**9**). Although the P-3 responded that it was on a search mission (**M**), it was being closely monitored.

At about 1017L, reports of "F-14" were heard in the CIC **(5)**, which could be indirectly linked to the Mode II detection **(2)**, 49 ADT declaration of the contact as "unknown-assumed enemy" and the fact that the contact departed Bandar Abbas **(I)** where Iranian F-14s were recently moved **(A)**. These F-14 reports played a key role in the IDS' specific report of F-14 Mode II-1100 over the internal net at 1020L **(18)**, which perpetuated the F-14 mind set even further **(C & D)**.

It was also at 1017L that the *Sides* detected and assigned the contact from Bandar Abbas as TN 4131 **(K)**, which was the same contact as detected by the *Vincennes* **(1)**. According to Captain Rogers, this resulted in two track numbers being assigned to the same contact, which triggered the Aegis weapon system on the *Vincennes* to perform an automatic correlation of track numbers **(6)**, which resulted in the assignment of TN 4131 to the contact from Bandar Abbas **(12)** and the return of TN 4474 back into storage as an unused track number **(11)**. In other words, TN 4474 was dropped from the system, which had an adverse impact at the critical 20 NM decision point five minutes later **(40)**.

Efforts were being made by CIC personnel to positively identify the aircraft. A visual identification by another U.S. aircraft was not feasible due to the location of the USS *Forrestal* in the Gulf of Oman **(F)**. However, a commercial airline schedule from Bandar Abbas was consulted by the IDS **(7)** who determined that the contact was not Iran Air Flight 655 **(10)** because it was 27 minutes late from its regularly scheduled departure time of 0950L **(N)**. The 49 ADT's determination of the contact as "unknown-assumed enemy" **(3)** as well as reports of possible F-14 being heard in CIC **(5)**, led to the first of five Military Air Distress (MAD) verbal challenges **(13)**. In this instance, as in all challenges issued henceforth, there was no response received from the contact (**W**). This lack of response over the MAD channel led to another warning issued over the International Air Distress (IAD) channel (**15**) which was the first of four challenges. Still no response (**X**). There were a total of nine challenges issued to the contact from the *Vincennes*.

Returning back to the IDS, at 1020L, he saw Mode II-1100 and Mode III-6675 indications on his remot control indicator (RCI) (**16**), while a minute earlier, he determined that the contact was not a commercial airliner (**10**). Both factors primarily led to his decision to report F-14 and Mode II-1100 over the internal net (**18**). Indirect factors included: Other CIC members were seeing Mode II readings (**19**), reports of F-14 were being heard in the CIC (**5**), and in-flight modifications to aircraft modes and codes (**U**). These Mode II reports (**19 & 16**) also resulted in the TIC's re-challenge of TN 4131, who still obtained a Mode III reading (**22**). The IDS' report contributed to "GW's" report of an inbound F-14 to "GB" (**25**) and the OSDA's tagging of TN 4131 as an F-14 on the large screen display located above the command console area (**24**). "GW" also stated to "GB" that the *Vincennes'* challenges were being ignored (**25, W & X**), who in turn ordered the *Vincennes* to take tactical control of the *Sides* (**CC**).

At 1021L, "GW" identified TN 4131 as an Iranian F-14 to "GB" (**27**), leading to "GW's" request to engage TN 4131 at 20 NM, unless it turned away (**31**). "GB" concurred with his request (**Z**), but stipulated that prior to firing, the *Vincennes* must warn the aircraft (**AA**). However, "GB" could not verify "GW's" information due to time constraints (**BB**).

To compound matters, the CIC Officer observed TN 4131 rising at around 8-9000 feet **(28)** after the IDS declared that the contact was an F-14 **(18)**. He reported to the CO and "GW" that the contact was possibly a commercial airliner **(29)**, at which time the commanding officer acknowledged his remark. Concurrently, radio warnings continued **(30)**, and the contact was observed slightly west of the A-59 center line as shown on the large screen display **(O)**. These were more deviations from normal patterns and operating procedures as flown by commercial airliners **(E)**.

Meanwhile, according to Captain Rogers' interpretation, the USS *Spruance* had coincidentally assigned a track number, TN 4474, to an A-6 on a surface combat air patrol (SUCAP) mission in the Gulf of Oman **(P)**, which happened to be the same track number the *Vincennes* originally assigned the contact departing Bandar Abbas at 1017L **(1)**. This tactical picture containing TN 4474 was also held by the HMS *Manchester*, who entered the Southern Persian Gulf link at around 1022L, bringing with it the kinematics of the A-6 associated with TN 4474 **(Q)**. Consequently, the TN 4474 kinematics entered back into the *Vincennes*' tactical picture **(DD)**, which had a direct impact on the response to Captain Rogers' question when the *Vincennes* approached weapons envelope window of 20 NM **(36 & H)**, at which time Captain Rogers asked, "What is 4474 doing?" **(1 & 40)** He was also not aware of the auto-correlation of track numbers **(6, 11 & 12)** nor was he aware of the HMS *Manchester's* entry into the link **(P, Q & DD)**. Captain Roger's question **(40)** invoked a response from an unidentified operator that the contact was descending from 12,000 feet and closing at 459 knots **(43)**, which happened to be the kinematics of the A-6. Also, reports of descending altitude were recalled by various CIC members--MSS, 49 ADT and SITREP WRITER (**41**). It was during this time that the system tapes revealed that the FC-1 hooked TN 4474 (**37**), which showed TN 4474 at a range of 110 NM, an altitude of 11,900 feet, speed of 448 knots and bearing of 139 (**42**); however, it is not clear whether this person communicated this information. There is a strong relationship between the information the FC-1 obtained when he hooked TN 4474 and the response Captain Rogers recalled receiving. Therefore, the connection will be labeled as a weak connection (dotted line) as to the FC-1 actually being the individual who responded to Captain Rogers' question (**40, 37 & 42**).

Additionally, during this 20 NM critical decision point, the 49 ADT saw a Mode II IFF indication on his remote control indicator (**38**). He also saw the contact descending (**59**) which led to his announcement over net 12, another internal communications net, that the contact was descending, but did not refer to it by track number (**60**). Radio warnings continued to be issued with no response being received (**45**).

The AAWC requested and received permission to illuminate the aircraft at the 20 NM point; however, the AAWC was not successful in illuminating the aircraft with fire control radar until the minute of engagement (**52**). Upon the aircraft's illumination, Captain Rogers recalled that it appeared to veer towards the USS *Montgomery* (**55**).

Another unusual characteristic was that the *Vincennes* detected no radar emissions from the contact (**R**). "GW" heard continuous reports of deceasing altitude (**49**) and the TIC started to interject range updates on every open spot on the internal net 15/16 (**48**), which led him to make reports once a mile after 11 NM (**51**). The IDS and IAD both observed the contact going at a high rate of speed **(50 & 53)**. And, lastly, the final warning **(AA)** was issued over the MAD **(54)** again, no response **(AA)**. After the final warning, Captain Rogers turned the firing key **(57)**, enabling the MSS to initiate the launch sequence **(58)** which led to a direct hit of an aircraft that happened to be a civilian airliner **(V)**.

To recap, the basic factors/events contributing to Captain Rogers' decision to engage were the following:

- The contact did not respond to verbal warnings **(13, W, 15, X, 30, 45, 54 & Y)**
- The contact demonstrated an attack profile of increasing speed, decreasing altitude, and closing range **(41, 42, 43, 49, 50, 51 & 53)**
- No radar emissions were detected **(R)**
- Mode II IFF indications were reported historically correlating to Iranian F-14s **(2, 16, 18, 19, & 38)**
- The contact was alluded to and reported as an F-14 **(A, B, D, H, 3, 5, 10, 18, 21, 24, 25, 27 & BB)**
- The aircraft deviated from normal commercial patterns **(E, J, N, O, R & 55)**
- Suspicious presence of a P-3 and its inbound heading **(G, S, 4, L, 8, 9 M, 3, I & B)**
- Warnings from Intelligence **(A, C, D & E)**
- Not being aware of a change in track numbers from TN 4474 to TN 4131 **(1, K, 6, 11, 12, P, Q, DD, Z, 40, 43, 37 & 42)**
- Positive visual identification was not feasible **(F)**
- The contact was within the air-to-surface weapons envelope of 20 NM **(31, AA, Z, DD, 40 & 43)**

In summary, there were a myriad of internal and external factors that contributed to Captain Rogers' decision to engage. Captain Rogers had to contend with a multi-dimensional, simultaneous threat involving surface and air forces, while being provided fragments of information under extremely tight time constraints. At the risk of his ship and crew, he waited until the aircraft was within 15 NM for it to demonstrate that it was not hostile before taking proactive measures. However, no sign from the aircraft ever came to discount the information he was being provided.

3. Discussion

Figure IV-1 is a path analysis of the overall *Vincennes* incident, tracing the sequence of events over to time. In a pictorial sense, this linear model depicts the complexity of activities that took place over a seven minute period. It also portrays the evolving context that was being created as a result of the interactions between the internal and external factors, which contributed to Captain Rogers' decision to engage what he believed to be an F-14.

Additionally, at certain points in time, seemingly unrelated, independent events/factors impacted the *Vincennes'* system. By following the arrows, one can trace when an event occurred, where the event made its impact, and the way the system adjusted to its occurrence. Essentially, the crew's concept of reality was an evolutionary process fueled by random variations of events/factors occurring both internally and externally entering and leaving the *Vincennes'* system. According to Morgan, "These random modifications [were] introduced through...the combination of chance interactions and connections that give rise to the development of new system relations (1986, p. 239).

This autopoietic concept[3] has similar undertones to the recent scientific developments by the 1978 Nobel Prize recipient, Illya Prigogine, for his research on "dissipative structures" in chemical reactions, which demonstrate that random change in a system can lead to new patterns of order and stability (Morgan, 1986, p. 239). An extension of this research can be applied to the *Vincennes* incident, in which a new state of order (context) was created with each occurrence of a random, independent event. Essentially, the context progressively evolved with each "kick" to the *Vincennes'* system. By using the path model, one can detect the varying degrees to which the context was redefined in terms of individual crew members and in terms of the CIC as a system. This is particularly evident with the IDS, TIC, and 49 ADT recollected accounts as well as with track number and IFF issues. One can effectively see the interrelationship between internal and external factors, in which the nature and outcome of their interaction invoked a new backdrop with each occurrence. Metaphorically, this is analogous to the creation of a new setting for every subsequent act in a play without a defined script, whereby the stage design is dependent upon the random nature of events and their interrelationships that had already been presented and acted out. Along the same lines, during the last 189 seconds prior to missile impact with the civilian airliner, the F-14 context was progressively amplified, culminating in a new order of reality to the extent that Captain Rogers and his CIC organization eventually engaged what they believed was an F-14.

Although different states of being can emerge from random events, when applied to a combat environment characterized by ambiguity, time compression and uncertainty, this state of being or perceived context may become distorted due to the misinterpretation of events or the fact that events can be misleading in and of themselves. This distortion can be attributed to the nature of a combat environment that compels the decision maker, who is an "intendedly rational" actor, grappling with ill-defined, complex situations, having to make a decision and implement it based on incomplete information as to what is actually occurring. (Daft, 1986, p. 364) Here, the garbage can model[4] attempts to explain how decisions are made when the organization is subjected to this high degree of ambiguity that typifies "organized anarchy"[5] (Daft, 1986, p. 364). According to March and Olsen,

> In pure form, the garbage can model assumes that problems, solutions, decision makers and choice opportunities are independent, exogenous streams flowing through a system (Cohen, et al., 1972). They are linked in a manner determined by their arrival and departure times and any structural constraints on the access of problems, solutions and decision makers to choice opportunities. In the absence of structural constraints within a garbage can process, solutions are linked to problems, and decision makers to choices, primarily by their simultaneity. (1986, p. 17)

The path analysis demonstrates that the sequencing of events is not necessarily a logical process, but are random processes that are linked with respect to the time at which they occurred and their simultaneity of occurrence. This is particularly evident at 1022L, the 20 NM critical decision point. Essentially, "[s]olutions appear before problems, or in search of problems to attach themselves to, and problems may exist without ever being solved." (Swain, 1990, p. 14)

The *Vincennes* incident as depicted by the Events Path Model in Figure IV-1 exemplifies the situation under which the garbage can decision making process takes place:

> The unique and important characteristic of the garbage can model is that the decision process is not a sequence of events that begins with a problem and ends with a solution....[T]he problem-identification and problem-solution stages may not be connected to each other. Ideas may be proposed as a solution when no problem is specified. Problems may exist and never generate a solution. The reason problems and solutions are not connected is that decisions are the outcome of independent streams of events within an organization.... When a problem, solution, participant and choice happen to connect at one point, the problem may be solved. But it also may not be solved. The solution may not fit. [Figure IV-2 is a diagram of the Garbage Can Model.(Daft, 1986, pp. 364-365)

The problem in the *Vincennes* incident was not necessarily the fact that a civilian airliner got shot down. The real problem involved aircraft identification that led to the shoot down. Practically the entire seven minute air engagement process involved efforts taken by CIC personnel to identify the aircraft. At the jeopardy of his ship and crew, Rogers waited until the last possible moment for an indication from the aircraft that signified the contact was not hostile. There was no feedback. The information gathered and presented to Rogers were contributing factors that further confirmed the identity of the aircraft as being an F-14 showing hostile intent, except for one input from the CIC Officer, who stated the aircraft was "possible COMAIR." However, the preponderance of information indicated otherwise. Based on the choice opportunities available to Captain Rogers, with "solutions" existing independently of the "problem," an improper solution (F-14) became "attached" to the problem of aircraft identification. This mismatch, which can occur under extremely uncertain conditions, contributed to the amplification of the F-14 context within the *Vincennes* system, and was a key factor in Rogers' decision to engage. Obviously, the garbage can process employed under these conditions led to an undesirable outcome for a civilian airliner was shot down.

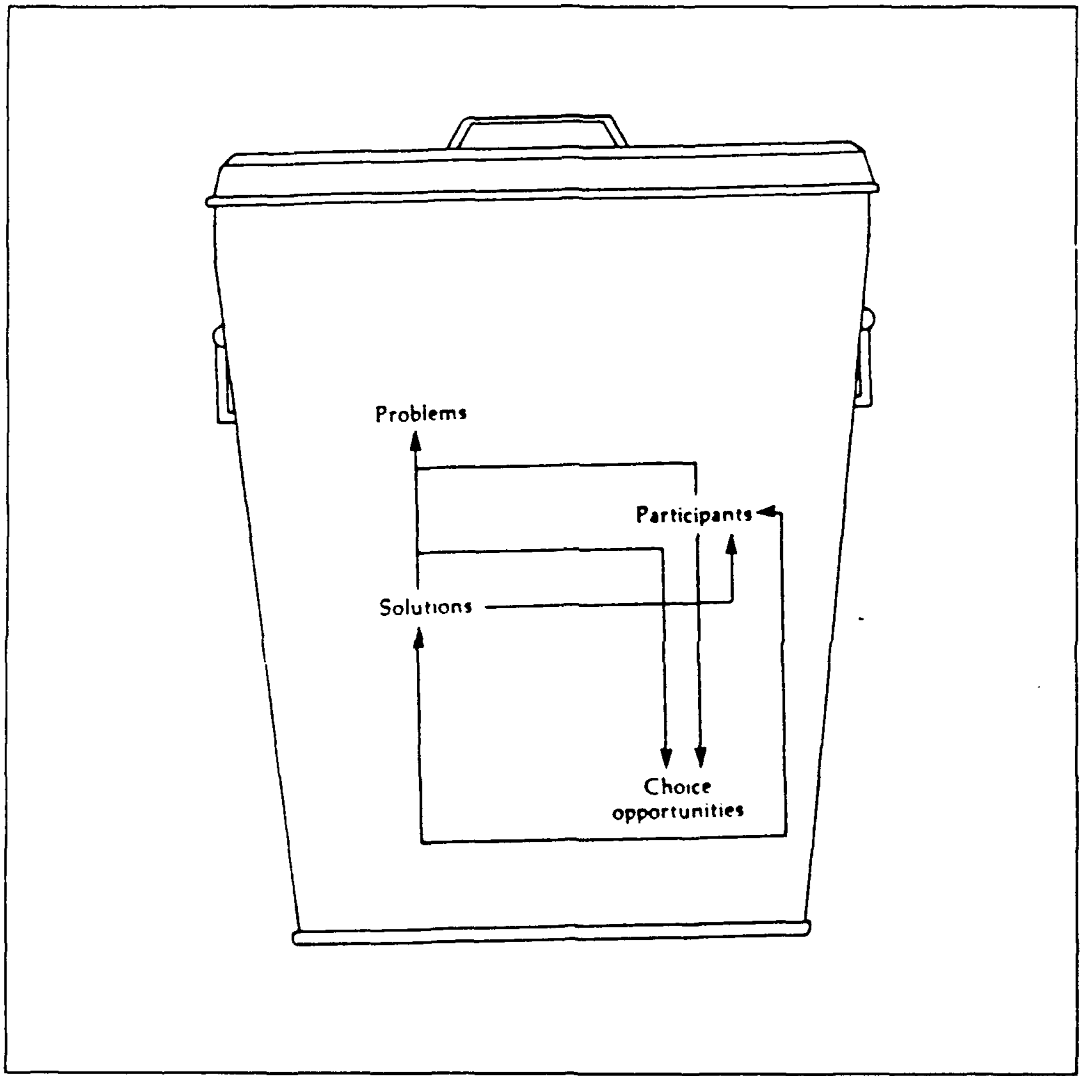


Figure IV-2. Garbage Can Model (Robey, 1986, p. 44)

C. IDENTIFICATION OF "CAUSAL FACTORS" USING A DYNAMIC SYSTEMS MODEL

1. Dynamic Systems Model

The systems map in Figure IV-3 is a combination of the "Leavitt Diamond" as presented by Harold J. Leavitt in his paper entitled "Applied Organizational Change in Industry: Structural, Technological and Humanistic Approaches," (Leavitt, 1965, pp. 1144-1170) and the Group Behavior Model as presented by Michael B. McCaskey in his case, "Framework for Analyzing Work Groups." (1985, p. 11) This hybrid model will also be used to analyze the "causal factors" that contributed to the accidental shoot down of the civilian airliner.

Before discussing the *Vincennes* incident in relation to this model, a brief explanation of the model will be provided:

Starting from left to right, the first block, *context*, involves the following question: What is the nature of the tactical environment? Context and/or environment are "the background factors out of which a group arises and in which a group operates." (McCaskey, 1985, p. 3) The environment/context consists of social and political forces, the purpose for which the group/organization was created, physical setting, size, competitors (threat/enemy), allies/friends, suppliers, regulators, and history.

Along with context, the next category in the Dynamic Systems Model involves *key success factors*. The question at hand is: What does it take to be successful? Generically, key success factors involve responsiveness, accuracy, and innovation to just

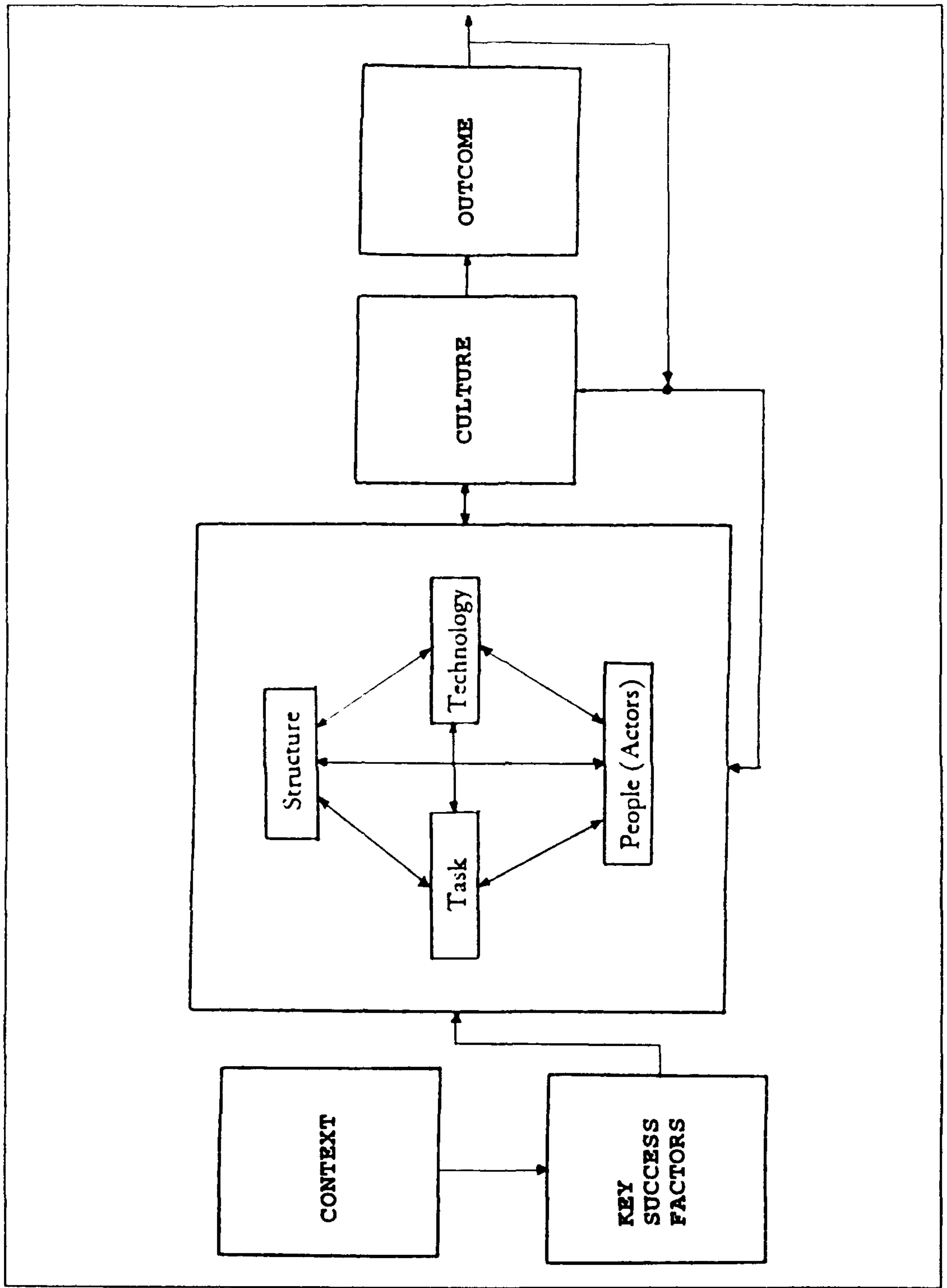


Figure IV-3. Dynamic Systems Model (McCaskey, 1985, p. 11; Leavitt, 1965. p. 1144) name a few items. In the military setting, key success factors can be effective employment of force, tactics, and decision making strategies; effective allocation of combat power; being able to out think the enemy and anticipate to affect surprise; being able to identify who to "attack effectively first." (Hughes, 1986, pp. 34-35)

The largest block in the model is consists of the "Leavitt Diamond," which is comprised of task, technology, people and structure. These *design factors* are important to the behavior of groups, which involve the people who form the group, the tasks they are required to perform, the technology or means available to them, and the formal structure and operating mechanisms of the organization to which they belong. The key is to arrange these factors in such a way to enhance an organization's effectiveness and chances of success (McCaskey, 1985, p. 4; Leavitt, 1965, p. 1144). These design factors are described in the following:

> *Task*: What needs to be done? Tasks usually involve the production of goods and services and all operationally meaningful sub-tasks required to accomplish the mission. (Leavitt, 1965, p. 1144) Task requirements entail interactions among people and equipment; variety of activities; novelty or routineness; and varying degrees to which the tempo (work pace) is under an individual's control. (McCaskey, 1985, p. 5)

> *People*: What human resources are available? Human beings are composed of a myriad of subtle and shifting characteristics. Some key characteristics on which to focus include skills and interests of individual members; learning styles; values, assumptions, and experience; expectations of leadership; and preferences regarding degree of autonomy and individual challenge. (McCaskey, 1985, pp. 4-5)

> *Technology*: What are the means by which a task can be accomplished? In broad terms, technology is a process by which inputs are converted to outputs (Robey, 1986, p. 137). The technology of an organizational system consists of "tools, techniques, devices, artifacts, methods, configurations, procedures and knowledge used by organizational members "to acquire inputs, transform inputs into outputs and provide outputs or services to clients or customers.... The primary function of technology is

> to enhance the amount of work an individual can accomplish and the reliability of individual performance. (Pasmore, 1988, pp. 55-56 and 57-58)
>
> *Structure and Operating Mechanisms*: What are the basic groupings of people and activities, and how do they operate? Organizational structure boils down to "systems of communication, systems of authority, and systems of work flow." (Leavitt, 1965, p. 1144) Integrating devices such as coordination, hierarchy, information systems, plans and procedures are affiliated with structure, while control systems, reward systems, training and development, and recruitment and selection are associated with operating mechanisms. (McCaskey, 1985)

In addition to the design factors, the next category of interest involves *culture*. What are the prevalent norms and values in an organization, and does the culture enhance or detract from effectiveness? The patterns of behavior and values that members create for themselves constitute a group culture. These are ways of thinking and behaving that a group evolves over time. (McCaskey, 1985, p. 8) A more specific definition is provided by Edgar Schein:

> The pattern of basic assumptions that a given group has invented, discovered, or developed in learning to cope with its problems of external adaptation and internal integration, and that have worked well enough to be considered valid, and, therefore, to be taught to new members as the correct way to perceive, think, and feel in relation to these problems. (Robey, 1986, p. 425)

The last category involves *outcome*. What is considered a good or bad outcome? An outcome is simply a result. It can be defined in terms of productivity, quality, goal achievement, etcetera. Outcomes can be multi-dimensional and also serve as a source of feedback to the system. (McCaskey, 1985, p. 12)

As displayed in Figure IV-3, not only are the categories comprising the design factors highly interdependent in and of themselves, but the environment, key success factors, design factors, culture and outcome are also interdependent with respect to each other as shown by the arrowheads and feedback loops. This means that a change in any one category could result in varying degrees of compensatory or retaliatory change in others. (Leavitt, 1965, p. 1145)

In sum, this Dynamic Systems Model indicates that what a group produces, its outcomes, are influenced by a set of factors called group culture. Group culture refers to the patterns of behaving and thinking that develop in the group. Group culture arises from the interaction of four design factors--the people in the group, the tasks they are required to perform, means by which inputs are transformed into outputs, and the structure and operating mechanism of the organization where the group operates. The design factors and how they interact are in turn shaped by key success factors and the context or environment--the unit, its history and traditions, political, social and tactical contexts, and geographical location. These factors and their interactions can ultimately affect the outcome of a given group/organization. It is important to note that the whole system is dynamic. Changes to any one part of the model can eventually lead to changes throughout the model. Depending on the complexity of the system, changes, adjustments, or disturbances sometimes percolate through the system in unanticipated ways, resulting in unexpected outcomes.

2. Application

Elements comprising the Dynamic Systems Model along with their relationship to the *Vincennes* incident are primarily discussed in this section.

a. Context

The contextual element in the Dynamic Systems Model was primarily addressed in the events path model. However, to briefly recap, the local environment in which Captain Rogers and his CIC organization were operating were far from ideal. Extreme ambiguity and uncertainty, time compression coupled with chaotic, unpredictable conditions contributed to the fusion of misleading information fragments. The preponderance of evidence provided to Captain Rogers met the criteria of a hostile contact flying an attack profile to the extent that two Standard missiles were launched in self defense. The local context set the stage for the eventual shoot down of a civilian airliner mistakenly identified as an F-14.

b. Key Success Factor

Regarding block two of Figure IV-3, a key success factor in any military activity is accurate target identification, especially when the "character of the tactical environment is shared by friend and foe." (Hughes, 1986, p. 238). In the "half-war, half-peace" atmosphere of the Gulf, there were no clear absolutes about the nature of the threat. In a cramped air space, harmless passengers and deadly enemies commingled, creating a tough deconfliction problem (Time, 1986, pp. 15-16). Additionally, in such an unpredictable environment, Captain Rogers and crew could not be sure that, even if the contact was seen as an Airbus, it was not an airborne equivalent of the explosive laden truck that destroyed the U.S. Marine Corps barracks in Beirut (Friedman, 1988, p. 1[illegible]3). Essentially, the *Vincennes* incident exemplifies the "classic military problem of identifying the guy you're shooting at." (Horgan, 1988, p.14)

Table IV-1 shows the crew's attempts at IFF to positively identify the contact of interest through the IFF process.

TABLE IV-1

ATTEMPTS AT IDENTIFICATION THROUGH IFF

TIME	SYSTEM DATA	RECOLLECTED DATA
1017L	Mode III-6760 "TN 4474" "Track of interest"	By AIC-3; III-6765; on CRO By 49 ADT; II & III; no code provided or means -- "TN 4474" By IDS; III-6765; no means provided By UBS; III-66??; Last two digits unknown and later saw an unspecified Mode II
1018L	Mode "C" "TN 4474"	By TIC; III; on CRO; no code provided -- "TN 4131" By TIC*; I & III; on CRO; no code provided --"TN 4472" or Iranian P-3
1019L	No mode data provided during this minute in report	No mode data provided during this minute from witnesses
1020L	Mode III-6760 "TN 4131"	By IDS; II-1100 & III-6765; on RCI; Reported possible F-14 and Mode II-1100 over net 15/16 to all stations -- "TN 4131" By AIC-3; II-1100 & III-6675; on CRO -- "TN 4131" By AAWC; II-1100; means not provided By TIC; III; no code or means provided -- "TN 4131"
1021L	No mode data provided	No mode data provided
1022L	No mode data provided	By 49 ADT; II; on RCI; announced over net 12 contact was descending, but did not refer to it by track number
1023L	No mode data provided	No mode data provided
1024L	Mode "C" "TN 4131"	By AIC-3; II-1100 & III-6760; no means provided; wrote this on his console before intercept

Source: Fogarty, 1988, pp. 29-39
* -- Iranians known to change their modes and codes as they cross the Gulf
I, II & III -- Abbreviations for Mode I, Mode II, Mode III
Note: Track number was included if it was specifically referred to in the text
"Recollected data" consists of the following sequence as segregated by semi-colons: Who; what mode and code; by what means; and track number designation.

Mixed readings were being detected, which made the identification process even more difficult. The P-3 was squawking Modes I and III and the contact of interest as recalled by various witnesses was squawking Modes II and III. However, according to the Fogarty report, the system data always showed the contact to be ascending and Mode III-6760. These multiple IFF readings and their association with each other along with recent historical precedent created an atmosphere of suspicion as to the pilot's intent.

This identification process was further confounded by the enhanced ducting conditions that were prevalent in the Gulf. For example, during his testimony before the Senate Armed Services Committee, Captain George N. Gee, Director, Surface Combat Systems Division, discussed the effects of ducting on radar in the Gulf, in which the normal 18-20 nautical mile radar horizon of the ship was extended. Here, the contact was over-the-horizon and was detected at 47 NM at low altitude (Senate Hearing, 1988, p. 49). This enhanced radar range and the fact that the airport was a joint military/civilian airport, meant that crew members were possibly obtaining IFF detections that were not necessarily from the track of interest, especially if the remote control indicator (RCI) was used. Considering the ducting conditions and use of the RCI, more uncertainty was introduced into the identification process. More specifically, since the RCI interface was not slaved to a hooked track, it essentially became a source of misleading information, especially when it was inadvertently correlated with a hooked track:

> The IDS miscorrelated an RCI readout of Mode II-1100 with TN 4131. This occurred, according to analysis of the data, when the IDS hooked TN 4131 as it departed Bandar Abbas and left it hooked for almost 90 seconds. This meant that

> as the hooked symbol moved towards the USS *Vincennes*, the read gate for the RCI remained near Bandar Abbas.... Therefore any number of military aircraft present at the airfield could have responded to Mode II IFF interrogation by USS *Vincennes* due to the ducting prevalent that day. (Fogarty, 1988, p. 47)

Incidentally, at 1024L, the time of missile impact, an Iranian C-130 took off from Bandar Abbas, squawking Mode II prior to and during its departure (Senate Hearing, 1988, p. 53).

As can be seen with the IFF process, it was nearly impossible to get reliable identification on the contact. Consequently, in a military operation where the key success factor cannot be achieved, it then transforms into a key factor for failure, ultimately contributing to a bad outcome. The inability of the *Vincennes* to obtain reliable identification was a contributing factor to the shoot down and highlights the problem entailing

> the inability to distinguish between friend or hostile aircraft or ships at the distances high-tech weapons systems operate, distances that are beyond the visual range of the systems' operators. Aegis is not designed to make that distinction, nor is any other currently deployed system. It was this weakness that led to the destruction of the airliner, and to the carnage inflicted on the USS *Stark* in 1987 when a Iraqi plot fired two missiles at an unidentified blip on his cockpit radar screen. (Hill, 1989, p. 200)

c. *Task*

According to Martin van Creveld in Command in War, uncertainty is the main problem all command and control systems must deal with and is best understood as the product of two factors:

> the amount of information available for decision making and the nature of the task performed.... Everything else being equal, a larger and more complex task will demand more information to carry it out. Conversely, when information is insufficient (or when it is not available on time, or when it is super abundant, or

> when it is wrong...), a fall in the level of performance will automatically ensue. The history of command can be thus understood in terms of a race between the demand for information and the ability of command systems to meet it. (1985, p. 265)

The nature of the task (countering the emerging Iranian Silkworm missile threat) as faced by the *Vincennes* was a task riddled with uncertainty, especially with the Iran-Iraq War in progress and the controversial U.S. involvement in the protection of reflagged ships. According to Admiral Crowe, the Persian Gulf was like "fighting in a lake," where maneuverability was greatly reduced and the time available for important decisions was greatly compressed (Apple, 1988, p. A8). The Aegis system is a highly sophisticated, effective system; however, it was designed to detect targets at great range, which sacrificed the ability to distinguish the size of a target:

> 'In combat on the open sea, size doesn't matter much; a small plane or missile can sink a ship. But in the Gulf, where big civilian planes share airspace with small warplanes, size can be a crucial clue.' (Watson, 1988, p. 20)

Due to this reduction in maneuverability and decision making time combined with the fact that the Aegis weapon system was originally designed for the open ocean environment (Fogarty, 1988, p. 49), an optimization problem was created with respect to the ability to effectively accomplish the task at hand. A key constraint to this "product mix" of minimizing the "cost" of target misidentification involved the issue of being able to determine size. In broad terms, the size constraint was problematic and contributed to the adverse outcome of the deconfliction aspect of the task. Regarding the uncertainty involved with a highly ambiguous, unstructured task, a high degree of risk on the part of the decision maker was incurred, not only at Captain Rogers' level but at the policy level in government as described in the following:

> 'In these tough situations, things sometimes go wrong,' a longtime Presidential advisor said yesterday. 'You know that. You have sophisticated machines and young sailors operating under hard conditions. So you take what you consider reasonable chances on behalf of important goals, and you hope for the best.'(Apple, 1988, p. A8)

The consequences of human error or systems failure are usually the greatest when the tolerance for error is slightest, particularly in an uncertain task environment where the task is not structured and the environment is unpredictable. The propensity for error becomes magnified.

d. Structure

Regarding the organizational structure (Figure II-6), the AAW TAO was an effective approach to handling the fast paced, dynamic air environment. However, the demands placed on external communications between Golf Bravo and Golf Whiskey were unexpected. Basically, Golf Whiskey, or the AAW TAO, became engrossed in the relay of information to higher headquarters such that he could not perform his primary duties to the extent required. According to the Fogarty report, Golf Whiskey lost his "ability to independently assess the actual profile and [identification] ID of TN 4131." (1988, p. 46) Since Golf Whiskey was involved in keeping Golf Bravo informed, the added workload was passed down to the AAWC console operator who was not the most experienced and qualified in his position (Fogarty, 1988, p. 46). He in turn could not take up the slack and verify the identification and track profile information. Essentially, there was a breakdown in these "gatekeeper" positions which serve as a "filtering function...[that] exercise control over the information flow to all subsequent receivers." (Krone, Jablin and Putnam, nd, p. 23) They could not provide the "sanity check" that was necessary due to task overload with extraneous and unforeseen demands. Since they could not perform the primary duties as effectively as intended and provide an independent assessment of information that they were geared for, a communications breakdown was experienced: There was no time for the captain to personally verify the information being provided to him; there was no time for Golf Bravo to independently verify the information being provided to their headquarters by the *Vincennes* due to the lack of a real time link; there was no visual identification provided by air support; and, since the AAW TAO and AAWC console operator were overloaded and could not provide information verification as originally intended, misleading and erroneous information was being perpetuated throughout the system, ultimately impacting the commanding officer's decision as shown in Figure IV-4 in the next section.

Additionally, the internal communication net 15/16 was also overloaded due to an unexpected surge in personnel on the net. Not only were there static and noise interfering with the communications flow, but it was also difficult to hear what watchstanders were saying because the amplifiers could not physically handle the load. Due to the physical impairment of the internal communications equipment, watchstanders resorted to shouting so that they could be heard (Rogers, 1992). Essentially, communication and information flow, which are key integrating devices in an organizational structure, became hampered.

Along with communication and information flow, the adherence to procedures was also lacking. Based on Captain Rogers' account regarding track numbers, a critical procedural problem involved the misuse of track numbers/blocks and lack of compliance to the link protocol system. This procedural problem was a contributing factor that led to the misidentification of the aircraft. Another procedural problem involved internal net communications in which net 15/16 became saturated with unauthorized personnel interjecting information over the net. Sometimes, this information was conveyed without console operators relating it to a specific track number. These types of issues added to the confusion of an already chaotic environment.

With respect to operating mechanisms, sources of control will be discussed. As mentioned earlier, the AAW TAO organizational set up for Persian Gulf operations aboard the *Vincennes* was in essence a controlling mechanism to help keep the fast moving anti-air warfare tactical picture in order. However, due to task overload, time compression and uncertainty, the verification function was rendered ineffective.

A slightly different angle with respect to another control mechanism will be presented regarding the use of the rules of engagement (ROE). Control is necessary in an organization, for without it, members may not act in ways that lead to the attainment of organizational goals (Robey, 1986, p. 313). Using this as a baseline, the military ROE are a source of control that combine top level guidance with lower level discretionary power. ROE are an attempt to balance two sources of competing requirements: "The need for initiative and flexibility in the field and the need for political control over the use of military force." (Sagan, 1991, p. 101) Although the Fogarty report stated the CJTFME and the Commanding Officer of the *Vincennes* properly selected and applied the correct rules of engagement (Fogarty, 1988, p. 46), there is an element of concern that they were "hair trigger" rules in which "the new ROE contributed to the *Vincennes* tragedy by encouraging a more rapid response to ambiguous warning than occurred in the *Stark* attack[6]." (Sagan, 1991, p. 101) Blaming the "hair trigger " rules in the *Vincennes* tragedy would not be accurate, but they did play a role in what Sagan calls "a 'permissive cause' or a 'necessary, but not sufficient' cause." (1991, p. 100) The difference between the *Stark* and the *Vincennes* situations involves inaction on one hand (error of omission), while on the other hand, preemptive action (error of commission). Both situations were bound by a narrow range of action as authorized by the rules (Hayes, 1989, pp. 54-55).

As discussed so far, one can appreciate the explosive mix of circumstances the *Vincennes* was under. Yet, did the rules of engagement make a significant difference in the decision to use force to deal with the presumed threat? According to Bradd C. Hayes, in "Naval Rules of Engagement: Management Tools for Crisis," they probably did not for the hostile environment and the ongoing engagement among other factors played as a significant role in the decision as did the rules of engagement (1989, p. 55). In the long run, however, ROE cannot be discounted:

> If civilian authorities do not thoroughly review or fully understand ROE, the resulting rules might not conform to political requirements. If ROE are not adjusted in a crisis, inappropriate military activities may be instigated by lower level commanders. Yet, if rules are changed at the last minute, there might be inadequate time to communicate the changes to all relevant commanders. Finally, if unclear or contradictory ROE are issued to military forces, mis-signalling, undesired vulnerabilities, and inadvertent escalation might occur. (Sagan, 1991, p. 101)

The main point pertaining to ROE as a control is that they cannot serve as a "substitute for good training and prudent judgment on the part of individual commanders in such dangerous and ambiguous situations." (Sagan, 1991, p. 102)

e. People

As stated in the previous section, people are a key variable in the battle equation. It is important that they are trained and exercise good judgment. The Fogarty report stated: "Had the CO used the information generated by his C & D system as the sole source of his tactical information, the CO might not have engaged TN 4131." (1988, p. 43) This may be true, however, organizations are comprised of people and their innate talents as well as frailties, and their decision making involves bias. Referring back to the concept of decision making under conditions of uncertainty, it basically amounts to a matter of perception, or what a decision maker inside an organization can see from that vantage point (Robey, 1986, p. 313).

Captain Rogers was influenced by numerous factors that comprised a mix of crew member perception's, environmental inputs (internal and external) as well as his own perceptions as he synthesized this information in order to make his decision at the critical 20 NM point of the air engagement. His perceptions were influenced by a large number of personnel and organizational 'filters', which allowed some of the environment to be understood, but masked other parts. As illustrated in Figure IV-4,

> ...a decision maker's values, cognitive limits and previous experience can influence perception of the environment. Additionally, the organizational structure and processes that may act to limit a decision maker's perception are also included.

> Because organizations are specialized and departmentalized, individual members are exposed only to a limited part of the environment and are trained to see it in a particular way. (Robey, 1986, p. 313)

With respect to the *Vincennes* incident, the CIC was highly departmentalized in its set up, with each member developing his own view of the tactical picture based on limited access to the "big picture." Members provided inputs to the captain that reflected their version or interpretation of the tactical picture. The commanding officer, in turn, processed, synthesized, and fused this information, which was sometimes incomplete and erroneous. As the decision maker, Captain Rogers, developed a perspective that was more global, but was still dependent on the nature and quality of the information provided. The captain did not have time to personally verify the information provided, but did have great confidence in his CIC team (Rogers, 1992). Therefore, the captain relied on the information provided by his people and sensors. The quality of his decision was as good as the quality of the information he was provided as well as his ability to exercise good judgment, which is a function of training and experience.

f. Technology

The last element to be discussed in the "Leavitt Diamond" portion of the Dynamic Systems Model is technology. As stated earlier, technology is the process by which inputs are turned into outputs. Van Creveld makes the following conclusion about technology, "understand what it [technology] cannot do and then proceed to find a way to do it [the mission] nevertheless." (Hughes, 1986, p. 193) The key point here

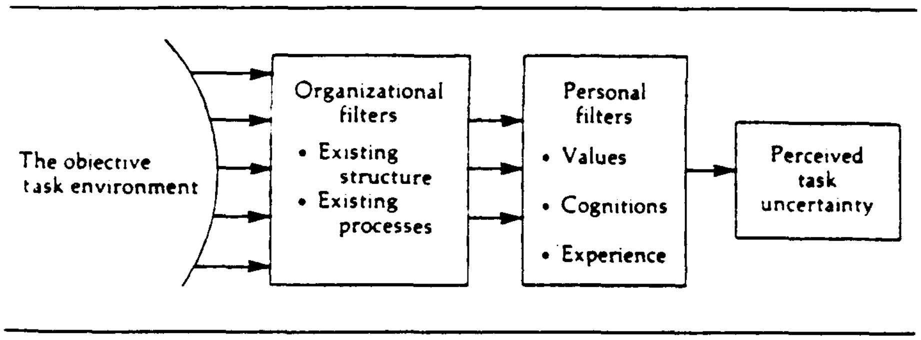


Figure IV-4. Influences on Decision Makers' Perceptions of Environmental Uncertainty (Robey, 1986, p. 313) is to know the limits of one's technology and work around those limitations to accomplish the mission. Before discussing technological issues, a brief description of the Aegis system is in order:

> The Aegis command and control system puts up an electronic shield of radar around itself and any ships within a 250 mile radius. It thus acts as a defense system for the whole battle group. The heart of the system is the phased array radar, SPY-1, which sends out multiple pulses capable of simultaneous tracking of hundreds of targets. Its data is fed to the Combat Information Center. Other equipment identifies friend or foe...conducts surface searches, guides missiles to selected targets, provides long range air searches and tracks submarines. The second function of Aegis is to control the weaponry on board.... The computers take information from the ship's own sensors and from other craft in the area, [and] then...[determine] intercept times for enemy missiles, ships and aircraft. The chief armament on the USS *Vincennes* is the Standard SM-2 missile, which was used against Flight 655. (TIME, 1988, p. 12)

In a nutshell, the basic problem of the Aegis weapon system involved limitations in the man/machine interface. According to William P. Gruner, the basic issue is that the system was poorly suited for use by human beings during rapid military action:

> ...the brain has one basic and serious shortcoming when applied to rapid-action warfare as typified by the *Vincennes* incident. Simply put, the rate at which the brain can comprehend information is too slow under fast-paced action. It has neither the time to understand all the inputs it receives, nor the ability to effectively perform all the other functions it would be capable of in a less harried environment. This performance limitation causes the brain to 'forget' data inputs, overlook stored data, draw hasty conclusions, and produce flawed answers for the human being it serves. (1990, p. 40)

Electronic data subsystems process and display information at extremely high rates, while, on the other hand, the comprehension capability of operators has remained more or less stagnant. Consequently, when operators interface with electronic data subsystems, the users become overwhelmed by large amounts of changing data. Using a metaphor in electronic circuitry, the designers of the system created an impedance mismatch between the operator/user and the electronic data subsystem (Gruner, 1990, p. 40). One way to remedy this problem is to distribute the workload among the operators so that no one operator is overloaded. However, this created an other problem with the Aegis weapon system which involved "distributing, correlating, and integrating the outputs and inputs of the resultant multi-operator system." (Gruner, 1990, p. 40) To compound this problem, electronic subsystems oftentimes rely on data bases that contain inaccurate data or entirely lack data elements that are vital to solving operational problems such as contact classification, identification and threat analysis. The net result can be errors that cause accidents. (Gruner, 1990, p. 41)

As can be seen thus far, many of the problematic issues encountered by the *Vincennes* are integration oriented, but are ultimately rooted in the lack of human factors considerations in the design phase. Dr David Meister, a resident scientist at the Naval Ocean Systems Center (NOSC), conceded that "human error probably did play a major role in the *Vincennes* incident, but not in the way the Fogarty report contend[ed]. 'It was human error...on the part of the people who designed the system.'" (Hill, 1989, p. 204) Surprisingly, only a few examples of man/machine interface oriented recommendations were made by the Fogarty team, such as making the RCI slave to a hooked track, reassessing the Aegis large screen display (LSD) to allow the option of displaying altitude directly on the LSD, and determining the cause of net 15/16 degradation (Fogarty, 1988, p. 53). Table IV-2, Man-Machine Interface Human Engineering Problems, is a breakdown of typical design problems inherent with the current naval NTDS system as presented by Glenn A. Osga, Naval Ocean Systems Center:

TABLE IV-2

MAN/MACHINE INTERFACE HUMAN ENGINEERING PROBLEMS

Terminology is mis-matched between functions, displays and manuals.
Terms are vague and inconsistently used.
Error messages are uninformative.
Errors force task restart.
Errors may render system inoperative.
Alerts are too numerous.
Displays are "data dumps" and not task supportive.
Procedures force numerous shifts between displays and controls.
Procedures are inconsistent and force rote memorization.
Users must memorize (up to 12) procedural outcomes.
Visual feedback during task processing is non-existent.
Controls force an inefficient menu hierarchy.
Display cursor velocity is inversely related to trackball velocity.
Tactical displays are "cluttered" and dense.
No help information on-line.
No database query facilities, information extraction burden is on the user.
Displays are primarily text with no graphics.
Related information is divided among numerous small displays.
Information is not integrated to support critical decisions.

Source: Osga, "User-Computer Interface Issues for Future Ship Combat Consoles," p. 2

In sum, according to Captain Wayne P. Hughes, U.S. Navy (retired), "[T]echnology advances keep weapons in a state of change, and tactics must mate with the capabilities of contemporary weapons." (1986, p. 32) However, Captain Hughes' remarks should be taken one step further as a result of the *Vincennes* incident. "...tactics *and human factors considerations in systems design* must mate with the capabilities of contemporary weapons." The most advanced weapon system can be rendered useless if it is too difficult to employ under normal circumstances, let alone combat conditions. Therefore, another contributing factor to the *Vincennes* incident lies in the poor interface between the Aegis weapon system and the operator due to procedural complexity, problematic presentation of information, as well as other user hostile aspects inherent with Aegis system design. The nature of the interface between man and machine should compensate for human weaknesses as a result of information overload, particularly during combat where task uncertainty, time constraints, and chaos are at their extreme. Otherwise, the system will not be used to its full potential and could become more of a detriment than an asset.

g. Culture

The author was unable to assess the culture of the *Vincennes* due to the inability to interview crew members. Because of the esoteric nature of culture and the lack of interview data, a determination as to its impact could not be made.

h. Outcome

The outcome was that the *Vincennes* mistakenly shot down a civilian airliner. This accident was not the result of any one particular error, event, breakdown, act of omission or commission, individual equipment or personnel limitation, but rather, it was the culmination of all the above. A negative synergy aimed towards system failure was achieved, in which a combination of small "errors" and their interactions within the system compounded to become one large scale error. The Dynamic Systems Model illustrates to some extent how this type of outcome is achieved. Again, the model is dynamic in which the elements such as environment, key success factors, task, structure, people, technology and culture are interactive producing an oftentimes unexpected outcome. The interaction of elements within a system are critical and are oftentimes overlooked, particularly when an accident occurs in which simple solutions are sought to complex dynamic problems. According to Lloyd R. Amey, in A Conceptual Approach to Management,

> Interrelatedness of parts is the essential characteristic of a system. The fact that (some of) the parts are interrelated means that the whole can behave in ways that none of the parts can: consider a human being and a single limb. We say the whole possesses certain 'emergent properties'--the whole is more than the sum of its parts. The effect of this kind of parts-whole relationship (2 + 2 = 5) is sometimes referred to as *synergy* or *gestalt*. (1986, p. 4)

In sum, the aggregate error resulting from the interaction and interdependencies of the various organizational and contextual factors as depicted by the Dynamic Systems Model contributed to the Iranian Airbus tragedy. As can be discerned, there were numerous causes that contributed to the accidental shoot down of Flight 655, that were magnified by their interaction with other problematic issues.

D. IDENTIFICATION OF "CAUSAL FACTORS" USING A CYBERNETIC MODEL

1. Cybernetics

Cybernetics is an interdisciplinary science focusing on the study of information, communication and control. The term was coined in the 1940s by a mathematician from MIT, Norbert Wiener, as a metaphorical application of the Greek word, *kubernetes*, which means steersman. "Wiener used this imagery to characterize processes of information exchange through which machines and organisms engage in self-regulating behaviors that maintain steady states." (Morgan, 1986, pp. 84-86) The main concept emerging from Wiener's research was that the ability of a system to engage in self-regulating behavior depends on processes of information exchange involving negative feedback. Peferring to the above metaphor, negative feedback is pivotal to the process of steersmanship:

> Systems of negative feedback engage in this type of error detection and correction automatically, so that movements beyond specified limits in one direction initiate movements in the opposite direction to maintain a desired course of action. (Morgan, 1986, p. 85)

The concept of negative feedback allows one to view routine behavior in an unconventional way as shown in Figure IV-5. For example, one would think that when a person picks up a pencil from a desk, that his hand, guided by his eye, moves directly toward the pencil in order to pick it up. Cybernetics suggest otherwise. For in cybernetics, this simple action occurs through a process of error elimination where deviations between hand and pencil are reduced at each and every stage of the process so that in the end, no error remains. He picks up the pencil by avoiding not picking it up. Similarly, this same process applies to riding a bike. A person manages to ride a bicycle by a means of a system of information flows and regulatory actions that help him/her to avoid falling off. To put it another way, negative feedback involves more leading to less and less to more. (Morgan, 1986, pp. 85-6)

We pick up an object by avoiding not picking it up!

In a similar way, we manage to ride a bicycle by means of a system of information flows and regulatory actions that help us to avoid falling off.

Negative feedback eliminates error: it creates desired system states by avoiding noxiant states.

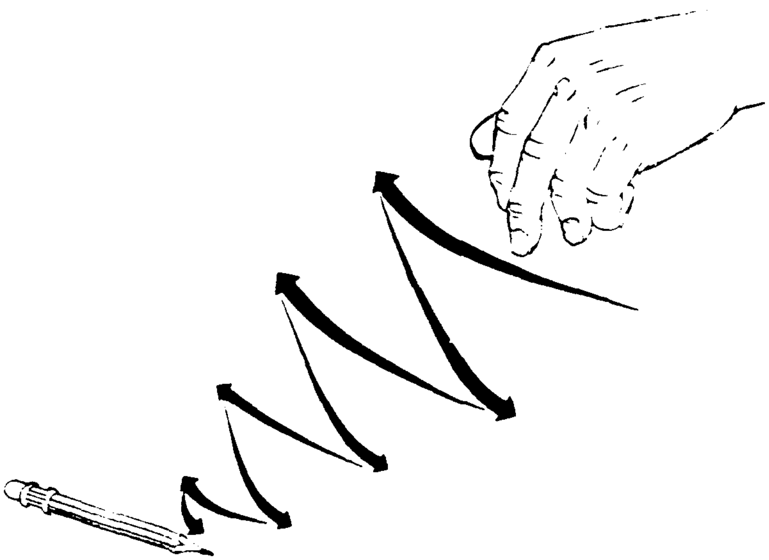


Figure IV-5. Negative Feedback in Practice (Morgan, 1986, p. 86)

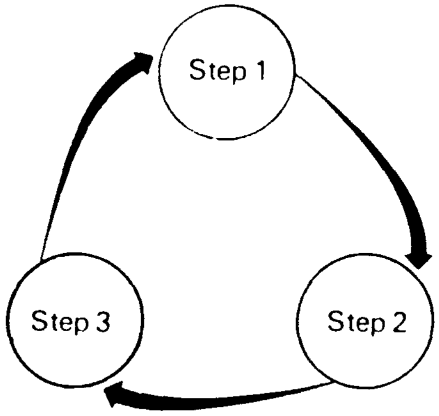
Cybernetics paves the way to a theory of communication and learning, stressing four key principles:

- Systems must have the capacity to sense, monitor, and scan significant aspects of their environment
- Systems must be able to relate this information to the operating norms that guide system behavior
- Systems must be able to detect significant deviations from these norms
- Systems must be able to initiate corrective action when discrepancies are detected (Morgan, 1986, p. 86-7)

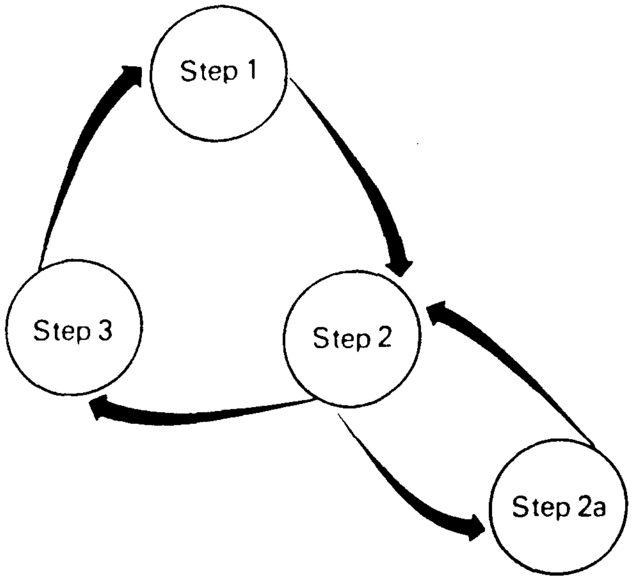
If these four conditions are satisfied, a continuous process of information exchange is created between a system and its environment, allowing the system to monitor changes and initiate appropriate responses. In this way, the system can operate in an intelligent and self-regulating manner. (Morgan, 1986, p. 87)

Now, where does learning fit in? The above conditions have led cyberneticians to draw a distinction between the process of learning and learning to learn. A thermostat is a simple cybernetic system and an example of a "single-loop" learning process as shown in Figure IV-6. A thermostat is able to learn in the sense of being able to detect and correct deviations from predetermined norms. But, a thermostat is unable to question the appropriateness of what it is doing. If the thermostat setting was changed to a new setting of 32 degrees Fahrenheit, the thermostat is unable to question whether this temperature setting is appropriate to the inhabitants' preferences and is unable to make adjustments to account for this deviation from the norm. Consequently, the inhabitants

Single-loop learning rests in an ability to detect and correct error in relation to a given set of operating norms:



Double-loop learning depends on being able to take a "double look" at the situation by questioning the relevance of operating norms:



Step 1 = the process of sensing, scanning, and monitoring the environment.
Step 2 = the comparison of this information against operating norms.
Step 2a = the process of questioning whether operating norms are appropriate.
Step 3 = the process of initiating appropriate action.

Figure IV-6. Single and Double-Loop Learning (Morgan, 1986, p. 88)

experience discomfort. On the other hand, more complex cybernetic systems such as the human brain are able to detect and correct errors in operating norms and thus influence the standards that guide their detailed operations. "It is this kind of self-questioning ability that underpins the activities of systems that are able to learn to learn and self-organize." (Morgan, 1988, p. 87) The basic difference between these two types of learning is identified in terms of "single-loop" learning as in the thermostat example and "double loop learning" as in the human brain as displayed in Figure IV-6.

"Can organizations learn and learn to learn?" As depicted in the single loop diagram, many organizations have become proficient at this type of learning. They have developed the ability to scan the environment, to set objectives, and to monitor general performance of the system in relation to these objectives. This includes controls such as budgets, exception reports, and/or any mechanism that highlights critical deviations. The ability to achieve proficiency at double loop learning often proves to be elusive. While some organizations have been successful in institutionalizing systems that review and challenge basic norms, policies and operating procedures, in relation to changes occurring in their environment, many fail to do so. This failure is indicative of bureaucratic organizations since their operating principles oftentimes obstruct the learning process. (Morgan, 1986, pp. 87-89)

2. Cybernetic Loops

Cybernetic theory requires the reader to think in terms of loops, rather than lines, and to replace the idea of mechanical causality, that A causes B, with the concept of mutual causality, which suggests that A and B may be co-defined as a consequence of belonging to the same system of relations (Morgan, 1986, p. 247). The methodology used to analyze the *Vincennes* incident is adopted from Magorah Maruyama's research, who focuses on positive and negative feedback in shaping system dynamics:

> Processes of negative feedback, where a change in a variable initiates changes in the opposite direction, are important in accounting for the stability of systems. Processes characterized by positive feedback, on the other hand, where more leads to more, and less to less, are important in accounting for system change. Together these feedback mechanisms can explain why systems gain or preserve a given form, and how this form can be transformed over time. (Morgan, 1986, p. 247)

Maruyama's loop analysis shows how positive feedback accounts for differentiation of complex systems in the following example:

> ...a large homogeneous plain attracts a farmer, who settles on a given spot. Other farmers follow, and one of them opens a tool shop. The shop becomes a meeting place, and a food stand is established next to the shop. Gradually a village grows as merchants, suppliers, farmhands, and others are attracted. The village facilitates the marketing of agricultural products, and more farms develop around the village. Increased agricultural activity encourages the development of industry, and the village gradually becomes a city. (Morgan, 1986, pp. 248)

In the above example, the homogeneous plain was transformed by a series of positive feedback loops that amplified the initial effects of the differentiation process (Morgan, 1986, p. 249). The growth of the city was not instigated by any one single cause, but by a "deviation-amplifying *process*." Maruyama argues that the processes of positive feedback characterized by deviation-amplification explain the "evolution" of things, whereby positive feedback produces changes that are out of proportion with the initial "kick" or incident that activated them. This kind of analysis can be used to foster a better understanding of events and processes that shape organizations and their contexts and can be used to understand the dynamics of many different types of organizational problems. (Morgan, 1986, p. 249)

3. Cybernetic Model of Mutual Causality--The *Vincennes* Incident

Figure IV-7 presents a cybernetic view of the *Vincennes* incident. Many of the links presented in this diagram are deviation-amplifying (solid lines). These positive feedback relations mean more leads to more and less leads to less, while the negative feedback relations (dashed lines) mean changes in one direction are associated with changes in the opposite direction. The dotted lines mean that there is an implied connection between the set of relations. Also, the letters and numbers of the Cybernetic Model correspond directly to the letters and numbers labelling the various events and factors in the Events Path Model, Figure IV-1. To recap, the **letters** represent events/factors that had occurred external to the CIC, while the **numbers** are events/factors that took place within the CIC.

A means for interpreting this model is demonstrated in the following description: A strategic node, which is a large ellipse with a bold outline, containing the contents "Iranian P-3 challenged by *Vincennes*" is located at the top left hand corner of the model. The number inside the ellipse refers to it as a factor that had occurred internal to the CIC--the *Vincennes* issued a challenge to the P-3. The numeric designation of "9" to this ellipse is equivalent to the labelling used on the Events Path Model, Figure IV-1. In fact, all labelling in the Cybernetic Model can be mapped back to the Events Path Model. Essentially, the entire Cybernetic Model is a translation of the Events Path Model

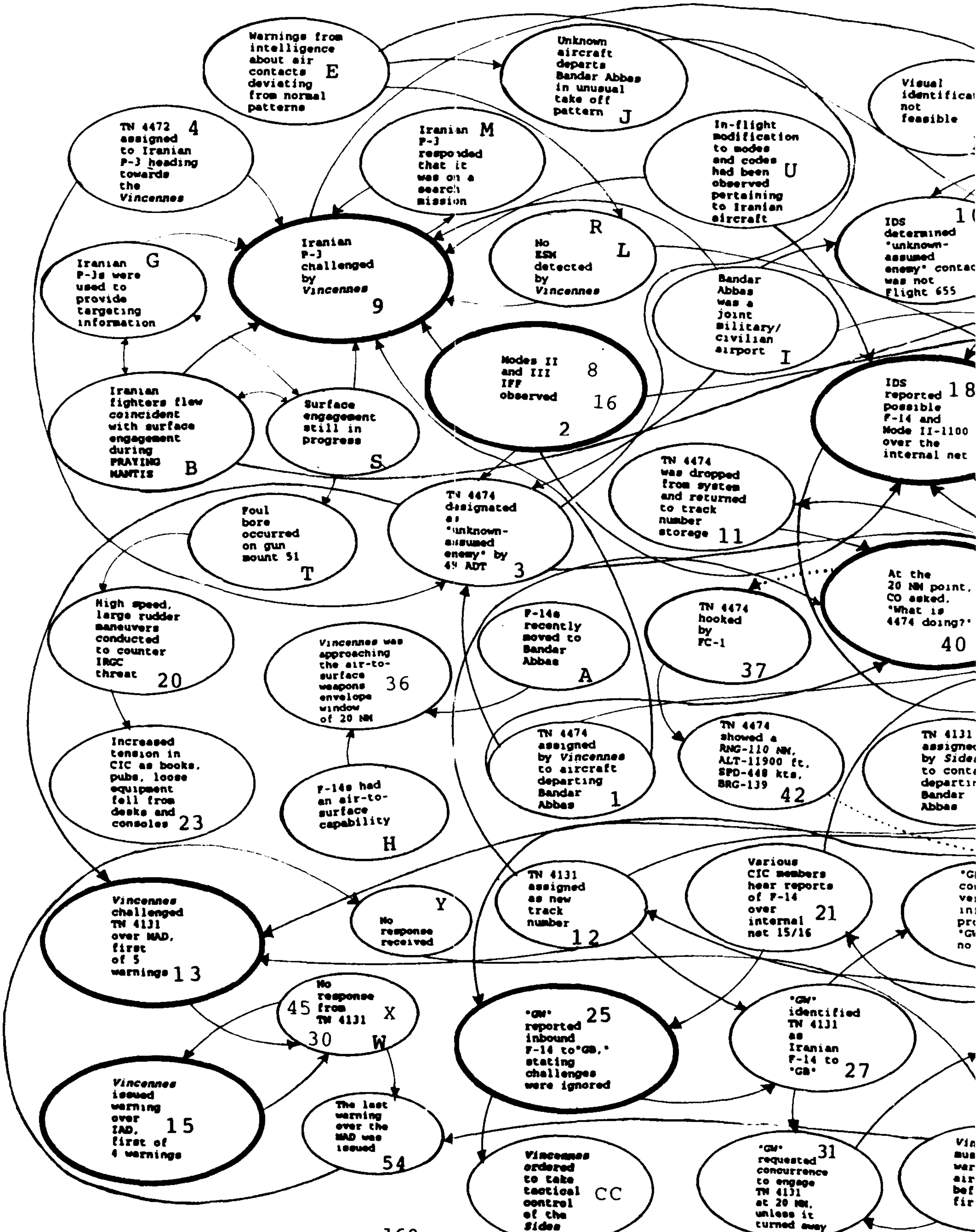

Warnings from intelligence about air contacts deviating from normal patterns E
Unknown aircraft departs Bandar Abbas in unusual take off pattern J
Visual identifica not feasible
TN 4472 assigned to Iranian P-3 heading towards the Vincennes 4
Iranian P-3 responded that it was on a search mission M
In-flight modification to modes and codes had been observed pertaining to Iranian aircraft U
IDS determined "unknown-assumed enemy" contac was not Flight 655 1
Iranian P-3 challenged by Vincennes 9
No ESM detected by Vincennes R L
Iranian P-3s were used to provide targeting information G
Bandar Abbas was a joint military/civilian airport I
Modes II and III IFF observed 8 16 2
IDS reported possible F-14 and Mode II-1100 over the internal net 18
Iranian fighters flew coincident with surface engagement during PRAYING MANTIS B
Surface engagement still in progress S
TN 4474 was dropped from system and returned to track number storage 11
Foul bore occurred on gun mount 51 T
TN 4474 designated as "unknown-assumed enemy" by 49 ADT 3
At the 20 NM point, CO asked, "What is 4474 doing?" 40
High speed, large rudder maneuvers conducted to counter IRGC threat 20
F-14s recently moved to Bandar Abbas A
TN 4474 hooked by FC-1 37
Vincennes was approaching the air-to-surface weapons envelope window of 20 NM 36
Increased tension in CIC as books, pubs, loose equipment fell from desks and consoles 23
F-14s had an air-to-surface capability H
TN 4474 assigned by Vincennes to aircraft departing Bandar Abbas 1
TN 4474 showed a RNG-110 NM, ALT-11900 ft, SPD-448 kts, BRG-139 42
TN 4131 assigned by Sides to cont departin Bandar Abbas
Vincennes challenged TN 4131 over MAD, first of 5 warnings 13
No response received Y
TN 4131 assigned as new track number 12
Various CIC members hear reports of F-14 over internal net 15/16 21
No response from TN 4131 45 X 30 W
"GW" reported inbound F-14 to "GB," stating challenges were ignored 25
"GW" identified TN 4131 as Iranian F-14 to "GB" 27
Vincennes issued warning over IAD, first of 4 warnings 15
The last warning over the MAD was issued 54
Vincennes ordered to take tactical control of the Sides CC
"GW" requested concurrence to engage TN 4131 at 20 NM, unless it turned away 31

Figure IV-7. Cybernetic Causality--The *Vincennes*

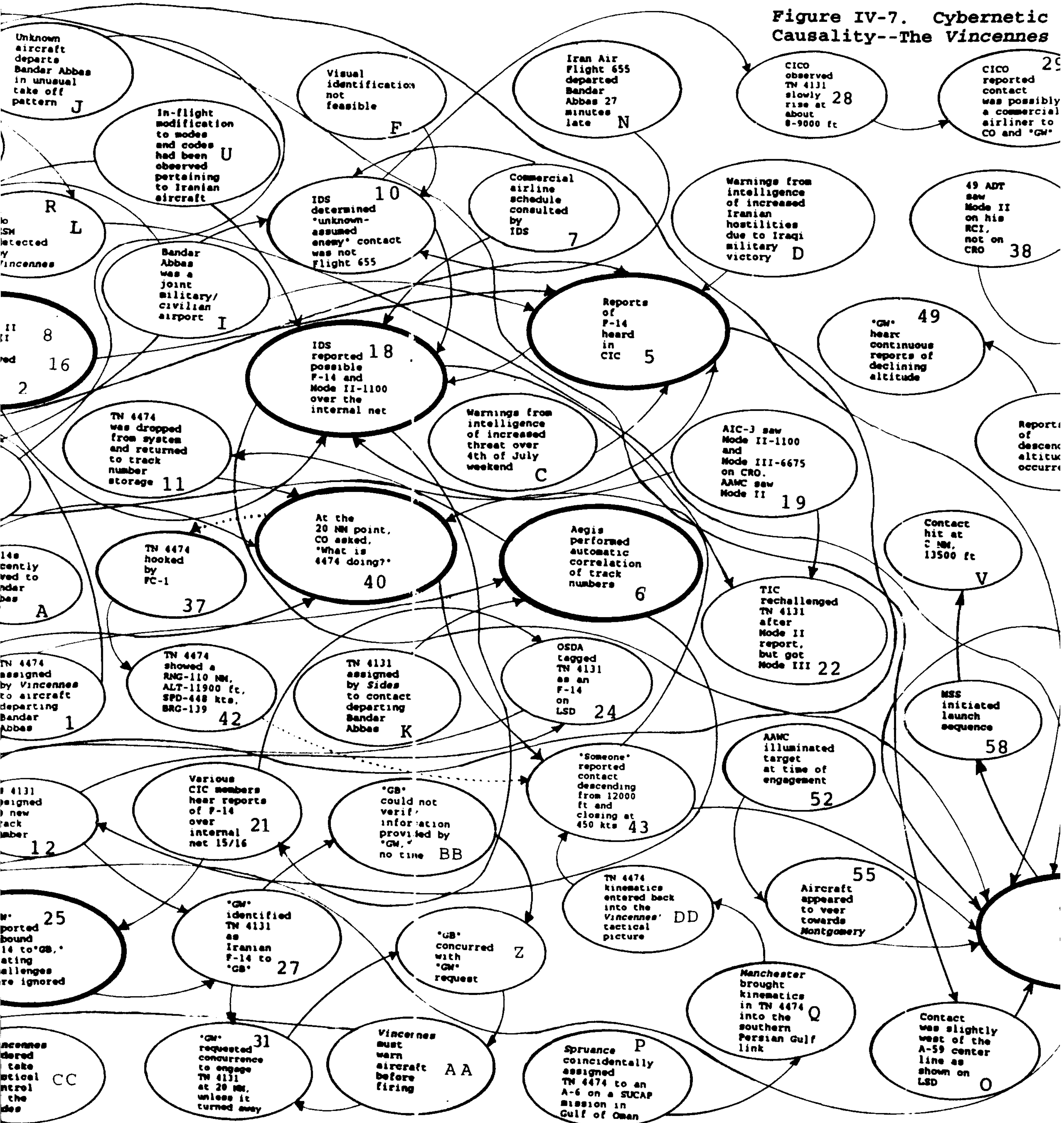
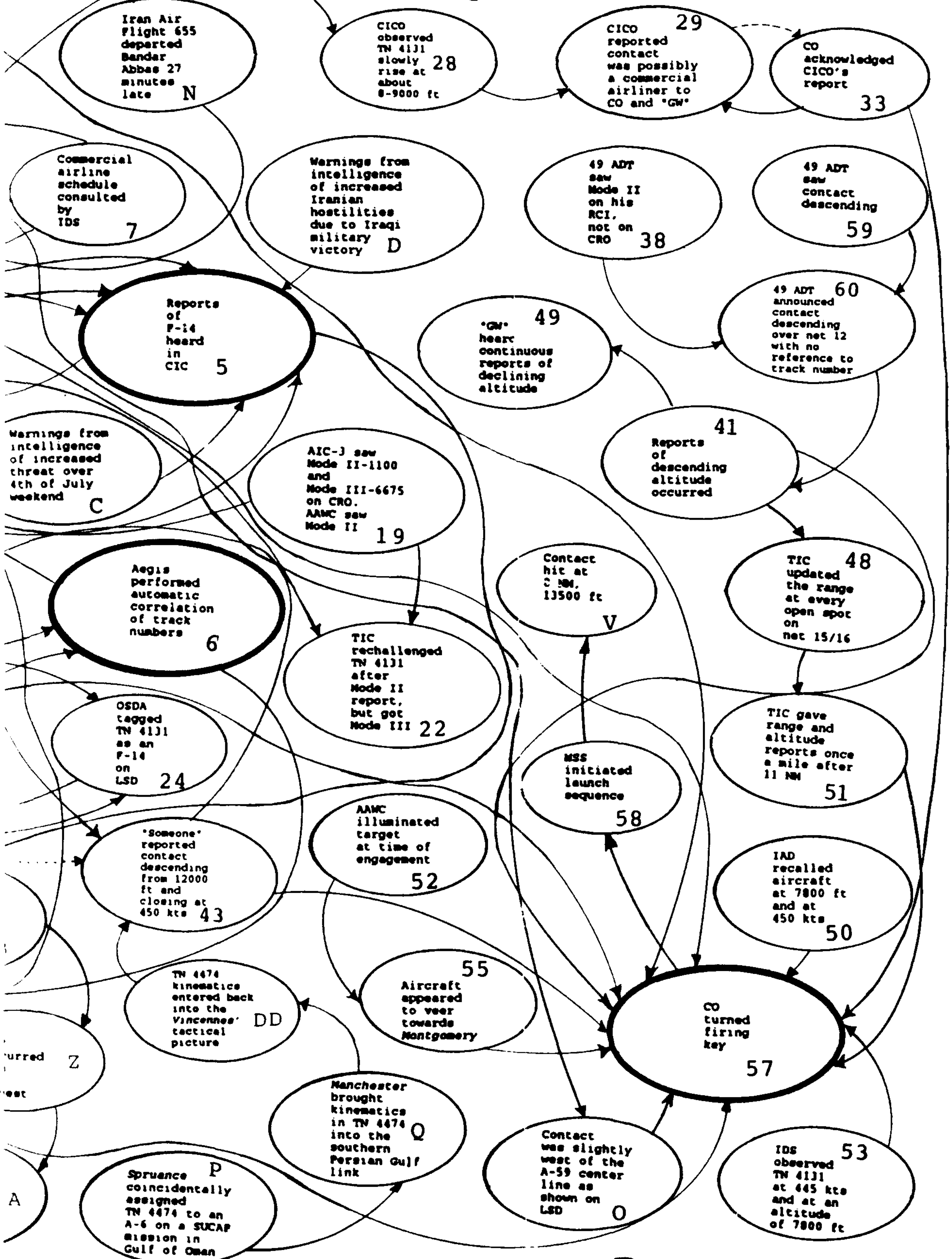


Figure IV-7. Cybernetic Model of Mutual Causality--The *Vincennes* Incident



in terms of loops and nodes to show flow and interaction. By tracing the lines entering and leaving the strategic node as in Node 9, one can get an idea of how this particular node impacts other nodes as well as how other nodes and loops impact it. For example, Node "B", which is an external factor to the *Vincennes'* CIC as it is labelled with a letter, is related to Nodes "G" and "S." Not only are all three nodes related to each other, but their individual relationships as well as their combined association to Node 9 affect this strategic node. Another example of this type of contributing factor involves Node "R L," which is a combination of similar "blocks" or factors from the Events Path Model pertaining to ESM. Node "RL" contributed to the challenge of the P-3, but also had a significant impact on Node 57, which was Rogers' decision to fire, because the contact of interest, like the Iranian P-3, was not emitting any radar. Although some relationships are stronger than others, one can follow the nodes and loops and trace their relationships. The important point to this model is to get an understanding of how events are interrelated to each other without the constraints of time.

Upon viewing Figure IV-7, we see that negative feedback relations (dashed lines) are practically nonexistent, except for one event involving the CIC officer notifying the commanding officer and Golf Whiskey or the AAW TAO that the contact was "possible COMAIR." (Fogarty, 1988, p. 34) Here, positive feedback loops characterized the *Vincennes'* air engagement, and the process became a deviation-amplifying process, with minimal impact from the negative feedback loop to keep the system stabilized. The best way to think of this process is like flying an airplane: If a pilot flies off course by using too much rudder in a particular direction, then to get back on course, he/she must move the rudder in the opposite direction. However, if no negative feedback is applied via the rudder, the pilot will find himself further and further off course. When left unchecked, positive feedback engages in a deviation-amplification process in which the error becomes progressively more pronounced. To keep the system in check or the aircraft on course, a series of negative feedback loops or small rudder movements in the opposite direction are required upon detection that the system or airplane is veering off course. Continual adjustment through the use of negative feedback as a control mechanism enables the system to stay within bounds and assures that the pilot arrives to his/her planned destination.

Systems can be viewed as "dynamic systems of loops," whereby change is the antithesis of organization and organization is the antithesis of change: "Change is the result of deviation amplifying loops (Maruyama, 1963; Watson, 1963), [while] organization...is the result of deviation countering loops (Weick, 1969; Crozier, 1963, 1970)." (Bougon and Komokar, 1990, p. 137) Nodes link together to form loops, in which the deviation amplifying loops are responsible for change, and the deviation countering loops are responsible for maintaining stability and control (Bougon and Komokar, 1990, p. 137). Viewing the *Vincennes* incident as a system of loops as depicted in Figure IV-7, the loops, in essence, created the organization. In cybernetics, "to change organizations is to change loops, and to change loops is to change organizations." (Bougon and Komokar, 1990, p. 137) Therefore, to effect change to an organization is really to effect change to its loops, which can be accomplished in three phases:

1. Identify the strategic nodes

2. Identify the strategic loops

3. Use the plasticity of many of the loops to direct the dynamics of the system's strategic loops in the desired direction. (Bougon and Komokar, 1990, p. 143)

In the Cybernetic Model of the *Vincennes* Incident, Figure IV-7, the strategic nodes are identified by the large ellipses and the strategic loops are those loops that contain the strategic nodes. Some loops are stronger than others, or they may be loosely or tightly coupled to the whole system. The problem is that the nodes and loops of interest to strategic change are the ones likely to coincide with strong, tightly coupled nodes as well as with the nodes and loops directly responsible for the system's identity. (Bougon and Komokar, 1990, p. 147). If this is the case, then attempts to directly or by incremental fashion to change these strategic nodes and loops will end in failure due to the intense amount of conflict generated. However, the solution is to focus change efforts on peripheral and/or weak loops rather than those directly responsible for system identity as presented in the following:

> [A]lter enough weak loops so that the strong nodes and loops defined by the initial whole become indirectly redefined by a new, emergent whole.... When loops are weak and loosely coupled, nodes can be added to, or removed from loops with reasonable effort.... [However,] by simply adding a node to a loop is not sufficient, to bring about change in the action of a loop, the addition must change its sign.... [In other words,] when adding or removing a node, to effectively change the action of the loop, a replacement node must reverse the effect of the node preceding it on the node following it. (Bougon and Komokar, 1990, p. 149)

By attacking the change process from an indirect, more subtle approach, the conflict generated as a result of the change will be low (Komokar and Bougon, 1990, p. 151).

Conversely, by the "brute force" method of affecting change on strong nodes and links, great conflict will ensue and the change process, more than likely, will fail

4. Application

In the case of the *Vincennes* incident, there was minimal negative feedback to keep the system from going out of control:

- There was no aircraft in the area to provide a positive visual identification concerning the unknown-assumed enemy contact of interest.
- Although the *Vincennes*' combat organizational structure for Persian Gulf operations (Figure II-6) was intendedly designed to provide negative feedback with respect to the fast moving AAW environment, due to task overload and distractions from their primary duties, the AAW TAO and AAWC console operator could not verify the information being provided to the captain. It was what they did not do that became the problem.
- Golf Bravo could not interject into the system and provide an independent assessment because of the lack of a "usable real time data link."(Fogarty, 1988, p. 50)
- Although the *Sides* was a detached participant during the air engagement and evaluated the contact as a non-threat, the commanding officer did not attempt to dissuade the *Vincennes* from shooting.[7]
- Air Traffic Control did not interject after numerous attempts on the part of the *Vincennes* and *Sides* in trying to contact and warn the aircraft.
- Although the CIC officer made the remark "possible COMAIR" to the commanding officer and Golf Whiskey, his remark, which was a source of negative feedback, was not forceful enough to counteract the momentum gained. The preponderance of evidence that suggested the contact was an F-14 on an attack profile amplified the process rather than provided a counterbalance to it.

What appears to be a possible solution to this problem is to design negative feedback loops in order to contribute to double-loop learning. This would provide a "double look" that questions the relevance of operating norms and what is going on in the system. (See Section 2) According to Morgan, "[s]ystems of negative feedback engage in this kind of error detection and correction automatically, so that movements beyond specified limits in one direction initiate movements in the opposite direction to maintain a desired course of action." (Morgan, 1986, p. 85)

This overall negative feedback process, which is a modified version of the "double-loop learning" process, is characteristic of a cybernetic system. By ensuring negative feedback is an integrated, automatic part of the system, then one has designed into the system a means by which organizations can learn. According to Cohen and Gooch in Military Misfortunes, the failure to learn[8] is a "taxonomy of misfortune." (1990, p. 26)

5. Summary

By following the arrows of the Cybernetic Model of Mutual Causality--The *Vincennes* Incident, one can trace events, their impact, and their relationships with other events. One can see how both internal and external factors affected the *Vincennes* system and, in turn, how the *Vincennes* system affected the context. In essence, the Cybernetic Model of Mutual Causality enables one to understand from a systems perspective the nature of the problem inherent with the *Vincennes* incident--the lack of negative feedback. It is not like the linear process of tracing a cascading error to its origin to account for the wrong answer, as in a complex thermodynamics problem. Unlike the cascading error analogy, the *Vincennes* incident does not boil down to a singular cause, like a simple "sign error," but rather, the "cause" is a far more complex interrelationship of causes and events, transcending the "misreading of altitude" (Senate Hearing, 1988, p. 16) attributed to "combat induced stress on personnel." (Fogarty, 1988, p. 51)

E. CONCLUSION

The Cybernetic Model of Mutual Causality depicting the *Vincennes* incident of Section D, demonstrates the importance of negative feedback to the maintenance of stability in a system. It also illustrates that outcomes are the products of a complex set of relationships. We also see, as shown in the Dynamic Systems Model of Section C, the existence of separate factors, that when taken in aggregate, can also lead to an undesirable outcome. Additionally, this model is an example of a highly interdependent system, in which a change in one element results a change in another. Finally, the Events Path Model of Section B, a linear model, reveals how a series of events over time culminated in the downing of the Airbus.

However, by dwelling on the linear map too long, one could to fall into the trap of "thinking in lines," searching for simple cause(s) that lie at the root of the problem (Morgan, 1986, p. 249). Although linear thinking used in the investigation process is pragmatic in its own right, it can lead to misleading conclusions. It can generate a linear solution when the actual problem is systemic. Upon dissection of the Path Model, Figure IV-1, one finds that even with this linear map, the problem cannot be attributed to just one cause that launched a chain reaction.

Consequently, an assortment of models, such as the Events Path Model, Dynamic Systems Model, and the Cybernetic Model of Mutual Causality, should be used to diagnose complex problems in order to effectively develop a more complete map the "causal factors." Of equal importance is to prevent the misapplication of methodologies and their associated models which often leads to an incomplete and/or erroneous diagnosis. This misapplication is evident in the Fogarty report, whereby the investigation team used a linear approach to diagnose a systemic problem. Due to this mismatch in methodologies, the investigation team could not accomplish a complete diagnosis as they could have if they employed a combination of models to help them assess "causal factors." The systems approach in analyzing complex dynamic systems is a necessary approach to problem identification and problem solving. The linkage between events, their interaction, and impact on the system are critical aspects of the diagnostic process.

NOTES

1. The events are not entirely inclusive, although they cover the major factors Captain Rogers specifically considered when he made his decision. These factors and events were derived from: the Fogarty report, pages 40-41; two personal interviews with Captain Rogers, 13 February and 8 and 9 April 1992; and excerpts from the Senate Hearing, 1988.

2. The formal definition of low intensity conflict (LIC) was adopted in 1985 by the Joint Chiefs of Staff and is defined as the following:

> Low-intensity conflict is a limited politico-military struggle to achieve political, social, economic, or psychological objectives. It is often protracted and ranges from diplomatic, economic, and psycho-social pressures through terrorism and insurgency. Low-intensity conflict is generally confined to a geographic area and is often characterized by constraints on the weaponry, tactics, and the level of violence. (Klare, 1988,p. 53)

3. Autopoiesis is a new approach to systems theory developed two Chilean scientists, Humberto Maturana and Francisco Varela. They maintain that all living organisms are organizationally closed, autonomous systems of interactions that make reference only to themselves. Their argument is based on the premise that living organisms are characterized by three key features: Autonomy, circularity and self-reference. These features enable living systems to "self-create" or "self-renew." Therefore, the term autopoiesis refers to this capacity for "self-production" through a closed system of relations. Maturana and Varela assert that the "aim of such systems is ultimately to produce themselves: Their own organization and identity is their most important product." (Morgan, 1986, p. 236)

Gareth Morgan explains that "random variations or kicks to the system help spur change to the whole, which foster evolution and organizational learning," in which large fluctuations trigger instability and quantum leaps capable of transforming the whole system of activity into a new order of existence (Morgan 1986, p. 240):

> From an autopoietic standpoint, random variation provides the seed of possibility that allows the emergence and evolution of new system identities. Random changes can trigger interactions that reverberate throughout the system, the final consequences being determined by whether of not the current identity of the system will dampen the effects of the new disturbance through compensatory changes elsewhere, or whether a new configuration of relations will be allowed to emerge. (Morgan, 1986, p. 240)

4. Daft identified four consequences of the garbage can model:

   1. Solutions may be proposed even when problems do not exist

   2. Choices are made without solving problems

   3. Problems may persist without being solved

   4. A few problems are solved (1986, pp. 365-366)

5. The following description of organized anarchy is provided by Daft:

> The organized anarchy describes organizations characterized by rapid change.... No organization fits the organized anarchy circumstances all the time. Most organizations will occasionally find themselves in positions of making decisions under unclear, problematic circumstances. (1986, p. 364.)

6. According to Bradd Hayes, the Joint Chiefs of Staff made the following changes to the rules of engagement after the *Stark* incident:

> The rules of engagement were changed to encourage anticipatory self-defense: the definitions of *hostile intent* and *hostile act* were now revised; all aircraft and ships were now considered potentially hostile; and all neutral and friendly shipping became eligible for U.S. assistance. (1989, pp. 54-5)

7. *The following account is from a letter published in the* U.S. Naval Institute Proceedings by Commander David R. Carlson with respect to the *Vincennes* incident:

> During the incident, the *Sides* was less that 20 NM from the USS *Vincennes* and under the *Vincennes'* tactical command.... We locked on and illuminated the...[aircraft] with our missile fire control radar. The aircraft continued climbing on a southwesterly course that would take it right over the USS *Vincennes'* position. Based on closest point of approach to the *Sides* (range and altitude), lack of any significant known F-14 anti-surface warfare (ASUW) capability, lack of detected radar emissions, and precedent, I evaluated the track as a non-threat. I continued to press my TAO for information concerning attempts to warn off...[the aircraft] and was advised that numerous attempts had been made without success, and that the effort was continuing....[The aircraft] did not appear to react to the illumination with fire control radar, and this was most unusual. The USS *Vincennes* announced her intentions to take [the aircraft] with missiles at 20 miles. I wondered aloud in disbelief, but did not do the thing that might have helped. I did not think to push for a re-evaluation of IFF. Had I done so, the information might have come

forward quickly enough to allow me to attempt to dissuade the *Vincennes* from shooting. (1989, p. 89)

8. "There are three basic kinds of failure: failure to learn, failure to anticipate, and failure to adapt." (1990, p. 26)

V. CONCLUSION AND RECOMMENDATIONS

The catalyst that instigated the analysis of the *Vincennes* incident stemmed from the following research questions:

1. How is it that a billion dollar warship designed to track and classify multiple aircraft in a combat environment shot down a commercial airliner?

2. How is it that the system data showed the contact to be ascending, while many watchstanders in the Combat Information Center (CIC) thought the contact was descending?

3. And finally, how is it that the findings of Rear Admiral Fogarty, the investigating officer, differed from the interpretation of Captain Rogers, the Commanding Officer of the *Vincennes*?

The research process was limited to unclassified materials and sources. The primary sources for the analysis were the Fogarty report, unclassified version, Senate Hearing before the Committee on Armed Services, and personal interview data obtained from several interviews with Captain Rogers.

The *Vincennes* shot down Iran Air Flight 655 due to her inability to positively identify the contact. By employing the Events Path Model, Dynamic Systems Model, and the Cybernetic Model of Mutual Causality, this identification problem was the result of a variety of "causal factors":

• Extreme ambiguity and uncertainty as well as time compression coupled with chaotic, unpredictable conditions contributed to the fusion of misleading information fragments. Not only did the local context set the stage for the eventual downing, but mixed IFF readings were added to the ducting conditions and the miscorrelation of Remote Control Indicator information, to make it practically impossible to obtain reliable contact identification through the IFF process.

• The watchstanders' concept of reality was an evolutionary process fueled by random variations of both internal and external events/factors. During the last 189 seconds, the F-14 context was progressively amplified, culminating in a new order of reality: Captain Rogers and his CIC organization engaged what they believed to be an F-14. Positive aircraft identification was the real problem that led to the shoot down. Practically the entire seven minute air engagement process involved efforts taken by CIC personnel to identify the aircraft.

• The inability to determine the size of a contact was another contributing factor. Aegis is a highly sophisticated, effective system; however, it was designed to detect targets at great range, which sacrificed the ability to distinguish the size of a target. The Aegis system was designed for the "open ocean" environment where the size of a contact was not as crucial of an issue as in a littoral or confined environment.

• Due to task overload, the organizational structure did not facilitate the verification of information as was originally intended with the AAW TAO set up. Since the AAW TAO could not perform his primary duties by providing an independent assessment of information, a break down in communications, coordination, and information flow were experienced, which had ramifications throughout the entire anti-air warfare function up through the chain of command to the commanding officer of the *Vincennes*.

• Captain Rogers' individual decision making process was influenced by numerous factors: watchstanders' perceptions, environmental inputs (internal and external) as well as his own perceptions to make his decision at the critical 20 NM point of the air engagement. Because he was in the middle of an explosive mix of circumstances, his decision was only as good as the information he was provided.

• The most advanced system can be rendered useless if it is too difficult to employ under normal circumstances let alone combat conditions. A contributing factor in the downing of Flight 655 was the poor interface between the Aegis weapon system and the operator, especially the procedural complexity and a problematic presentation of information illustrated in the auto-correlation and subsequent confusion of track numbers.

• A negative synergy moving towards system failure developed from a combination of small errors and their interactions within the system. All worked together to produce one large scale error. In sum, the aggregate error resulting from the interaction and interdependencies of the various organizational and contextual factors contributed to the Iranian Airbus tragedy.

• The *Vincennes* system was lacking in negative feedback in order to keep the system from going out of control. Negative feedback was not a well integrated, automatic part of the system organizationally, technologically, or procedurally.

With respect to the second research question concerning ascending versus descending altitude readings, the kinematic information and subsequent analysis indicated that two separate aircraft were being tracked, one that was climbing and the other that was descending. It is probable that various crew members aboard the *Vincennes* were detecting kinematic information from a second aircraft, an A-6, having the same track number as was originally designated to the unknown-assumed enemy contact of interest initially detected from Bandar Abbas. Even without Captain Rogers' interview data to serve as an avenue for comparison, the graphs and analysis show the existence of a second aircraft, but its identity may not have been known. Additionally, the quantitative analysis supports the track number sequence as presented by Captain Rogers during his interviews with the author. It is the opinion of the author that 49 ADT, AIC-3, IAD, IDS, RSC, AAWC, UBS, and MSS were not in all instances "misreading altitude (Senate Hearing, 1988, p. 16) due to "stress" and "scenario fulfillment," which were originally identified as being primary causes for this divergence between recollected and system data entries (Fogarty, 1988, p. 45). The cause of this divergence and subsequent chain of events can be attributed to the CIC's inability to identify and detect the two aircraft involved.

Regarding the third research question (differences in interpretation between Fogarty and Rogers), the issue of more complex causal modeling enriches one's understanding of events and their outcomes. The linear models are useful as a starting point, but should not be the sole means by which an diagnosis is made. This was a shortcoming of the Fogarty investigation. Unable to reconcile the system and the recollected data regarding the disparity in altitude, the Fogarty report attributed the primary cause of the tragedy to stress. On the other hand, Captain Rogers emphasized a more complex analysis of the

Vincennes incident. Building on his observations, we see that complex dynamic systems models are useful for identifying interdependencies and understanding how change affects other aspects of a system. Then, too, cybernetic models are useful for flow analysis, determining the extent of negative feedback or for positive feedback required to facilitate a stabilization or change process in a system. Introducing these tools for analysis would aid investigation and diagnosis of these types of occurrences, for policy makers who want to improve system functioning, Command, Control, and Communications (C3) students who need to learn how to design and redesign systems, and for investigators who need to go beyond linear models in their diagnostic work..

In sum, the research process pertaining to the *Vincennes*' air engagement of Iran Air Flight 655 revealed the followings:

- Rogers' version regarding the existence of two planes and the confusion over track numbers was supported. His interpretation was consistent with the data.

- Based on this analysis, the real issue was the confusion over two aircraft and the inability of the Aegis system operation to distinguish between them.

- The importance of finding the right problem is clearly demonstrated. The Fogarty investigation team could not account for the discrepancy in the data and so introduced the interpretation of individual stress as the causal factor. Further analysis in this thesis opens up the possibility that other factors beside stress were at work. In fact, the new problem definition becomes the inability of using the Aegis system to differentiate between two aircraft.

Consequently, if this overall assessment holds true, then the following specific recommendations can be made, which are geared towards the incorporation of negative feedback into the system to help prevent another "*Vincennes* incident":

Aircraft warnings need to be more specific and descriptive by describing location in relation to a geographical point and use of identification modes and codes (Fogarty, 1988, p. 52)

Improve communication with Air Traffic Control (ATC) agencies between the U.S. and other countries. Commercial air oriented issues are not going to diminish, but only get worse as air traffic becomes more crowded. This will help resolve issues of identification, communication and procedural problems. (Fogarty, 1988, p. 52)

Obtain radios that will enable ship personnel to communicate and monitor Air Traffic Control frequencies, which will provide immediate feedback as to whether the aircraft heard the warnings or not. They could be contacted via local ATC facilities if the ship's efforts are unsuccessful. This will also reduce the language barrier, considering that it is not clear that the pilot of the Airbus understood English or not.

Develop an understanding of cultural differences between U.S. cultural values and the culture that dominates the area of operation. For example, the concept of time and what is considered "late" varies from culture to culture. Being 27 minutes late in an aircraft departure may not be considered late, but rather "on time."

Radio talker responsibilities should be delegated to a less critical position and be dedicated, if necessary (Fogarty, 1988, p. 52). The AAW TAO and AAWC could not perform the verification function and their primary duties that they originally were intended to do. In a generic sense, critical positions should be identified and should only be called upon to perform their primary duties as assigned, otherwise they will be spread too thin. Since communication is critical to higher headquarters, then someone with a less hectic job should be assigned those duties. The command by negation still applies.

Improve operator training to ensure operators are aware of the of the ball tab error in relation to range, ducting and its ramifications with respect to radar, as well as the advantages and disadvantages regarding the use of the RCI to determine mode and code. Until the RCI is slaved to a hooked track through a software or hardware change, there is still the propensity for operators to miscorrelate the RCI data with the hooked contact.

Improve procedures and operator training in link protocol applications, such as in the proper use of track blocks and numbers. Adherence to procedures is paramount, especially as the NTDS gets more complicated and as more "actors" outside of the U.S. domain factor into the future battle equation.

Improve the man/machine interface between Aegis, which will in turn improve user performance. These include: procedural simplification, information integration, control/display optimization, appropriate use of graphics; and information query." (Osga, nd, p. 2) This also includes the basic human factors principals of reducing user shift between multiple displays, provide on going feedback of task progress and decrease the impact of task interruptions. An example of this type of change is that presently the user must shift between three controls and three displays. The alternative would be to co-locate all useful task information on pop-up windows on the same display. Graphic representation of trends should be emphasized. (Osga, nd, p. 2)

To help prevent a "coincidence" in track number application, i.e. the same track number used twice to represent two separate tracks, a track number should be "retired" after it has been auto-correlated and returned to storage for a reasonable period of time. Devise a better means "to keep track" of track numbers vice the "grease pencil" method and as well as a means to communicate this information, particularly on contacts of interest, to key decision makers.

Install or reconfigure a console that will provide "raw" video. Since the Aegis symbology is processed, the operator does not know how "big" the contact is. This terminal will serve as a back-up or offer another perspective to the tactical picture. Aircraft will not always be available to provide a visual identification.

Improve communications between ships. Sometimes another ship seeing the tactical picture from a different angle can provide another perspective or be another source of verification particularly where identification is involved.

Improve link capability so that higher headquarters can see what is going on for themselves in a tactical sense vice having to be told through voice channels. A real time link will also enable higher head quarters provide feedback or again offer an other perspective to the tactical on scene commander.

Reorient training, whether it be simulated or in the form of exercises, to be more geared towards deconfliction issues inherent with a low intensity conflict situation where there are no declared enemies, an uncertain task environment, and fragmented/incomplete information availability. This type of training should emphasize team decision making, and coordination and communication principles. Also, it should be accomplished with and without the commanding officer or partial involvement of the commanding officer so that the team would be able to react as if the captain was there due to the shared mental model (Orasanu, 1990, p. 4) achieved among all CIC members. This is to take in account a full, partial or non-availability of the commander in the event a sudden tactical situation should develop.

Automate negative feedback principles within the Aegis system as much as possible. Knowing that combat situations in the future will be extremely time sensitive, the more negative feedback or double checking aspects that can be automated the better for the operator and decision maker.

To ensure a wealth of highly trained personnel with Aegis background, apply a designator to personnel records so that a person with an Aegis background will always be assigned to that type of ship and particular weapon system. Having highly trained personnel is one thing, but the combination of highly trained and experienced personnel with a particular complicated weapon system is another. Back in the WW II era, surface warfare officers transferable to other types of ships with relative ease, due to the fact that technology was not as complicated. However, with the specialization, in depth training and experience required to operate highly sophisticated modern day weapon systems, this WW II concept can no longer hold. Therefore, partition classes and types of ships accordingly, and assign personnel based on their specialty with respect to that particular type or class of ship, i.e., an Aegis trained officer will always remain on Aegis ships. This concept is similar to the management of Air Force pilots. For example, an F-15 will remain an F-15 pilot and will relocate to bases where there are F-15s to fly. Provisions are made for cross training if desired and meets the needs of the Air Force. The idea here is to keep highly specialized and trained officers and crew members within their specialty of weapon system/platform.

In addition, other learnings were uncovered as a result of this research process:

Absence of effectively integrated organizational design factors, such as technology, task, people and structure, in a military organization can be a force deflator, vice a force enhancer. An impact in any one area causes a compensatory or retaliatory change in another, ultimately impacting and transforming the system as a whole. These design factors are highly interdependent and their interaction can develop a synergy that can positively or negatively impact a combat outcome. Had communications, coordination, information flow, and adherence to established procedures been more effective, the *Vincennes* CIC watchstanders may not have confused the track numbers.

Negative feedback is critical to the maintenance of stability within a system. Assuming that stability is the goal, the positive deviation-amplification process, in which an error becomes more compounded if left unchecked, must be counter-balanced by negative feedback to keep the system from going out of control. Negative feedback mechanisms in the form of technical enhancements, organizational modifications, particularly in communications, information flow, and procedures, as well as better training will enable a system to provide its own "sanity check." Had negative feedback been more effectively incorporated, the system may have been able to provide early detection of contact mismanagement as well as compensation for human error.

Man/machine interface (MMI) design factors need to be incorporated early into the design of a weapon system. For the most part, combat systems are not employed under ideal conditions with ideal operators. The worst case scenario dealing with conditions of ambiguity, an uncertain task environment, time compression, information overload and tension must be considered. To reach maximum combat effectiveness, the human factor needs to be designed into the system from the start, to include all hardware and software issues. This is particularly important in future weapons systems already in the design phase. Had the Aegis weapon system been more user friendly, the operators may have been able to use the system to its maximum potential.

Timely and accurate fusion of information is critical to a positive decision outcome. Whether this fusion takes place in a computer or in a commanding officer's brain, the quality of the decision outcome is dependent on the accuracy of the information provided. Had the commanding officer been better informed and provided with accurate and timely information, the decision to engage a civilian airliner may not have transpired.

With respect to C3, another development emerged as a result of this research process using the Lawson Command-Control Cycle, or Lawson C2 Cycle (a model to diagram command and control flow). It was discovered that the model has no negative feedback designed into it to keep the system stabilized as shown in Figure V-1. For example, if the ENVIRONMENT is chaotic and unpredictable providing deceiving information, and the information from the SENSE function is erroneous, misleading or not applicable, or even if the DESIRED STATE is flawed, not applicable or misapplied to the situation at hand, there is no mechanism that keeps the Lawson C2 Cycle from amplifying the error(s). Although one would surmise that the COMPARE function of the Lawson C2 Cycle would serve as a source of verification, it really does not. The COMPARE function is only a part of a single-loop process as demonstrated by the single-loop learning models presented in Chapter IV. The important aspect of the Lawson C2 Cycle is the COMPARE function. However, in metaphorical terms with respect to the learning process, the COMPARE function is equivalent to that of a thermostat's operating

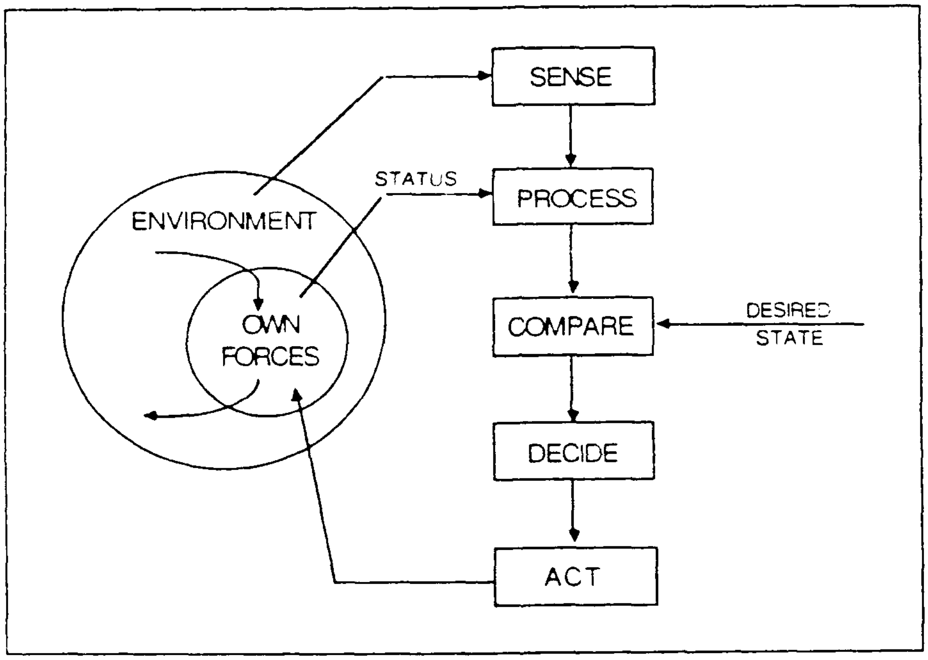


Figure V-1. Lawson Command-Control Cycle (Hughes, 1986, p. 186; Orr, 1983)

mechanism. Both are based on a comparison of a DESIRED STATE with the ENVIRONMENT as discussed in the following quote:

> The emphasis of the Lawson model is on the comparison of the current (or predicted) state to the Desired State. The model is basically an analogy of a control system. The Sense function takes measurements of the...situation for the control system, while Process involves driving the...[system] model with the measurements to determine current state. When there is no difference between the current state and the desired state, no change in control is needed. When there is a difference, the controller [decision maker] 'Decides' what control signal to send (Act) to the...[system] to cause it to converge on the desired state. (SAIC, 1989, p. 19)

Drawing on the learning from this research, and by applying a cybernetic approach to the Lawson C2 cycle, a means of verification in the form of negative feedback can be provided to keep the cycle from turning into a spiral of destruction. This proposed "Cybernetic Adaptation to the Lawson C2 Cycle," as shown in Figure V- counters the amplification in the system and also serves as a source of verification and a source of organizational or systemic learning. The Cybernetic Adaptation to the Lawson C2 Cycle is a double-loop learning process, in which the process of questioning whether the operating norms are appropriate is introduced into the system. This adaptation allows for both direct and indirect sources of negative feedback through four avenues in the form of verification, reporting, guidance and assessment. The most direct form of negative feed is the "verification loop" or "double look" process from the DECIDE function to the EVALUATE function. The EVALUATE function is a combination of the Lawson's COMPARE and DESIRED STATE functions of the C2 loop. The feedback provided from the DECIDE diamond will enable the system to keep

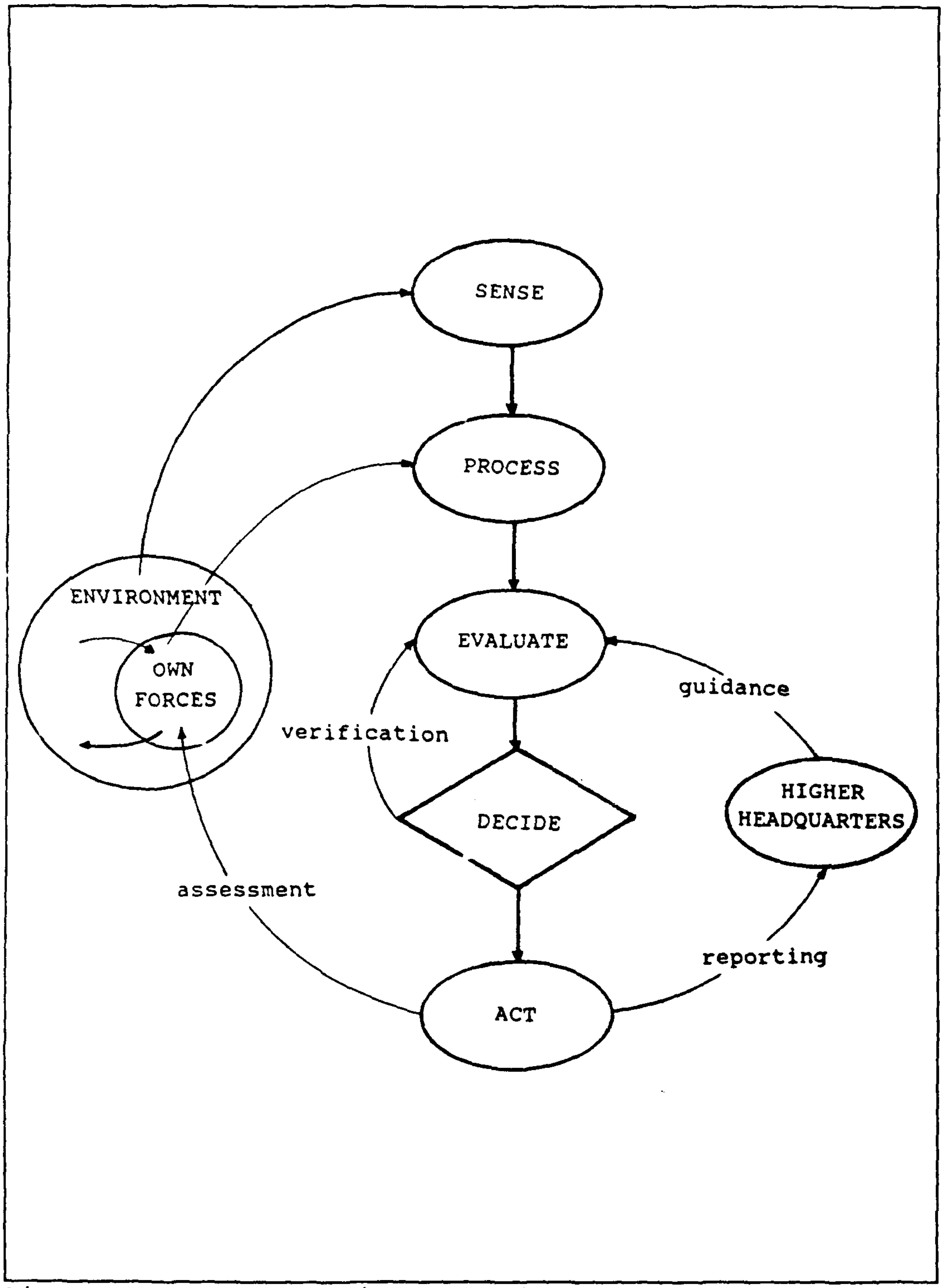


Figure V-2. Cybernetic Adaptation of the Lawson Command-Control Cycle itself in-check automatically, for feedback is used as an input to the EVALUATE function. The verification feedback loop is the most direct form of negative feedback to the system, whereas assessment, reporting, and guidance are secondary sources of negative feedback.

This overall negative feedback process is characteristic of a cybernetic system. By ensuring negative feedback is an integrated, automatic part of the system, then one has designed into the system a means by which organizations can learn. According to Cohen and Gooch, in Military Misfortunes, the failure to learn is a "taxonomy of misfortune." (1990, p. 26) By analyzing the *Vincennes* incident and incorporating the lessons learned from this tragedy, the Navy, other military organizations, as well as the society they are chartered to defend and protect, can benefit from this experience.[1]

With respect to complex dynamic systems, in the words of Charles Perrow, in his book Normal Accidents, if system characteristics, such as interactive complexity and tight coupling (no slack or buffer between two items (1984, p. 90) exist, inevitably an accident will occur:

> As systems grow in size and in the number of diverse functions they serve, and are built to function in ever more hostile environments, increasing their ties to other systems, they experience more and more incomprehensible or unexpected interactions. They become more vulnerable to unavoidable system accidents. (Perrow, 1984, p. 72)

Although Perrows' statement sounds pessimistic, it is a factor with which the Navy and others who design and build complex systems must contend. There is an inherent impulse to add and apply more technology to help solve systemic problems, when in fact technology can increase "interactive complexity and tighten the coupling," thereby making the system more prone to certain kinds of accidents. This inevitable conclusion is further elaborated by Perrow:

> I believe we are justified in calling it a *normal accident*, or a system accident. The odd term *normal accident* is meant to signal that, given the system characteristics, multiple and unexplained interactions of failure are inevitable. This is an expression of an integral characteristic of a system, not a statement of frequency. It is normal for us to die, but we do it only once. System accidents are uncommon, even rare; yet this is not all that reassuring, it they can produce catastrophes. (1984, p. 5)

Consequently, by analyzing and learning from the *Vincennes* incident, preventive measures can be undertaken to avoid or mitigate the impact of a future accident of this nature, which is a normal outcome of complex dynamic systems.

NOTES

1. This event also called into question the definition of failure and the validity of the reward/punishment system as to who should carry the blame. As in trying to find a singular cause that triggered the *Vincennes* incident, which is not possible, it becomes even more difficult to attribute a singular person, to carry the blame. Traditionally, the ship's commanding officer was ultimately accountable. However, Captain Hughes in his book, Fleet Tactics, conveys an interesting corollary to the concept of accountability:

> In today's Navy, ship design and manning incorporate more and more the requirements for battle under conditions II and III. In such combat, tactical commanders and their captains will have to imbue a sense of presence-in-absentia, because the action may be over before the captain is at his station, won or lost by an officer who asked himself, 'What would the captain do?' (1986, p. 173)

This description is a reality of the modern battlespace and the speed at which events can take place. Although the captain was in control during the *Vincennes* incident, the event only took seven minutes to unfold. Compound this with an environment that is more muddled than ever before, with no clear "battlefield" demarcation points and no clear delineation as to who one's enemies really are, then it becomes understandable how a failure or accident of this magnitude can take place. Even more importantly, the *Vincennes* incident is "just a tip of the iceberg," for the world is no longer bipolar, but an even more complicated system of multiple actors. With this systemic view, the traditional view of accountability becomes problematic.

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APPENDIX A

GLOSSARY

ACRONYM	*DEFINITION*
A-59	Amber 59 Airway
AAW	Anti-Air Warfare
AAWC	Anti-Air Warfare Coordinator
AB	Alpha Bravo (Call Sign)
AC	Aircraft
ACS	Air Control Supervisor
ACTS	Aegis Combat Training System
ADS	Aegis Display System
ADT	Automatic Detection and Tracking
AECM	Active Electronic Countermeasures
AEW	Airborne Early Warning
AIC	Air Intercept Controller
ALT	Altitude
ARC	Air Radar Controller
AS	Alpha Sierra (Call Sign)
ASAC	Anti-Submarine Air Control
ASAS	Anti-Submarine Air Supervisor
ASO	Acoustic Sensor Operator
ASROC	Anti-submarine Rocket
ASTAB	Automated Status Board
ASUW	Anti-surface Warfare
ASW	Anti-submarine Warfare
ATC	Air Traffic Control
ATO	Airborne Tactical Officer
AW	Alpha Whiskey (Call Sign)
AWACS	Airborne Warning and Control System
AX	Alpha X-ray (Call Sign)
BG	Battle Group
BOL	Bearing Only Launch
B/R	Bearing/Range
CAS	Combined Antenna System

CBDR . . . . Closing Bearing, Decreasing Range
C3 . . . . Command, Control,and Communications
C3I . . . . Command, Control, Communications and Intelligence
C & D . . . . Command & Decision System
C & R . . . . Command & Reporting
CAP . . . . Combat Air Patrol
CASREP . . . . Casualty Report
CDR . . . . Commander
CENTCOM . . . . U.S. Central Command
CFAR . . . . Constant False Alarm Rate
CIC . . . . Combat Information Center
CICWS . . . . CIC Watch Supervisor
CICWO . . . . CIC Watch Officer
CINC . . . . Commander in Chief
CIWS . . . . Close In Weapon System
CJTFME . . . . Commander Joint Task Force Middle East
CINCCENT . . . . Commander in Chief, Central Command
CMEF . . . . Commander Middle East Force
CO . . . . Commanding Officer
COC . . . . Control Officer Console
COI . . . . Contact of Interest
COMAIR . . . . Commercial Airliner
COMIDEASTFOR . . . . Commander of the Middle East Force
COMMS . . . . Communications
CPA . . . . Closest Point of Approach
CPG . . . . Central Persian Gulf
CRO . . . . Character Read Out
CSC . . . . Combat System Controller
CSO . . . . Combat System Officer
CSOOW . . . . Combat System Officer of the Watch
CSRT . . . . Combat System Readiness Test
C/S . . . . Course/Speed
CT . . . . Cryptological Technician
CTF . . . . Commander Task Force
CTSL . . . . Central Track Stores Locator
CVBG . . . . Carrier Battle Group
CWC . . . . Composite Warfare Command
CWI . . . . Continuous Wave Illumination

DC . . . . Damage Control
DDEU . . . . Digital Display Entry Unit
DDRT . . . . Digital Dead Reckoning Tracer
DECM . . . . Deceptive Electronic Counter Measures

DEG/T . . . . Degrees True
DET . . . . Detachment
DROP SYNC . . . . Drop Synchronization
DSA . . . . Data Link Support and Administration
DWN . . . . Down
D/W . . . . Dead in the Water

EC . . . . Embarked Commander
ECCM . . . . Electronic Counter-Countermeasures
ECDA . . . . Embarked Command Display Assistant
ECM . . . . Electronic Counter Measures
EMCON . . . . Emission Control
EMO . . . . Electronic Maintenance Officer
EOOW . . . . Engineering Officer of the Watch
EOP . . . . Engineering Operating Procedures
ESM . . . . Electronic Support Measures
ESMO . . . . ESM Operator
EW . . . . Electronic Warfare
EWCO . . . . Electronic Warfare Console Operator
EWS . . . . Electronic Warfare Supervisor

FAAWC . . . . Force Anti-Air Warfare Coordinator
FAD . . . . Force Air Defense
FAP . . . . Facilities Attack Profile
FASUC . . . . Force Anti-Surface Warfare Coordinator
FASWC . . . . Force Anti-Submarine Warfare Coordinator
FC . . . . Force Coordinator
FCS . . . . Fire Control System
FEWC . . . . Force Electronic Warfare Coordinator
FICPAC . . . . Fleet Intelligence Command, Pacific
FLEETEX . . . . Fleet Exercise
FM . . . . From
FT . . . . Feet
FTC . . . . Force Tactical Commander
FWC . . . . Force Warfare Coordinator

GB . . . . Golf Bravo (Call Sign--CJTFME)
GFCS . . . . Gun Fire Control System
GFCSS . . . . Gun Fire Control System Supervisor
GHz . . . . Gigahertz
GLO . . . . Gunnery Liaison Officer
GMLS . . . . Guided Missile Launching System
GOO . . . . Gulf of Oman

GQ . . . . General Quarters
GRS . . . . Grid Reporting System
GS . . . . Golf Sierra (Call Sign--USS *Hancock*)
GW . . . . Golf Whiskey (Call Sign--USS *Vincennes*)
GWS . . . . Gun Weapon System

HASC . . . . House Armed Services Committee
HE . . . . High Explosive
HEMT . . . . High Explosive Mechanical Time Fuse
HVU . . . . High Value Unit
HWS . . . . Harpoon Weapon System

IATA . . . . International Air Traffic Association
ICAO . . . . International Civilian Aviation Organization
IAD . . . . International Air Distress
ID . . . . Identification
IDS . . . . Identification Supervisor
IFF . . . . Identification Friend or Foe
INSURV . . . . Inspection and Survey
IR . . . . Infrared
IREPS . . . . Integrated Refractive Effects Prediction System
IRGC . . . . Iranian Revolutionary Guard Corps
IRGN . . . . Iranian Revolutionary Guard Navy

JEWC . . . . Joint Electronic Warfare Center
JDF . . . . Jamming Direction Finder
JOOD . . . . Junior Officer of the Deck
JTFME . . . . Joint Task Force Middle East
K/FT . . . . Thousand Feet
KTS . . . . Knots
K/YDS . . . . Thousand Yards

L . . . . Local Time
LAAWC . . . . Local Anti-Air Warfare Coordinator
LAC . . . . LAMPS Air Coordinator
LAMPS . . . . Light Airborne Multipurpose System
LAT/LONG . . . . Latitude/Longitude
LIC . . . . Low Intensity Conflict
LNCHR . . . . Launcher
LOB . . . . Line of Bearing
LSD . . . . Large Screen Display

MAD . . . . Military Air Distress

MARPATR . . . . Maritime Patrol
MARREP . . . . Maritime Report
MAX . . . . Maximum
MB . . . . Millibars
MEF . . . . Middle East Force
MEFEX . . . . Mideast Force Execution Net
MERCH . . . . Merchant
MHz . . . . Megahertz
MIDEASTFOR . . . . Middle East Force
MONT . . . . USS *Montgomery*
MPA . . . . Main Propulsion Assistant
MSS . . . . Missile System Supervisor
MT . . . . Mount
MTI . . . . Moving Target Indicator

N . . . . North
N PLOT . . . . North Plotter
NAV . . . . Navigation System
NC . . . . Net Control
NCS . . . . Net Control Station
NCU . . . . Net Control Unit
NGFS . . . . Naval Gun Fire Support
NM . . . . Nautical Mile
N/NE . . . . North by Northeast
NOTACK . . . . No Attack
NOTAM . . . . Notice to Airman
NOTMAR . . . . Notice to Marines
NTDS . . . . Naval Tactical Data System

OL . . . . Ocean Lord
OOD . . . . Officer of the Deck
OPDEC . . . . Operational Deception
OPORD . . . . Operations Order
OPREP . . . . Operations Report
OPSO . . . . Operations Officer
ORTS . . . . Operational Readiness Test System
OSDA . . . . Own Ship Display System
OTH . . . . Over the Horizon

PB . . . . Patrol Boat
PD . . . . Point Data
PEC . . . . Passive Equipment Cabinet
POA & M . . . . Plan of Action & Milestones

PG	Persian Gulf
PPI	Plan Position Indicator
PROP	Propeller
PU	Participating Unit
RBL	Range and Bearing Launch
RCI	Remote Control Indicator
RCP	Remote Control Panel
RCS	Radar Cross Section
RCVD	Received
RDP	Radar Digital Plotter
READEX	Readiness Exercise
REFTRA	Refresher Training
REMRO	Remote Radar Operator
RF	Radio Frequency
RHAW	Radar Homing and Warning
RM	Radio Monitor
RNG	Range
ROE	Rules of Engagement
RP	Republic of the Philippines
RPO	Radio Physics Optics
ROS	Remote Optical Site
RPS	Radar Picket Station
RSC	Radar System Controller
RT	Radiotelephone
RTN	Return
RVP	Radar Video Processing
S PLOT	South Plotter
SAG	Surface Action Group
SAM	Surface-to-Air Missile
SAU	Surface Action Unit
SHF	Super High Frequency
SHM	Ship Heading Marker
SITREP	Situation Report
SIWO	Signals Intelligence Warfare Officer
SM	Standard Guided Missile
SM2 BLK 2	Standard Guided Missile, Block 2
SO	Sonar Operator
SOH	Strait of Hormuz
SOHWPA	Strait of Hormuz Western Patrol Area
SOP	Standard Operating Procedures
SP	Sound Powered

SPD .... Speed
SPG .... Southern Persian Gulf
SPY-1A .... Radar System AN/SPY-1A
SRBOC .... Super Rapid Blooming Offboard Chaff
SRC .... Surface Radar Coordinator
SSES .... Ship's Signal Exploitation Space
SSSC .... Surface/Subsurface Surveillance Coordinator
SSSS .... Surface/Subsurface Surveillance Supervisor
SSWC .... Surface/Subsurface Warfare Coordinator
STC .... Sensitivity Time Control
STD MSL .... Standard Missile
STIR .... Surface Track & Illuminating Radar
STO .... System Test Officer
SUCAP .... Surface Combat Air Patrol
SURFPAC .... Surface Force Pacific
SVCS .... Services

TACCOM .... Tactical Communications
TACAN .... Tactical Air Navigation
TACON .... Tactical Control
TAO .... Tactical Action Officer
TC .... Tactical Command
TDS .... Tactical Data System
TF .... Task Force
TG .... Task Group
TIC .... Tactical Information Coordinator
TN .... Track Number
TRKS .... Tracks
TS .... Track Supervisor

UHF .... Ultra High Frequency
UNITREP .... Unit Report
USDAO .... United States Defense Attache' Office

VAB .... Variable Action Button
VCN .... USS *Vincennes*
VECTACS .... Vector Attack
VFK .... Variable Function Key
VHF .... Very High Frequency
VIC .... Vicinity

W .... West
WASEX .... War at Sea Strike Exercise

WCC . . . . Weapons Control Console
WCCO . . . . Weapons Control Console Operator
WCIP . . . . Weapons Control Indicator Panel
WCO . . . . Weapons Control Officer

XO . . . . Executive Officer

Z . . . . Zulu Time

APPENDIX B

THE *STARK* INCIDENT

A. OVERVIEW

At approximately 2109 local time, 17 May 1987, the frigate, USS *Stark*, was hit by two Exocet anti-ship cruise missiles fired by an Iraqi F-1 aircraft. This unprovoked, indiscriminate attack took place in international waters, 12 miles outside the Iranian Exclusion Zone. As a result of the attack, 37 sailors were killed. (Sharp Investigation, 1987, pp. 1-2) Figure B-1 shows the geographical location of where the *Stark* attack took place.

B. HISTORY

1. Iran-Iraq War

Hostilities between Iran and Iraq had existed for centuries, with the border between the two countries under constant dispute. Hoping to take advantage of internal disturbances in Iran that precipitated from the Iranian revolution in 1979, Iraq launched a strike into Iran on 22 September 1980. Iraq expected the Iranian Army to collapse and the government in Tehran to agree to a cease fire; however, Iran remained steadfast despite the advance of Iraqi forces. A year later, in a series of counter attacks, Iran regained most of the Iraqi occupied territory and the conflict essentially transformed into

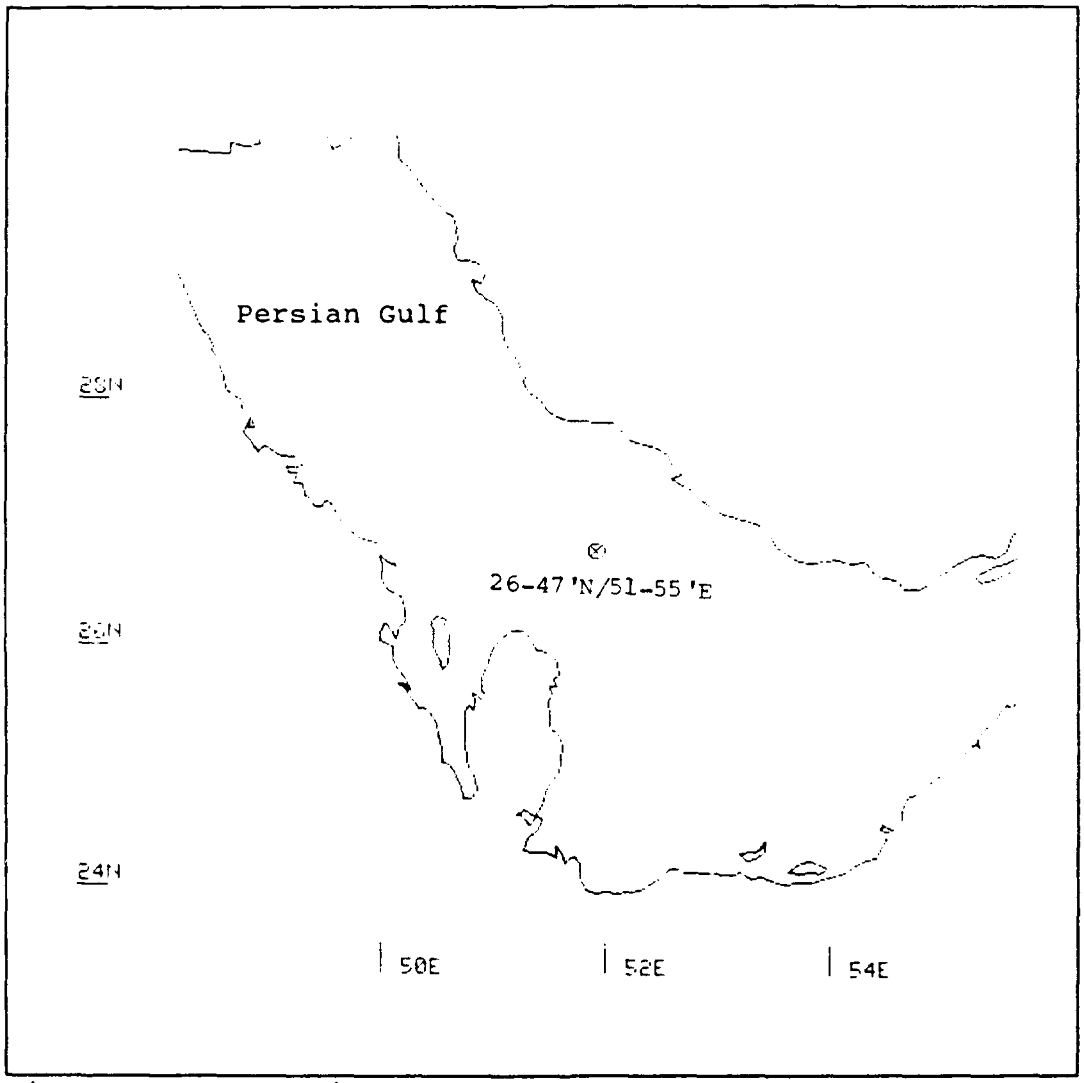

Figure B-1. Location of *Stark* Attack

a static "war of attrition in which the line of battle...moved little more than a few miles from the pre-war border." (Glenn and Warner, 1987, p. 8)

2. The Tanker War

During the first three years of the war, the ships that were attacked were directly involved with combat resupply (Glenn and Warner, 1987, p. 8). On 27 March 1984,

> Iraq escalated the air war, into what has been called the 'Tanker War,' by attacking Iran's economic shipping and oil installations. Iraq's objectives were to prevent or reduce the importation of vital materials required by Iran for its war effort, to reduce or terminate Iran's oil revenues which helped finance the war, and to internationalize the war. (Glenn and Warner, 1987, p. 8)

From 27 March 1984 to 17 June 1987, a total of 248 ships were attacked. Iraq initiated 153 of these attacks while Iran conducted 95. Although the Tanker War did not cause serious disruptions in oil flow to the West, Kuwait came under increasing pressure from Iranian attacks. Kuwait needed protection for her tankers and began to explore various options to include assistance from the Soviet Union. (Glenn and Warner, 1987, p. 9) The U.S. response to Kuwait's requests for assistance was to

> expedite procedures for the registry of eleven Kuwaiti oil tankers under the American flag [and]...to provide appropriate protection by U.S. military forces...to the eleven reflagged Kuwaiti oil tankers while operating in the Persian Gulf region and transiting the Strait of Hormuz. (Glenn and Warner, 1987, p. 12)

C. SEQUENCE OF EVENTS

1. AWACS Tracking Activities

An Airborne Warning and Control System (AWACS) aircraft from the 945th AWACS Squadron, Tinker Air Force Base, Oklahoma, was on a routine mission in the Persian Gulf when, on 17 May 1987, at 1955 local (L), its radar acquired an unknown track heading on a southeasterly course. The track was positively identified as an Iraqi Mirage F-1 by a joint Saudi-U.S. ground tracking system. (Staff Investigation, 1987, p. 7)[1] The AWACS aircraft followed the track, assigned it track number 2202, and provided periodic updates every three to five minutes as to its geographic location (Sharp Investigation, 1987, pp. 3 and 9)[2]. Because the aircraft was a Mirage F-1 and considered a "critical class track," special reporting procedures were required. This involved continuous notification to all ships in the area of this track as well as to the Commander of the Middle East Force (COMIDEASTFOR) on the flagship USS *LaSalle*. Here, the reporting was accomplished through the Navy Tactical Data System (NTDS) to the USS *Coontz* and relayed to the *Stark* on a real time basis. (Staff Investigation, 1987, p. 7) All position information reported to COMIDEASTFOR and the *Stark's* Combat Information Center (CIC) was based on the data link from AWACS, not on information derived from *Coontz'* own radar system (Sharp Investigation, 1987, pp. 9-10).

2. Actions by Iraqi Aircraft

Iraqi pilots did not visually identify their targets prior to firing. According to Representative Les Aspin, Chairman of the House Armed Services Committee, in a news release upon completion of his staff investigation of the *Stark* Incident:

> the greatest danger in the Gulf was an inadvertent attack. The Iraqis normally fire at radar blips and do not check them visually even in daylight hours--unlike the Iranians who check out each target first. Furthermore, the Iraqi pilot said he did not hear either of the radio warnings broadcast by the *Stark*, indicating he wasn't listening. We have indications that the Iraqi Air Force really does not discipline its pilots to monitor the international emergency frequencies. In sum, the surprise is not that an Iraqi missile fired at an unintended target, but that it did not fire at an unintended target before this. (1987)

The flight path of the Iraqi fighter that fired on the *Stark* exhibited several unusual characteristics. First, the F-1 was flying at least 15 miles closer to the Saudi Arabian coast than normal. Also, "[i]t was flying at night and at a lower altitude and slower speed.... In addition, only a handful of Iraqi aircraft had been tracked this far south before." (*Staff Investigation*, 1987, p. 7) Figure B-2 shows an illustration of the Iraqi F-1 flight path.

To add another dimension to this situation, the Iranians had declared a war zone called the Iranian Exclusion Zone early in the war: "Its boundary lines effectively bisect[ed] the Gulf and the zone encompasse[d] virtually half the waters in the Gulf." (Staff Investigation, 1987, p. 10) Basically, any vessel in the war zone was highly susceptible to attack by either Iraqi or Iranian forces (Staff Investigation, 1987, p. 10).

It should be noted that there were discrepancies between U.S. and Iraqi accounts as to the position of the *Stark* and the Iraqi aircraft at the time of the missile

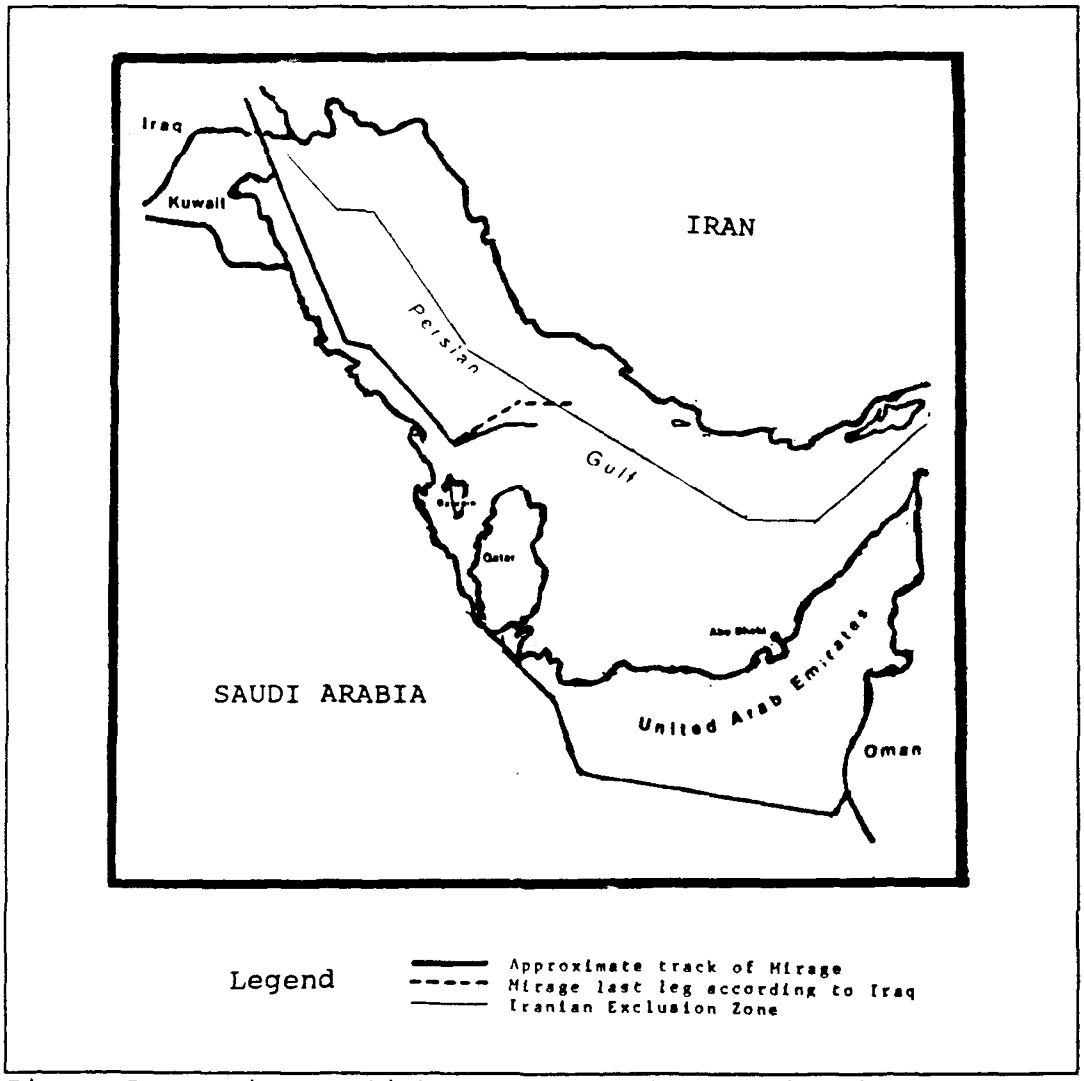

Figure B-2. Mirage Flight Path (Staff Investigation, 1987, p. 9) attack. Although the Iraqi track, as depicted on a map provided by Iraqi military officials, placed the *Stark* within ten miles of the war zone, multiple U.S. sources placed the *Stark's* location 12 miles outside the war zone. These multiple sources demonstrated close agreement (±2 miles of each other), casting serious doubt as to the accuracy and credibility of the Iraqi account of the *Stark's* location. It was not entirely clear as to what actually prompted the Iraqi pilot to fire upon the *Stark*. (Staff Investigation, 1987, p. 10)

3. Rules of Engagement

Prior to the change of operational control (inchopping) to COMIDEASTFOR, the *Stark* received a briefing on the Rules of Engagement (ROE) by MEF staff personnel in Djibouti on 28 February 1987. Also, operations and intelligence briefings were presented. During these briefings, "[t]he ROE briefer highlighted that the probability of deliberate attack on U.S. warships was low, but that the indiscriminate attack in the Persian Gulf was a significant danger." (Sharp Investigation, 1987, p. 6) The ROE in effect were originally promulgated on 1 October 1985 by the MEF Commander (Staff Investigation, 1987, p. 4). The following is an unclassified synopsis of existing ROE as described in the "Report on the Staff Investigation into the Iraqi Attack on the USS *Stark*" by members from the House of Representatives Committee on Armed Services:

> In general, the rules provide that if an aircraft demonstrates hostile action or hostile intent, U.S. commanders are authorized to take proportionate means to defend themselves. The determination of hostile intent is within the judgment of each ship's commanding officer.... The rules further provide that aircraft of the belligerent Persian Gulf nations, as well as unidentified aircraft, are all to be regarded as potentially hostile. Potentially hostile contacts that appear to be approaching within specified distances of U.S. units should be requested to identify themselves and to state their intentions. The rules recognize that the establishment of communications might not be possible, in which event U.S. commanders are

directed to use any means available to identify themselves and to warn the contact to stay clear. Commanders are also directed not to stop if one attempt to attract the attention of an approaching contact has not elicited a response to their radio warnings. They should take graduated actions in attempting to attract the attention of the approaching contact, including training guns and firing warning shots. (1987, p. 4)

4. Events aboard the *Stark*

On the evening of 17 May 1987, the *Stark* was getting ready to conduct a full power run in preparation for a Mobile Training Team exercise. The *Stark* was operating in an area along the Iranian Exclusion Zone called Radar Picket Station-South. While the engines were at full power, there was some concern over abnormal engine temperature readings. This caused the *Stark* to reduce its speed from 30 knots to 15 knots and to change its course to a northwesterly direction of 300 degrees. (Staff Investigation, 1987, p. 12)

During this period, the *Stark* was in alert Condition Three, which was "the normal wartime operating state," entailing a battle station manning posture comprising of one-third of the ship's crew (Staff Investigation, 1987, p. 12). Figure B-3 shows a schematic of the *Stark*.

At about 2012L, (Sharp Investigation, 1987, p. 9) the *Stark* was informed by a U.S. AWACS plane that "an Iraqi Air Force Mirage F-1 aircraft was approximately 200 miles away flying along the Saudi Arabian coast." (Sagan, 1991, p. 94) The primary radar for tracking aircraft, the AN/SPS-49 Air Search Radar, has a range that is capable of extending to 200 miles; however, "the range is highly dependent on weather conditions and target altitudes. Because this radar could not track the Mirage at 200 miles or

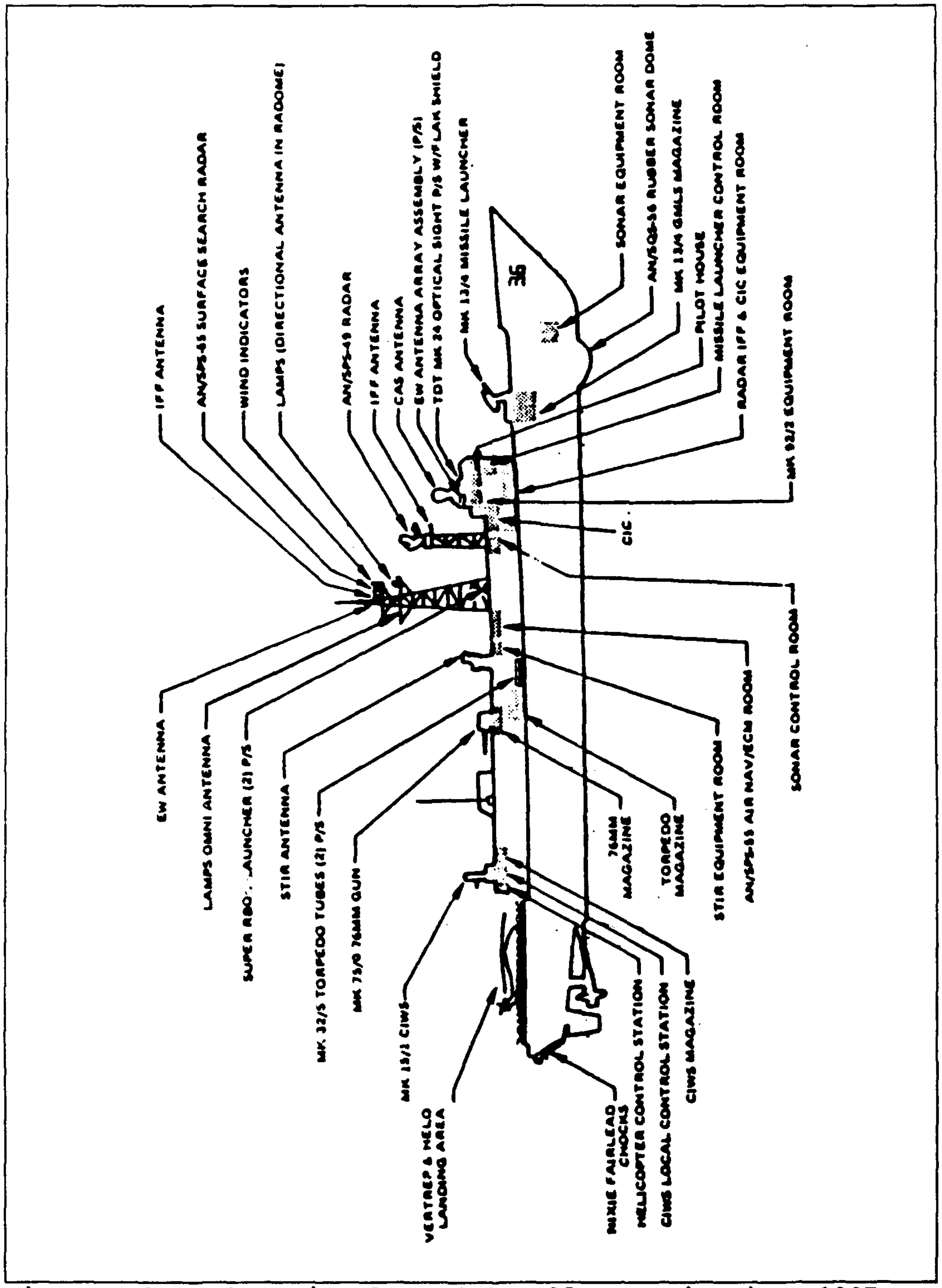

Figure B-3. Schematic of *Stark* (Staff Investigation, 1987, p. 18) greater, the AWACS aircraft provided a downlink to the USS *Coontz* and on to *Stark*. (Staff Investigation, 1987, p. 12) The transmission was instantaneously relayed (Staff Investigation, 1987, p. 12) and was monitored in the *Stark's* CIC (Sharp Investigation, 1987, p. 10). The *Stark's* Commanding Officer, Captain Glenn R. Brindel, recollected the following in his official statement:

> On the evening of the 17th of May at approximately 2015L while in CIC and prior to going to the bridge, to conduct a full power trial, I was told of an Iraqi aircraft in the Northern Gulf who had been identified by AWACS. It was at well over 200 miles but heading south. I told the TAO [Lieutenant Basil E. Moncrief, who was on watch for over an hour prior to the attack,] to keep a close eye on the contact, and reminded him that a number of recent Iraqi sorties had been coming further south. While on the bridge, I was notified that *Coontz* had radar contact on this aircraft. I questioned why we did not. I believe the aircraft was 120 miles out at this time. CIC responded that *Coontz* was closer and weather conditions were responsible. That was the last I heard of the contact until approximately 25 minutes later when we were hit by the missile. At the time of the missile attack I was in my cabin adjacent to CIC. I left the bridge at approximately 2100 after the full power run had been delayed for engine adjustments. On the way from the bridge to CIC, I stopped at my cabin to make a head call. I paused at my desk momentarily to look at some paperwork and heard and felt the first hit. I ran immediately then into CIC. Before I could ascertain our status or take any action...the second missile hit the ship. (Brindel, 1987, pp. 29-30)

At approximately 2058L (Sharp Investigation, 1987, p.11), after shifting the AN/SPS-49 radar to the 80-mile mode to attempt to acquire the track, "[t]he *Stark* picked up the fighter on her own air search radar when it was 70 miles from the ship." (Sagan, 1991, p. 94) However, the Captain was not notified: "Lt Moncrief [the Tactical Action Officer (TAO)] assumed the commanding officer had been on the bridge earlier and had heard CIC report to the bridge that they detected a radar contact which correlated to the Iraqi aircraft." (Sharp Investigation, 1987, p. 32)

In the meantime, the CIC was not fully manned. FC3 Caulkins, who was both the WCC-1 Combined Antenna System (CAS) and Close In Weapon System (CIWS) operator in the CIC received permission to from the Fire Control Technician to go to the head and left at about 2050L. Fourteen minutes later, Caulkins had not returned to his watch, and another member of the CIC was sent to find him (Sharp Investigation, 1987, p. 10). While the WCC-1 and CIWS positions were vacant, the Weapons Control Officer (WCO) and CICWO positions were also shy one crew member because, "[t]he Commanding Officer's Battle Orders required that one officer fill the WCO and CICWO watch stations simultaneously." (Sharp Investigation, 1987, p. 15)

Meanwhile, at 2102L, an enlisted Electronic Warfare (EW) Technician operating the SLQ-32 electronic countermeasures system detected radar emissions that correlated to a Cyrano IV, "the air intercept radar carried on an Iraqi F-1 aircraft." (Sharp Investigation, 1987, p. 11) The "lock-on" lasted approximately five seconds (Staff Investigation, 1987, p. 13). At about 2103L when the track was 43 NM out from the *Stark*, OS1 Duncan, who was at the Anti-Submarine Air Controller (ASAC) console, requested permission from Lt Moncrief to transmit a standard warning to the F-1 over the Military Air Distress frequency. However, Lt Moncrief responded "'No, wait,'" (Sharp Investigation, 1987, p. 11) in anticipation that the Mirage might turn away (Sagan, 1991, p. 94).

While this was going on, Lieutenant Commander Ray J. Gajan, *Stark's* Executive Officer (XO), walked in the CIC at about 2104L. "He was looking for Lt Moncrief to discuss administrative matters relating to the Ship Control Department. The

XO noticed that Lt Moncrief was busy, and so he waited near the chart table to observe events in CIC." (Sharp Investigation, 1987, p. 11)

According to Rear Admiral Grant Sharp's Formal Investigation, the Iraqi aircraft turned toward the *Stark* at 2105L at 32.5 NM (1987, p. 12). The Closest Point of Approach (CPA) to the ship was calculated to be around four miles. Although the aircraft was rather distant from the ship, "it was flying on a course that would bring it within four miles from the ship if the aircraft did not alter its course. The TAO said he expected the Mirage would be turning away at any moment, according to the Watch Supervisor." (Staff Investigation, 1987, p. 13) The aircraft was on a constant bearing, decreasing range, CBDR (Sharp Investigation, 1987, p. 12).

A minute or so after discovering this change in course and the close proximity of the CPA, the TAO directed ENS Wright, who was on watch in the CIC, to notify the Captain, but he could not be located. Both the bridge and his cabin were called. (Sharp Investigation, 1987, p. 12)

At about 2107L, numerous other events were taking place. Namely, the Iraqi aircraft launched the first Exocet Missile at the 22.5 NM point, which was well within nominal Exocet striking range of 38 NM (Sharp Investigation, 1987, p. 2). At this time, the Forward Lookout detected a "bright flash in the distance followed by the appearance of a small blue dot on the horizon." (Staff Investigation, 1987, p. 14) This contact was about 15 degrees off the port bow and initially identified as a surface contact (Sharp Investigation, 1987, p. 12).

In conjunction with the forward lookout event, the second radar lock-on was detected by the CAS, lasting five to seven seconds. The EW operator asked the TAO for permission to arm the ship's chaff launchers, located on the deck above the CIC. This task was accomplished in about thirty seconds. (Staff Investigation, 1987, p. 13)

The following sequence of events transpired concerning the announcement by the EW operator that the ship was locked-on by the aircraft fire control radar:

> In the waning minutes prior to the attack, the TAO attempted to increase *Stark's* combat readiness; but it was too late. [intentionally deleted in sanitized report] [T]he positions of CIC Watch Officer (CICWO) and Weapons Control Officer (WCO) were combined and filled by a single officer. When the aircraft began its attack run, the position of Weapons Control Officer was vacant. Before the position could be properly manned, the Mirage had already fired both Exocets and the first Exocet was nearing its terminal phase. The Fire Control Technician [FC3 Caulkins] assigned to operate the MK-92 STIR fire control radar and Close In Weapon System (CIWS) had previously left CIC on personal business; and at the time of the attack, that position was also vacant....Neither Lt Moncrief nor FC2 Collins brought CIWS into the [intentionally deleted in sanitized document] mode. CIWS was in 'stand-by' mode during the entire attack. (Sharp Investigation, 1987, pp. 2-3, 14)

The F-1 fired a second Exocet missile at the *Stark* with a weapons release point of 15.5 NM at approximately 2108L. At this point in time, the equipment did not detect the inbound missiles and the crew did not realize they had been fired upon. The TAO

> ordered the ship's Mark 92 Fire Control System--which guides the ship's three inch guns, Standard missiles, and Harpoon missiles--to lock-on the aircraft with its primary radar, the [Surface Track and Illuminating Radar] STIR. The radar operator advised he could not comply because the radar was blocked out by the ship's superstructure. The TAO ordered that the secondary radar, the CAS, be utilized." (Staff Investigation, 1987, p. 22)

Figure B-4 shows a schematic of the Close In Weapon System (CIWS) blind zone aboard the *Stark*.

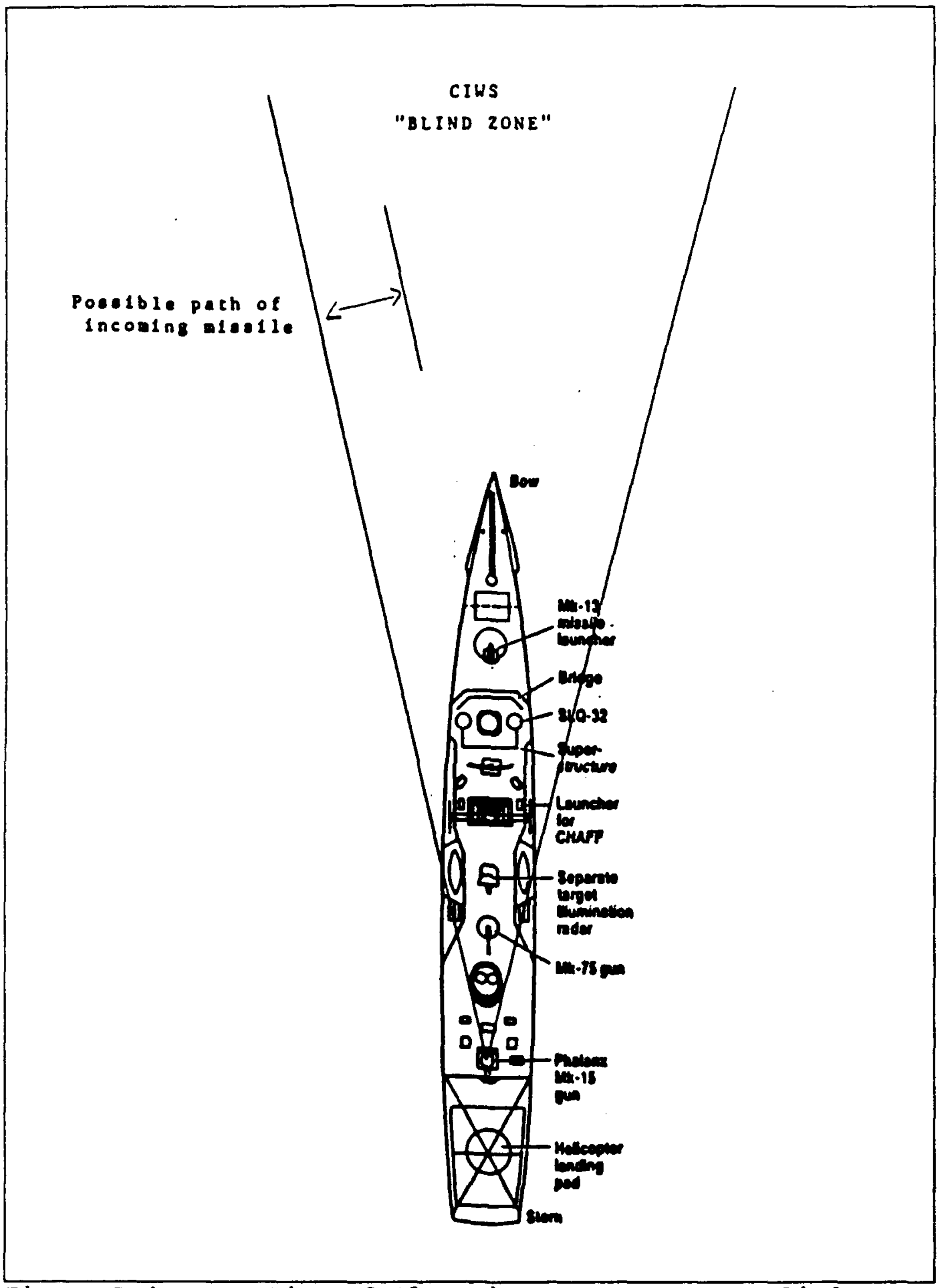

Figure B-4. Top View of Close in Weapon System "Blind Zone" aboard *Stark* (Staff Investigation, 1987, p. 21)

A minute later, the CAS locked on to the Iraqi aircraft which was about ten NM away, and the TAO directed warnings be issued to the Iraqi Aircraft (Sharp Investigation, 1987, pp. 12 and 14):

> When the aircraft was approximately 13 miles from *Stark*, the ship transmitted a radio message identifying it as a U.S. Navy ship and asked the plane to identify itself. There was no response from the aircraft. A similar request for identification and intentions was transmitted by *Stark* when the aircraft was 11 miles from the ship. Again, there was no response from the aircraft." (Staff Investigation, 1987, p. 3)

Only seconds before impact, at 2109L, the lookout finally realized that the "blue fireball" (Staff Investigation, 1987, p. 14) was an incoming missile and started to scream, "MISSILE INBOUND, MISSILE INBOUND" over the JL sound powered circuit. This information was relayed to the bridge and to JL phone-talker in the CIC. Unfortunately, the TAO did not get this information. At 2109L, the first missile hit the *Stark*, at which time General Quarters (GQ) sounded. Twenty to thirty seconds later, the second Exocet hit the ship, port side, and detonated. (Sharp Investigation, 1987, pp. 14-15)

5. Weapon Systems

Weapon systems available to *Stark* but not employed included: Standard missiles (SM-1 ME missiles), MK75 76mm gun, Close In Weapon System (CIWS), 50 Caliber guns, and Super Rapid Blooming Off Board Chaff (SRBOC) (Sharp Investigation, 1987, p. 16). At the moment of impact, a synopsis of the weapon and radar system status consisted of the following according to the officials conducting the Formal Investigation for the Navy:

> the STIR fire control radar was in stand-by and was thought to be masked by the ship's superstructure; the MK-92 CAS fire control radar was in search mode and

was never used to lock-on to the aircraft until the missiles were seconds away from impact; the Super Rapid Off Board Chaff (SRBOC) was not armed until seconds before the first missile hit; and the CIWS was still in stand-by, having not been properly brought in to the AAW manual mode.... At the time of the missile launch, the AN/SPS-49 two dimensional air search radar and the MK-92 CAS search radar were the only radars being used to track the aircraft. No fire control radars were locked-on and tracking the aircraft. (1987, p. 3)

NOTES

1. "Staff Investigation" is a shortened version citing the "Report on the Staff Investigation into the Iraqi Attack on the USS *Stark*," 14 June 1987. The report was based on an investigation conducted in the Persian Gulf by Committee Staffers and on hearings of the House Armed Services Committee. The conclusions were signed by Reps Les Aspin, Chairman of the House Armed Services Committee, William L. Dickinson (R-ALA), Senior Republican on the Committee, and Bill Nichols (D-ALA), Chairman of the Investigation Subcommittee.

2. "Sharp Investigation" refers to Rear Admiral Grant Sharp's unclassified report, "Formal Investigation into the Circumstances Surrounding the Attack on the USS *Stark* (FFG 31) on 17 May 1987 (U)," 12 June 1987.

APPENDIX C

OJ-194 PLAN POSITION INDICATOR (PPI) DISPLAY CONSOLE

The OJ-194 PPI Display Console is the primary input/output device for the UYA-4 display subsystem of the Naval Tactical Data System (NTDS). It provides detection, tracking, threat evaluation and engagement control of surface, air, and subsurface contacts obtained from own-ship and off-board sensors. The OJ-194 has many versions and is found in nearly all NTDS equipped U.S. Navy ships as well as on various ships of NATO countries. (Bodziak, Henry, and Viland, 1990, p. 1)

The console is a cathode ray tube (CRT) display unit, with capabilities tailored to the specific function being performed. Table C-1 shows the primary controls and displays for CIC consoles and a brief description of their functional use. There are two displays: The Plan Position Indicator (PPI), which shows the tactical picture as a two-dimensional positional display, and the character read out (CRO), which gives information on specific tasks, status information, and menu driven data on an alpha-numeric display. Co trol is provided by key panel and rolling ball to operate a cursor, which is used to point and mark items of interest. The primary method of obtaining information on a track is by placing the cursor on it and then "hooking" it by button action. Another method is by entering the track number on the digital display entry unit. (Rogers, 1992; Moser, 1992; Bodziak, Henry, and Viland, 1990, p. 1) Figure C-1 shows a typical OJ-194 lay out (Osga, no date, p. 2).

TABLE C-1

OJ-194 CONSOLE CONTROLS AND DISPLAYS

CONTROLS/DISPLAYS:	DESCRIPTION OF PRIMARY USE:
PANELS:	
Intercom Panel	Local and net communications
Display Control	PPI display settings
Action Entry Panel	Function and data entry or display
Category-Select Panel	Control NTDS symbols/graphics on PPI
DISPLAYS:	
Plan Position Indicator (PPI)	Geographic/track position
Character Read Out (CRO)	Alpha-numeric display and entry
INPUT DEVICES:	
Trackball	Control cursor on PPI display
Trackball Buttons	Frequently used for PPI functions
Digital Data Entry Unit (DDEU)	Numeric entry and special functions
Source: Osga, no date, p. 2	

The OJ-194 console may be used by the most junior seaman recruit on up. The most frequent users are the Operations Specialists, who perform tracking, aircraft control and similar duties; Sonar Technicians, for certain ASW tracking functions; Electronic Warfare Specialists and Cryptological Technicians for electronics surveillance and intelligence functions; and by officers for command and control of ASW, AAW, and ASUW operations. (Bodziak, Henry, and Viland, 1990, p. 2)

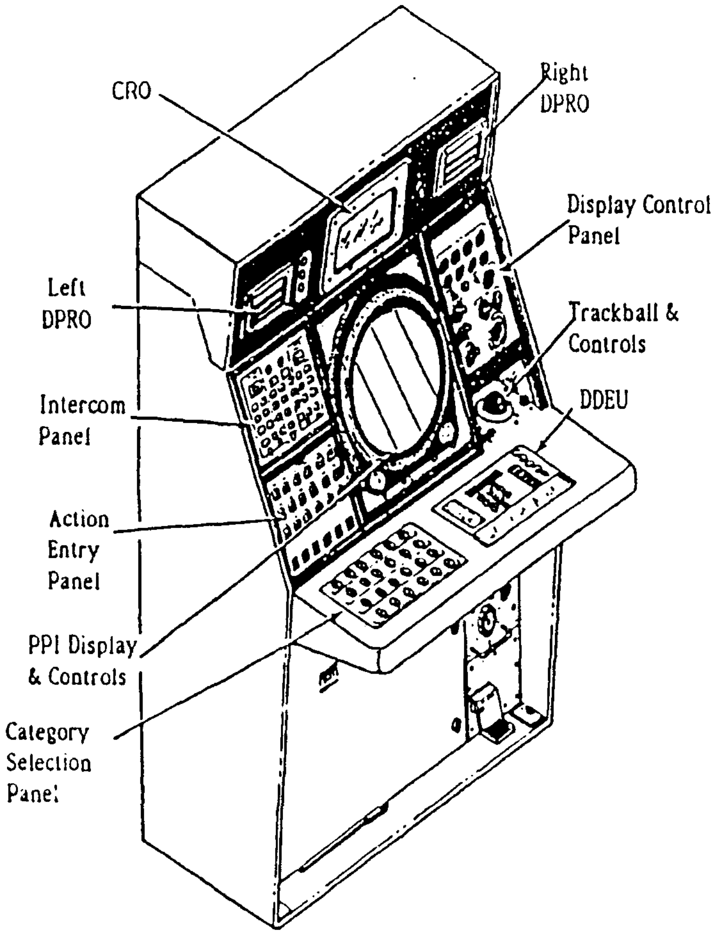

Figure C-1. Typical OJ-194 Console Lay Out

APPENDIX D

COMPREHENSIVE DATA LISTING

There were two types of data depicting the flight of Iran Air Flight 655 during the seven minute air engagement: System or "actual" data which was extracted from the data tapes of the Aegis Command and Decision (C & D) system and the recollected data as to the "perceived" flight of Iran Flight 655, which was obtained from witness statements and testimony. The Fogarty investigation team integrated the actual system data with the recollected data to develop a time line of events to form a more comprehensive portrayal as to what happened and when. (Fogarty, 1988, p. 2)

The system and recollected data obtained from the Fogarty report was broken down into the following groupings for comparative purposes:

- Group 1--System Data with Outlier
- Group 2--Recollected Data by Witnesses
- Group 3--System Data without Outlier
- Group 4--System Data with Speed Variable and Outlier
- Group 5--System Data with Speed Variable and no Outlier
- Group 6--System and Recollected Data with Speed Variable and Outlier
- Group 7--Refined Recollected Data by Witnesses
- Group 8--Refined Recollected Data with Outlier

In Groups 1, 4, and 6, all system data identifying Flight 655, entailed all TN 4131 and TN 4474 hook entries, to include the FC-1 hook of TN 4474 at 1022L. Here, at 1022L, the system data indicated that a crew member manning the FC-1 position hooked TN 4474 with the following kinematics: Range of 110 NM, bearing of 139, altitude of 11,900 feet and speed of 448 knots (Fogarty, 1988, p. 34). This entry appeares "inconsistent" with the rest of the system data regarding Flight 655 and was labelled as an "outlier." Therefore, the groupings with the annotation "outlier" means that the FC-1 hook of TN 4474 was already in the system data as revealed by the system data tapes, but was "inconsistent" with the remaining system data points. In some data sets such as Groups 3 and 5, the "outlier" was eliminated by the author for comparison purposes to see its impact on the correlation coefficient and overall relationship with the data. Conversely, in Group 8, the "outlier" was physically incorporated into this data set by the author to assess its effect on the overall relationship.

Another type of grouping that was created included the speed variable as shown in Groups 4, 5, and 6, in which the relationship of aircraft speed was compared with the rest of the variables. Not all entries from both system and recollected data sources as presented in the Fogarty report included speed. Only two entries based on witness recollection contained the speed variable.

In the following pages, data set groupings are depicted in consolidated form in Tables D-1 to D-8.

TABLE D-1

SYSTEM DATA WITH OUTLIER

GROUP 1				
Range	**Altitude**	**Time**	**Speed**	**TN**
47	900	1017	---	4474
44	2500	1018	232	4474
40	4000	1019	303	4131
34	6160	1020	334	4131
29	7000	1021	350	4131
25	8400	1022	---	4131
22	9200	1022	---	4131
20	10000	1022	360	4131
110*	11900*	1022*	448*	4474*
16	11230	1023	371	4131
15	11000	1023	---	4131
14	12000	1023	382	4131
12	12370	1024	380	4131
10	12950	1024	385	4131
8	13500	1024	383	4131

* -- Denotes "outlier."

TABLE D-2

RECOLLECTED DATA BY WITNESSES

GROUP 2					
Who	**Range**	**Altitude**	**Time**	**Speed**	**TN**
GW	$ 39	9800	1020	---	4131
AIC-3	30	9000	1021	---	4131
AAWC	30	$ 8500	1021	---	----
OSDA	29	8000	1021	---	4131
49 ADT	25	12000	1022	---	4131
CSC	22	10300	1022	---	4131
IAD	20	10500	1022	---	4131
AIC-3	20	9000	1022	---	----
TIC	15	11000	1023	---	----
AIC-3	15	7700	1023	---	4131
IAD	$ 15	7800	1023	450	----
RSC	12	$ 5500	1024	---	----
IDS	$ 11	7800	1024	445	4131
49 ADT	10	7800	1024	---	4131
TIC	10	10000	1024	---	4131
AAWC	% 8	$ 6500	1024	---	----
MSS	6	7000	1024	---	----
UBS	6	7000	1024	---	----

$ -- Several witness accounts were provided in the form of ranges. These ranges were averaged to obtain a single value in order to plot the data point.

% -- "At engagement" was estimated by the author to mean 8 NM.

TABLE D-3

SYSTEM DATA WITHOUT OUTLIER

GROUP 3		
Range	**Altitude**	**Time**
47	900	1017
44	2500	1018
40	4000	1019
34	6160	1020
29	7000	1021
25	8400	1022
22	9200	1022
20	10000	1022
16	11230	1023
15	11000	1023
14	12000	1023
12	12370	1024
10	12950	1024
8	13500	1024

TABLE D-4

SYSTEM DATA WITH SPEED VARIABLE AND OUTLIER

GROUP 4			
Range	**Altitude**	**Speed**	**Time**
44	2500	232	1018
40	4000	303	1019
34	6160	334	1020
29	7000	350	1021
20	10000	360	1022
110*	11900*	448*	1022*
16	11230	371	1023
14	12000	382	1023
12	12370	380	1024
10	12950	385	1024
8	13500	383	1024

* -- Denotes "outlier."

TABLE D-5

SYSTEM DATA WITH SPEED VARIABLE AND NO OUTLIER

GROUP 5			
Range	**Altitude**	**Speed**	**Time**
44	2500	232	1018
40	4000	303	1019
34	6160	334	1020
29	7000	350	1021
20	10000	360	1022
16	11230	371	1023
14	12000	382	1023
12	12370	380	1024
10	12950	385	1024
8	13500	383	1024

TABLE D-6

SYSTEM AND RECOLLECTED DATA WITH SPEED VARIABLE AND OUTLIER

GROUP 6			
Range	**Altitude**	**Speed**	**Time**
44	2500	232	1018
40	4000	303	1019
34	6160	334	1020
29	7000	350	1021
20	10000	360	1022
110*	11900*	448*	1022*
16	11230	371	1023
15	7800	450	1022
14	12000	382	1023
12	12370	380	1024
11	7800	445	1024
10	12950	385	1024
8	13500	383	1024

* -- Denotes "outlier."

TABLE D-7

REFINED RECOLLECTED DATA BY WITNESSES

GROUP 7		
Range	**Altitude**	**Time**
25	12000	1022
15	7700	1023
$ 15	7800	1023
12	$ 5500	1024
$ 11	7800	1024
10	7800	1024
% 8	$ 6500	1024
6	7000	1024
6	7000	1024

$ -- Several witness accounts were provided in the form of ranges. These ranges were averaged to obtain a single value in order to plot the data point.

% -- "At engagement" was estimated by the author to mean 8 NM.

TABLE D-8

REFINED RECOLLECTED DATA WITH OUTLIER

GROUP 8		
Range	**Altitude**	**Time**
25	12000	1022
110*	11900*	1022*
15	7700	1023
$ 15	7800	1023
12	$ 5500	1024
$ 11	7800	1024
10	7800	1024
% 8	$ 6500	1024
6	7000	1024
6	7000	1024

$ -- Several witness accounts were provided in the form of ranges. These ranges were averaged to obtain a single value in order to plot the data point.

% -- "At engagement" was estimated by the author to mean 8 NM.

* -- Denotes "outlier."

APPENDIX E

CORRELATION COEFFICIENT SUMMARY

The method used to study the joint behavior of two variables and to determine whether they are related or not involves the computation of their correlation coefficient,"r." Here, the correlation coefficient measures the degree of linear relationship among the variables in a sample of data. The objective of this appendix is to analyze the degree to which various combinations of variables are related, such as speed versus range, altitude versus time, etc., to help explain the divergence between system and recollected data entries as to the flight path of Flight 655.

The following rule of thumb was used to determine the strength of the correlation:

- Weak if $0 \leq |r| \leq .5$,
- Strong if $.8 \leq |r| \leq 1$, and
- Moderate otherwise (Devore, 1987, p. 484-487).

A summary of correlation coefficients as computed by Minitab is provided in Table E-1. The data list groupings tables from Appendix D are the source from which the Correlation Coefficient Summary was created.

TABLE E-1

CORRELATION COEFFICIENT SUMMARY WITH RANGE, ALTITUDE, TIME AND SPEED VARIABLES

SYSTEM DATA WITH OUTLIER[a]-GROUP 1	
Altitude versus Range	-.293
Altitude versus Time	+.979
Range versus Time	-.440
RECOLLECTED DATA BY WITNESSES--GROUP 2	
Altitude versus Range	+.483
Altitude versus Time	-.488
Range versus Time	-.980
SYSTEM DATA WITHOUT OUTLIER[a]--GROUP 3	
Altitude versus Range	-.997
Altitude versus Time	+.992
Range versus Altitude	-.990
SYSTEM DATA WITH OUTLIER[a] AND SPEED VARIABLE--GROUP 4	
Speed versus Time	+.791
Speed versus Range	+.171
Speed versus Altitude	+.870
SYSTEM DATA WITH SPEED VARIABLE AND NO OUTLIER[a]--GROUP 5	
Speed versus Time	+.927
Speed versus Range	-.912
Speed versus Altitude	+.921
SYSTEM AND RECOLLECTED DATA WITH SPEED VARIABLE AND OUTLIER[a]--GROUP 6	
Altitude versus Range	+.999
Altitude versus Time	-.866
Range versus Time	-.833
Speed versus Time	-.596
Speed versus Range	+.150
Speed versus Altitude	+.115
REFINED RECOLLECTED DATA BY WITNESSES--GROUP 7	
Altitude versus Range	+.813
Altitude versus Time	-.842
Range versus Time	-.931
REFINED RECOLLECTED DATA WITH OUTLIER[a]--GROUP 8	
Altitude versus Range	+.723
Altitude versus Time	-.899
Range versus Time	-.708

a -- Denotes system data outlier for FC-1 hook of TN 4474

Source for data entries: Fogarty, 1988, pp. 29-39

Overall, strong correlation coefficients were observed in the following data sets: "System Data without Outlier," "System Data with Speed Variable and no Outlier," and the "Refined Recollected Data by Witnesses." Highly disparate coefficients ranging from weak to strong within a data set category included the following: "Recollected Data by Witnesses" and "System and Recollected Data with Speed Variable and Outlier." The FC-1 hook of TN 4474 seemed to have the greatest adverse effect on the correlation coefficients when it was a part of a data set, except for the last data set entitled, "Refined Recollected Data with Outlier." The lack of the FC-1 effect in the last data set is significant in that it fits well with the rest of the data as shown by the moderate to strong relationship. The FC-1 hook of TN 4474 and the rest of the refined recollected data suggest that the kinematic data is characteristic of another aircraft other than Iran Flight 655.

APPENDIX F

REGRESSION ANALYSIS

The objective of regression analysis is to investigate the relationship between two variables by assessing the extent of their linearity. The Simple Linear Regression Model of $y = mx + b$ was used to analyze the data's relationship, where "b" is the y-intercept value and "m" is the slope of the line (Devore, 1987, pp. 450-472).

To determine the x-intercept between system data and recollected data, especially when the graphs are combined, the slope intercept equation was used:

$$x = (b_2 - b_1) \div (m_1 - m_2), \quad \text{(Equation 1)}$$

where the x-intercept is in nautical miles. For the next series of equations, the following results were obtained regarding the x-intercept:

The regression equation for all system altitude versus range data points, to include the FC-1 hook of TN 4474, is as follows:

$$\text{ALT} = 10227 - 45.5 \text{ NM}, \quad \text{(Equation 2)}$$

and the regression equation for all recollected altitude versus range recollected data points regarding "Iran Flight 655" is as follows:

$$\text{ALT} = 7070 + 86.5 \text{ NM}. \quad \text{(Equation 3)}$$

The x-intercept between system and recollected data is 23.917 NM. Even with both data in "raw" form, the range is within the 20-25 NM window that represents minute encompassing 1022L.

In the next set of equations, the FC-1 hook of TN 4474 data point was deliberately removed to see how the x-intercept was effected. The equation for system data is the same for the linear fit drawn in Figure III-1 as shown in the following:

$$ALT = 16097 - 310\ NM. \quad \text{(Equation 4)}$$

while the regression equation for the recollected data points remains the same as Equation 3. The x-intercept was calculated as 22.767 NM, which, again, is within the 1022L time window.

The next set of equations include the equation of the line for all system data points without the FC-1 hook of TN 4474, Equation 4, and the reconstructed recollected data equation for altitude versus range:

$$ALT = 4716 + 247\ NM. \quad \text{(Equation 5)}$$

The x-intercept between Equations 4 and 5 is 20.433 NM, an even more refined value than 22.917 NM.

The significance of these x-intercepts is that they occur at a critical time during the air engagement. Not only did the *Vincennes* enter into the 20 NM weapons envelope, but it was also at the time when Captain Rogers asked, "What is 4474 doing?" Also, the FC-1 hooked TN 4474 at 1022L. This data point was not a part of the Flight 655 flight profile, but was most likely the kinematics of the A-6, according to Rogers' speculation. In order for the FC-1 to hook TN 4474 and obtain kinematic information associated with the A-6, that track number had to already have been re-entered into the *Vincennes'* tactical picture. Therefore, the *Manchester* could have brought the track back into the Southern Persian Gulf link at about 1022L, as suggested by the intersection values.

Otherwise, the FC-1 would not have been able to obtain any kinematic information about TN 4474, because TN 4474 was sent into storage as an unused track number after the auto-correlation process that took place where TN 4131 became the new track number for Flight 655.

The following table is a listing of all graphs from Chapter III containing fitted lines and the equations associated with those lines:

TABLE F-1

REGRESSION EQUATIONS

Figure Number	y =	mx +	b
III-1*	alt	-310 nm	16097
III-2*	alt	1750 time	-1779049
III-3*	nm	-5.62 time	5766
III-4 See Figures III-1, 2, and 3 for regression equations.			
III-5	alt	-629 time	651766
III-6	alt	86.5 time	7070
III-7	alt	1382 time	-1400350
III-8	alt	-1595 time	1639657
III-9	a: alt b: alt	1382 -1595	-14000350 1639657
III-10	alt	-181 rng	13952
III-11	rng	-.246 spd	108
III-12	rng	-.246 spd	108
III-13	spd	20.4 time	-20510
III-14	a: alt* b: alt	-310 nm 86.5 nm	16097 7070
III-15	a: alt* b: alt	1750 time -629 time	-1779049 651766
III-16	alt	1380 time	-1400350
III-17	alt	-2297 time	2358722
III-18	a: alt b: alt	-310 nm -1595 nm	16097 1639657
III-19	a: alt b: alt	1750 time 1380 time	1779049 -1400350

* -- FC-1 hook of TN 4474 was not included in linear fit drawn. Data point not included in regression equation.
alt -- altitude in feet
rng -- range in nautical miles
spd -- speed in knots
time -- time is based on a 24 hour clock
a: -- line a
b: -- line b

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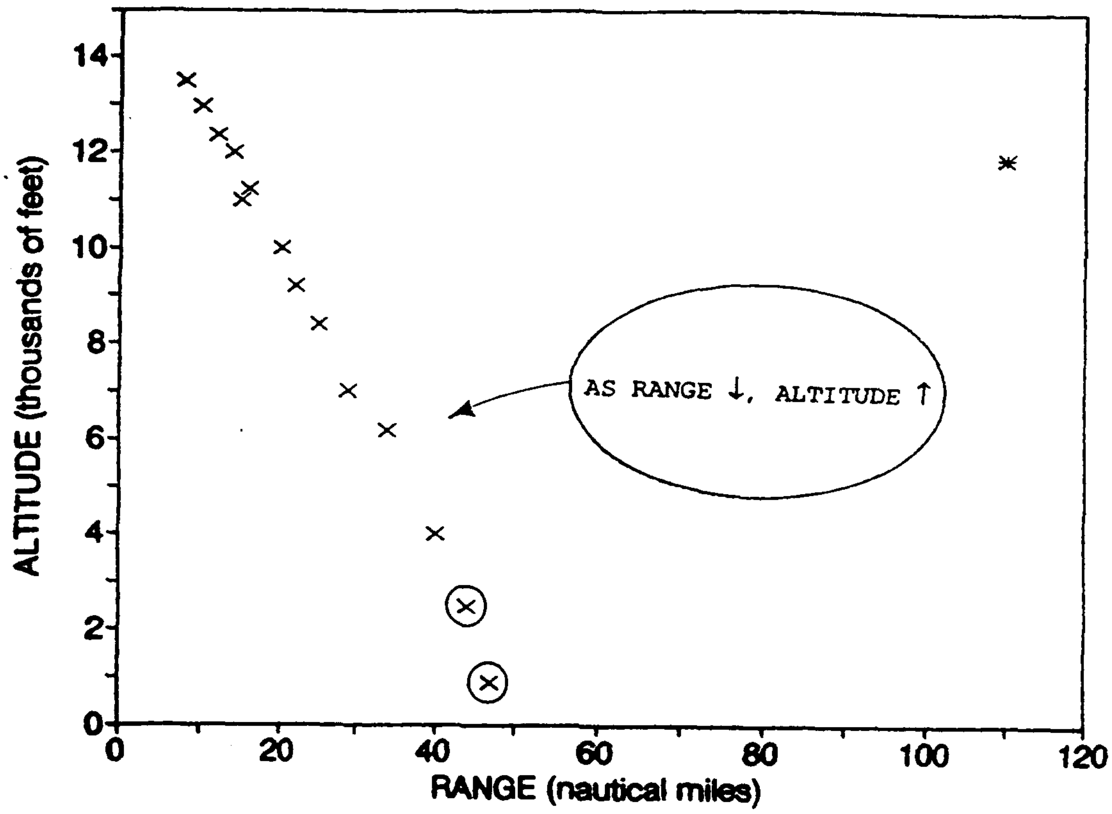
SUPPLEMENTARY

INFORMATION



LEGEND

* -- TN 4474 hooked by FC-1 at 1022L for 5 seconds with RNG 110 NM, BRG 139, ALT 11,900, SPD 448 (Fogarty, 1988, p. 34).

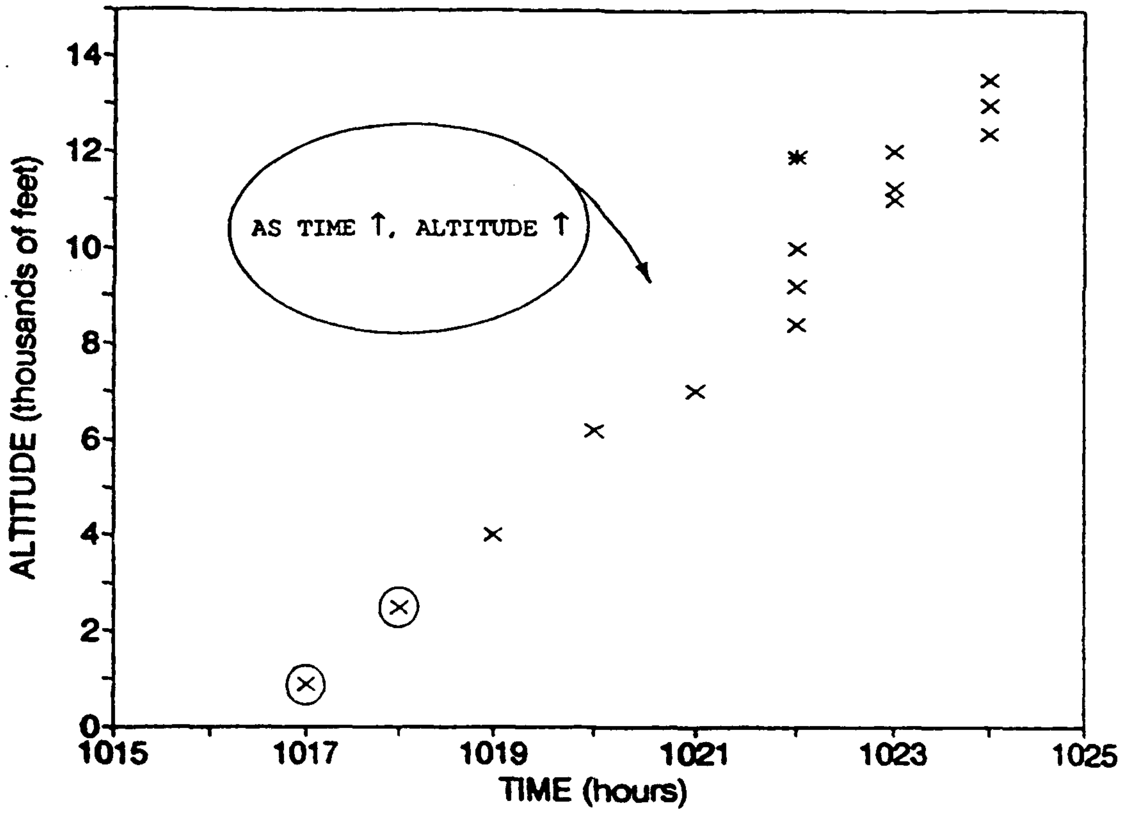
X -- Flight 655 with TN 4131 label

(X) -- Flight 655 with TN 4474 label

Slope: Negative

Correlation Coefficient: -.293

Figure III-1. System Data--Altitude versus Range



LEGEND

* -- *TN 4474 hooked by FC-1 at 1022L for 5 seconds with RNG 110 NM, BRG 139, ALT 11,900, SPD 448 (Fogarty, 1988, p. 34).*

X -- Flight 655 with TN 4131 label

(X) -- Flight 655 with TN 4474 label

Slope: Positive

Correlation Coefficient: +.979

Figure III-2. System Data--Altitude versus Time