DEPARTMENT OF THE AIR FORCE
84TH RADAR EVALUATION SQUADRON (ACC)
HILL AIR FORCE BASE, UTAH

13 Sep 01

MEMORANDUM FOR FEDERAL BUREAU OF INVESTIGATION (FBI)

FROM: 84 RADES/CC
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SUBJECT: Radar Data Analysis of East Coast Terrorist Activities, 11 September 2001 (World Trade Center, Pentagon, Pittsburgh PA).

1. Introduction. At the request of the Federal Bureau of Investigation (FBI), the 84th Radar Evaluation Squadron (84 RADES) analyzed data from US Air Force (USAF) radar sites with coverage on the four commercial aircraft used in the recent terrorist activities against the United States. Table 1 provides a mishap outline.

Table 1 Mishap Outline

Location	Airline/Flight	Aircraft Type	Crash Time	Tracking Radar		Radar ID	
				Location	Type	USAF	FAA
World Trade Center A/C #1	American Airlines (AA) – 11	Boeing 767	08:46 ET	Riverhead NY	ARSR-4	J-52	QVH
				North Truro MA	ARSR-4	J-53	QEA
World Trade Center A/C #2	United Airlines (UA) – 175	Boeing 757	09:02 ET	Riverhead NY	ARSR-4	J-52	QVH
				The Plains VA	ARSR-3	J-50	QPL
Pentagon	AA – 77	Boeing 757	09:37 ET	Gibbsboro NJ	ARSR-4	J-51	QIE
				Oceana VA	ARSR-4	J-01	QVR
				Detroit MI	ARSR-1E	J-62	QDT
Pittsburgh, PA	UA – 93	Boeing 747	10:00 ET	Riverhead NY	ARSR-4	J-52	QVH
				Gibbsboro NJ	ARSR-4	J-51	QIE
				The Plains VA	ARSR-3	J-50	QPL

2. Radar Capabilities. The radars used in this analysis are employed for USAF air defense and Federal Aviation Administration (FAA) air traffic control missions. The radars under discussion have differing capabilities. The ARSR-4 radar is a three-dimensional system providing azimuth, range and 3-D height. ARSR-4 radar data provided to military end users includes search radar 3-D height. Radar data provided to FAA end users is void of search radar 3-D height, but includes weather messages that are not distributed to the military end user. The ARSR-1E and ARSR-3 radars are two-dimensional radars providing only azimuth and range relative to the radar. In addition to primary (search) radar, all radar sites provide secondary (beacon) radar information. The radar sites interrogate and receive secondary (beacon) responses from aircraft transponders providing altimeter height and discrete mode 3A codes (squawk).

In general, the most reliable height information comes from aircraft transponder systems turned ON, responding to mode C interrogations. Mode C height accuracy is limited to ±100 feet (assuming standard barometric pressure), the value of the least significant bit in the mode C altitude report. Because mode C height is always based on a standard barometric pressure setting, it is not corrected for local pressure conditions, although an approximate correction can be made based on local atmospheric data (D-value). Note, aircraft true height is found by adding local D-value to the mode C reported height. The D-value generally varies ±1000 feet. The ARSR-4 3-D height data is generally accurate to within ±2000 feet when the aircraft is within 175 nmi of the radar site. The primary range accuracy limitation for both primary and secondary radar systems is ± 1/8 nmi due to the target reporting format employed by the radar system. Azimuth accuracy is limited to approximately 0.2 degrees for both primary and secondary radar systems.

In addition to these range, azimuth, and height accuracy factors, the radar sites require approximately 12 seconds to complete each 360-degree azimuth scan. This relatively slow scan rate precludes moment-by-moment, contiguous aircraft positional information (i.e., precludes precise track statistics such as heading and speed), particularly when aircraft are making rapid maneuvers. Because of these intrinsic radar limitations, all radar plots illustrated in this report on a scan-to-scan basis should be considered close approximations.

3. Flight Analysis. This section provides a narrative description of the radar data depicting the four incident aircraft. For single-track depictions, message types (reinforced, beacon-only, and search-only) are delineated by color and shape. Reinforced or correlated primary (search) and secondary (beacon) radar information is represented with green squares. Reinforced messages give the most accurate information in terms of aircraft altitude, bearing, and range. Primary (search) radar-only messages are represented with blue triangles. Secondary-only (beacon-only) messages are represented with red circles. For multi-track depictions, color is used to distinguish tracks and not message type. Message type can still be ascertained by symbol shape. Multi-track depiction colors are as follows: WTC aircraft one – red; WTC aircraft two – blue; Pentagon aircraft – purple; and Pittsburgh aircraft – orange.

3.1 WTC Aircraft One (AA 11). The Riverhead NY ARSR-4 provided full radar coverage of the AA Boeing 767 aircraft that impacted with the World Trade Center (WTC) at 08:46 Eastern Time (ET). Primary search-only data is available for the entire flight. Radar target reports begin shortly after takeoff at 08:10 ET. Radar data shows AA 11 climbing to flight altitude west of

Boston Logan International Airport. At approximately 08:20 ET, the aircraft's beacon transponder is turned OFF eliminating mode 3A code reports of 1443 as well as the aircraft's mode C height reporting. The remainder of the flight information comes from search-only radar returns that include 3-D height. At 08:37 ET, AA 11 deviates from its original flight route and turns towards New York City.

3.2 WTC Aircraft Two (UA 175). The Riverhead NY ARSR-4 provided full radar coverage for the UA Boeing 757 aircraft that impacted with the WTC at 09:02 ET. Radar data begins shortly after takeoff at 08:16 ET. Radar data shows UA 175 climbing to flight altitude west of Boston Logan International Airport. During this flight, the aircraft transponder mode 3A code changed twice. The initial mode 3A code of UA 175 was 1470. At 08:46 ET, the mode 3A code changed to 3020 and at 08:47 ET to 3321.

3.3 Pentagon Aircraft (AA 77). The Plains VA ARSR-3 provided radar coverage for the AA Boeing 757 aircraft that impacted the Pentagon at 09:37 ET. Radar data shows AA 77 climbed to flight altitude west of Washington Dulles International Airport. Mode C altitude information was available on the outbound track from the aircraft transponder. The mode 3A transponder code changed at 08:40 ET from 6553 to 3743. Radar data is not available from 08:50 to 09:09 ET because AA 77 left the NORAD radar coverage area. When AA 77 was reacquired, the transponder was OFF. Interior FAA radars may have coverage during the missing portion of flight. Only bearing and range information can be provided on the inbound leg because detection was accomplished by two-dimensional radar systems. Aircraft altitude is estimated at 25,000 feet when reacquired, based on radar horizon screening. At 09:34 ET, the Gibbsboro radar provided search height of 10,000 feet within three minutes of impact.

3.4 Pittsburgh Aircraft (UA 93). The Detroit MI ARSR-1E had initial coverage on the UA Boeing 747 aircraft that crashed near Pittsburgh PA at 10:00 ET. Radar data shows UA 93 climbing to flight altitude west of Newark International Airport. The aircraft had a mode 3A code of 1527 from time of take off at approximately 08:42 ET until the beacon transponder was turned off at 09:40 ET. At 09:47 ET, the aircraft left the coverage of the ARSR-1E radar, likely due to radar screening limitations. This occurred approximately 98 miles from the radar site. The Plains VA ARSR-3 reacquired UA 93 at 10:01 ET. Interior FAA radars may have coverage on this aircraft between the times of 09:47 and 10:01 ET. The aircraft transponder was turned back on for the last two radar detections. The final mode C altitude report was 6100 feet.

4. Description of products. 84 RADES is providing a CD-ROM and printouts of events.

4.1 CD-ROM Products. The CD-ROM included with this letter will automatically execute when inserted into a CD-ROM drive. A menu should appear on your screen showing the various RADES System 3 (RS3) replay projects, excel spreadsheets, and PowerPoint presentations. RS3 is the radar playback and analysis software application. To view one of these products, double click on the product in the auto-play window. A tutorial on RS3 is included and can be accessed by pressing the "View Advanced Options" button in the lower right corner of the dialogue box. Follow the on-screen instructions.

Table 2 RS3 Replays

Project Name (.rs3)	**Project Description**
Pentagon Event Aircraft Replay.rs3	Filtered file showing only Pentagon Incident Aircraft
Pentagon Time Filter Only Replay.rs3	Reflects all radar data in the area to include the Pentagon Incident Aircraft
Pittsburgh Event Aircraft Replay.rs3	Filtered file showing only Pittsburgh Incident Aircraft
Pittsburgh Time Filter Only Replay.rs3	Reflects all radar data in the area to include the Pittsburgh Incident Aircraft
WTC AC 1 Only Replay.rs3	Filtered file showing only WTC incident aircraft #1
WTC AC 2 Only Replay.rs3	Filtered file showing only WTC incident aircraft #2
WTC AC 1&2 Replay.rs3	Filtered file showing both WTC incident aircraft #1 and #2
WTC AC 1&2 Time Filter Only Replay.rs3	Reflects all radar data in the area to include WTC incident aircraft #1 and #2
All 4 Incident Aircraft Replay.rs3	Filtered file showing all four incident aircraft

Table 3 Track Data in Excel Spreadsheet

File Name (.xls)	**Description**
Radar Data All 4 Events.xls	Excel export of all radar data for four incident aircraft; separate worksheets by aircraft

Table 4 PowerPoint Diagrams

File Name: Multiple Incident Slides.ppt

Slide Number	**Description**
1	Flight path of WTC One from original radar detection point to crash overlaid on a map background
2	Flight path of WTC Two from original radar detection point to crash overlaid on a map background
3	Both WTC flights from original detection point to crash overlaid on a map background
4	Flight path of Pentagon aircraft from original radar detection point to crash overlaid on a map background
5	Flight path of Pittsburgh aircraft from original radar detection point to crash overlaid on a map background
6	All aircraft from original detection point to crash overlaid on a map background

Table 5 Video Products

File Name (.avi)	**Description**
All 4 AC.avi	AVI showing the flight paths of all 4 hijacked aircraft
WTC Combined.avi	AVI showing the flight path of the two aircraft that crashed into the World Trade Center
Pentagon.avi	AVI showing the flight path of the aircraft that crashed into the Pentagon
Pittsburgh.avi	AVI showing the flight path of the aircraft that crashed near Pittsburgh
WTC1.avi	AVI showing the flight path of the first aircraft that crashed into the World Trade Center
WTC2.avi	AVI showing the flight path of the second aircraft that crashed into the World Trade Center

4.2. Hardcopy Products. 84 RADES is providing a hardcopy of the PowerPoint diagrams.

5. Data Adjustments. The accuracy of radar data projection provided by RS3 is limited by factors discussed in paragraph 2. The RS3 uses the Earth-Centered Earth-Fixed (ECEF) method to calculate the latitude and longitude positions of a radar return based on the target height, range and azimuth from the radar site.

6. Points of Contact. If you have any questions or need more information, please contact Capt Dixon at DSN 777-4462, Commercial (801) 777-4462, e-mail: donald.dixon@hill.af.mil, or Mr. Clelland, DSN 777-2035, Commercial (801) 777-2035, e-mail: lanny.clelland@hill.af.mil.

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