Cause Determination Based on False Premises

The Partnair Accident in the Skagerrak, September 8, 1989

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2026

In memory of my father, Didrik Arnesen 1948–1989

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Foreword

Aviation is a vital part of society, and thanks to a sustained focus on safety and thorough investigation of accidents and incidents, the likelihood of perishing in an aircraft accident today is extremely low. This presupposes, however, that investigations are independent and that they identify the actual cause.

When the Partnair accident occurred on September 8, 1989, new legislation governing accident investigations had recently been enacted. Previously, a dedicated investigation commission—in which the police were also represented—was established following each aircraft accident, and the work was primarily carried out by individuals affiliated with the Armed Forces. Under the new legislation, a permanent accident investigation board was established, in which the police were no longer represented. Arnstein Øverkil, who had previously served as the police's permanent representative on investigation commissions, instead led the police's own criminal investigation of the Partnair accident in his capacity as Chief of Police in Asker and Bærum. The police and the accident investigation board serve different purposes in their investigations: where the police look for potential criminal offences, the accident investigation board's task is to determine the cause of the accident in order to improve regulations and prevent future accidents.

Background and Motivation

I hold a Cand. Scient degree in computer science and have worked for over 30 years in the development of IT systems. This background has given me experience with systematic analysis of complex interrelationships. In 2010, I obtained a private pilot licence (PPL), which has provided me with a fundamental understanding of aviation and flight operations.

I began my investigative work after watching the documentary series Partnair – Den glemte tragedien (Partnair – The Forgotten Tragedy), which aired on Viaplay in the autumn of 2023. I lost my own father in the Partnair accident when I was 13 years old, and the documentary series provided me with certain new information that awakened a strong desire to understand what actually happened.

Based on what I have found through this work, I am convinced that the official accident report has arrived at an incorrect cause determination. Rather than merely questioning the accident report, I wish to demonstrate why the conclusion cannot be correct—and thereby highlight how important it is that this accident is reinvestigated.

Purpose and Scope

My goal has been to document my analyses and conclusions in order to communicate these to journalists, next of kin, and others who wish to gain a better understanding of the case. This document is not to be regarded as an alternative accident report. It is a working document, and I do not claim that it is free of errors. Its purpose is twofold: to identify the weaknesses in the official accident report and to show which of its hypotheses are built on false premises. In addition, I put forward alternative hypotheses and show which observations and findings support them.

Sources and Documentation

My work is primarily based on documentation released by the police and the accident investigation board. I quote from these documents in the report but am not at liberty to publish them in their entirety. It is worth noting that several of the reports from the investigation work have been subject to classification, which has made it considerably more difficult to scrutinise the accident investigation board's conclusions—and which is a contributing reason why these weaknesses have not been uncovered earlier.

Methodological Approach

My approach has been to analyse as much as possible of the documentation from the original investigation. By reviewing the basis for the investigation reports, I have sought to verify the accident investigation board's conclusions. The board built its cause determination on a series of premises. By challenging these premises, one can assess whether the conclusion stands on solid ground, whether it wavers—or whether it collapses entirely.

The work has followed a systematic approach: formulating hypotheses, and then using data, observations, and findings to either strengthen or reject them. Through this process, I have arrived at hypotheses that can substantiate the sequence of events in this case.

An important principle in this work is Occam's razor: the simplest explanation compatible with all known facts is, as a rule, the correct one. If a hypothesis requires a long series of assumptions to hold, it is less likely to be correct than a hypothesis with few assumptions. This principle has been very useful in a case where it is possible to put forward many complex hypotheses. Rather than being carried away by complexity, it is important to focus on the simple explanations—precisely because these are most likely to be correct.

«Occam's razor (Latin: lex parsimoniæ, 'the law of parsimony') is a problem-solving principle in the philosophy of science. The principle holds that among two possible hypotheses (or explanations), all other things being equal, the simplest is most likely the correct one. The principle states that one should not operate with more assumptions than are needed to explain what is observed.» (Ockhams barberkniv, Wikipedia)

Findings

Personally, I prefer simple explanations over complex hypotheses with many dependencies and assumptions. Several of the hypotheses presented in this report coincide with hypotheses that have been put forward numerous times over the years. Through my analysis, however, I have also made new findings that I have not seen discussed previously. Several of these findings strengthen hypotheses about a sequence of events that is far simpler than what the accident investigation board assumed. In addition, there are some new findings that lead me to put forward hypotheses that some will perceive as controversial. These hypotheses are supported by concrete findings, not vague assumptions.

My work has led me to realise that the accident was caused by a long series of coincidences, and that it is also a series of coincidences that has contributed to the cause not being found long ago.

I cannot claim that I am one hundred per cent certain that I have found the full and complete truth. But I present what I believe is important for understanding the case, and my wish is that this work will be of help to others who wish to continue working on it.

Finally, I wish to emphasise: just because something seems unthinkable and improbable does not mean it is impossible. It is logical reasoning and hypotheses strengthened by concrete findings that underpin what I present.

Acknowledgements

Special thanks to Alexander Wisting. Without the work he has carried out over many years on the TV documentary Partnair – Den glemte tragedien (Partnair – The Forgotten Tragedy), published in 2023, I would never have begun looking into this case. We have collaborated closely since the documentary was released, and I have continuously shared my analyses with him as this document has taken shape. I greatly appreciate that Alexander has never given up on this case. In order to achieve the goal of having this case reinvestigated, it is essential that the information reaches as many people as possible—and that is difficult to accomplish without the media.

I also wish to thank Jorunn Steinmo, who contacted me in the spring of 2025 and helped obtain additional documentation. Without this assistance, it would have been difficult to understand what happened to the Partnair aircraft after it departed controlled flight and flew uncontrollably towards the sea.

Great thanks are also extended to Hans Arnegard for much valuable and invaluable help. There is scarcely anything about the Convair 580 that he cannot answer or find the answer to in all the binders he has from his time as a pilot, mechanic, and instructor for both pilots and mechanics on this aircraft type.

I wish to thank Oslo Police District, which has assisted in locating, digitising, and providing access to documentation related to the case. Without this help, it would have been far more difficult to scrutinise the accident investigation work carried out in the aftermath of the accident.

Finally, I wish to extend the greatest thanks to my family. This case has, since the autumn of 2023, consumed an enormous amount of my time, and I have at times been very absent. It has been so important to me to get to the bottom of why my father perished, and why the truth about this case has not come to light, that I have at times buried myself completely in the work. Thank you for your patience and support.

Hosle, June 2026
Lars Preben Sørsdahl

Introduction

On Friday, September 8, 1989, at 16:39 local time, a Convair CV-580 with registration LN-PAA crashed in the Skagerrak, just north of Hirtshals. The aircraft was en route from Oslo Fornebu to Hamburg with 50 passengers and 5 crew members on board. There were no survivors.

It was a charter flight for Wilhelmsen, operated by Partnair, and the flight had the route number Partnair 394. After approximately three years of investigation, the Accident Investigation Board for Civil Aviation concluded that the accident was caused by flutter in the tail control surfaces, induced by counterfeit parts in the aircraft's rudder. Flutter is a self-reinforcing vibration that occurs when aerodynamic forces and structural oscillations amplify each other. According to the accident investigation board, the vibrations built up gradually, without the crew being able to detect them, until the tail control surfaces ultimately disintegrated.

This conclusion has stood for 36 years, despite numerous objections to the accident investigation board's conclusion having been raised over the years.

Background to This Report

Approximately nine minutes before the Partnair aircraft disappeared from radar, a Norwegian F-16 fighter jet passed at supersonic speed directly towards the Partnair aircraft at the same altitude. The accident investigation board considered this close pass and concluded that it occurred too long before the accident to have had any connection.

This report shows that the accident investigation board's timeline is incorrect. The Flight Data Recorder shows that deviations in the Partnair aircraft's speed and heading began as early as 6 minutes before the aircraft hit the water—coinciding with the time of the F-16 pass. The accident investigation board interpreted these deviations as normal and limited its analysis to the final minute of the flight.

In addition, a review of the radar data shows that these have been altered after recording. The datasets from Mågerø and Skagen contain physically impossible situations, have been delivered in multiple versions with mutual discrepancies, and bear clear traces of manual manipulation. The radar data cannot be used as evidence for where the aircraft were in relation to each other.

Furthermore, several significant findings from the technical investigation were not addressed in the accident report. RARDE in England found, among other things, a hole in a shelf plate inside the aircraft, caused by a fragment travelling at 650 m/s—a velocity that cannot be achieved without an explosion. Trace amounts of the explosive RDX were found on two separate aircraft parts, molten iron that had solidified in the air, and traces of brief heating on interior parts. These findings were withheld from the public.

Purpose

The purpose of this report is to verify the accident investigation board's conclusion by analysing available documentation, including the Flight Data Recorder, radar data, and technical reports that have not been publicly available.

The report is not written to assign blame, but to highlight weaknesses in the investigation and to show that an alternative explanation—that a supersonic shock wave from the F-16 close pass damaged the Partnair aircraft's tail control surfaces—is a far simpler and more probable cause than the one the accident investigation board relied upon.

Structure of the Report

The report is structured so that each chapter illuminates one aspect of the accident:

Background provides an overview of the flight, the aircraft type, and the circumstances surrounding the accident.

Airspeed shows that the accident investigation board misread the Flight Data Recorder by approximately 15 knots in speed, which has affected their analysis of the sequence of events.

Navigation addresses the pilots' navigation plan and the course deviations prior to the accident.

Flight Data Recorder shows that the deviations in the aircraft's parameters began at the time of the F-16 pass—six minutes before the aircraft departed controlled flight—and that these deviations are consistent with a systematic troubleshooting process on the part of the crew.

Shock Waves describes the physical mechanism behind supersonic shock waves and how these can inflict structural damage on an aircraft.

APU shows that the loose APU unit in the tail, which the accident investigation board emphasised as a contributing factor, most likely came loose as a consequence of the accident—not as a cause.

The Close Pass addresses the two opposing F-16 fighter jets and explains the motivation for the Norwegian crew to carry out a close pass.

The Merge explains why the F-16 pilot's merge manoeuvre against a slow-moving propeller aircraft may have resulted in a significantly closer pass than intended, and how the shock wave geometry strikes the rudder's trim tab from the side.

Emergency describes a potential sequence of events from the moment something went wrong until the aircraft hit the water, based on the Flight Data Recorder and established flight operations knowledge.

Radar Echoes of Wreckage analyses Swedish radar observations of objects that separated from the aircraft, and shows that the accident investigation board's hypothesis about honeycomb cannot be correct.

Radar Data and Radar Analysis review the radar datasets from Mågerø, Skagen, and AWACS. The analysis reveals physically impossible situations, speed differences that cannot be explained by radar precision, time discrepancies that apply only to the F-16 data, and that the datasets have been delivered in multiple versions with manually introduced corrections.

Evidence That Was Not Examined presents findings from the RARDE reports and other technical investigations that have not been publicly available, including high-velocity fragments, RDX traces, sooted parts, and molten metal, as well as an analysis of the propellers indicating that the left propeller separated from the engine before the aircraft hit the water.

Concluding Remarks compares the two hypotheses and reflects on the investigation process and the need for transparency.

Background

Aircraft share certain similarities with ships, and many terms in aviation are borrowed from maritime navigation. Speed is measured in knots and distance is given in nautical miles. The aircraft is equipped with control surfaces, propellers, navigation lights, and navigation instruments. The airspeed indicator measures speed through the air mass, in the same way that a ship's speed log shows speed through the water. A ship stays afloat without expending energy, whereas an aircraft must move through the air mass to generate lift. Both aerodynamic lift and drag increase with the square of the speed—the higher the speed, the more energy is required to propel the aircraft forward.

Aviation has an extensive regulatory framework, and all parties have their rules and procedures to adhere to. Much of the regulation relates to safety and efficient traffic management. Both air traffic controllers and pilots are regularly evaluated to maintain their certificates. Although both aircraft and regulations are in continuous evolution, most things remain the same today as they were in 1989. Pilots and air traffic controllers still speak the same phraseology on radio, radio navigation equipment is still in use, and the Convair CV-580 still operates in commercial service. This means that with today's knowledge and information sources, it is entirely possible to review an accident that occurred far back in time.

Most components in an aircraft have redundancy, so that the loss of one component does not become critical. All critical instruments exist in duplicate, and the instruments also have partially overlapping functions. This makes it possible to detect instrument errors by cross-checking the instruments.

When studying an accident in retrospect, one must use all available information and cross-check it against other sources. If, for example, one does not have access to cockpit audio recordings or radio communications, one must attempt to use other information sources to understand what has happened.

In connection with the Partnair accident, the Cockpit Voice Recorder (CVR) did not function, which makes it difficult to know what the pilots were thinking and doing. By studying data from radar and the Flight Data Recorder (FDR), and combining this with logic and knowledge of how pilots are trained, it is nevertheless possible to form a picture of what the sequence of events may have been.

The Flight Data Recorder (FDR) is one of the "black boxes" that is sent for analysis after being recovered from the accident site. The FDR data has a time reference based on the number of minutes since take-off, and is referred to as "FDR time."

Group Polarisation

«Group polarisation denotes the phenomenon whereby members of a group often end up with more extreme viewpoints and make more extreme choices than they would have made individually.

If the individuals in a group have a tendency to make high-risk choices, the group will, according to this principle, make even riskier choices. If the individuals in the group are, however, reserved regarding a decision, they tend to become more reserved after discussion among themselves. The polarisation can thus go in both directions.

The term was first used by social psychologists Serge Moscovici and Marisa Zavalloni in the late 1960s. Earlier, James Stoner had used the term 'risky shift' to describe the phenomenon that a group's decision may be riskier than the average of the group's individual members would suggest. Moscovici and Zavalloni found that attitudes generally become more extreme within groups.» (Svartdal, 2021)

In this case, two aircraft are involved, and both had a larger crew in the cockpit than normal. The F-16 was a trainer version with two pilots, in what is fundamentally a single-seat fighter jet. The "risky shift" principle may help explain why a crew of two carried out a close-pass stunt that they as individuals might not have performed.

For the Partnair aircraft, the same principle may have influenced the decision-making process. There was, in fact, a mechanic in the cockpit together with the two pilots. Having a mechanic present would naturally influence the decision-making process during troubleshooting, especially when the problem might be related to engines and propellers. With three people discussing, it may take longer to reach a decision, and it may also influence whether one chooses to err on the side of caution and aborts the flight, or continues in order to evaluate further.

Basic Fighter Maneuvers (BFM)

One of the primary tasks of a fighter jet is to be able to defeat other fighter jets. To do this, the pilots must be well trained in manoeuvring the fighter jet to get into position to shoot down the adversary. This type of air combat is called a "dogfight."

«Basic fighter maneuvers (BFMs) are the building blocks of fighter tactics. They may be classified as primary maneuvers, which can be performed without regard to an adversary (e.g., accelerations, climbs, turns), and relative maneuvers, which must be described or performed in relation to another aircraft. The physics and techniques involved in most primary maneuvers are discussed in the Appendix and therefore are not covered here. No guts, no glory. If you are going to shoot him down, you have to get in there and mix it up with him. Major Frederick C. "Boots" Blesse, USAF 10 Victories, Korean Conflict» (Shaw, 1985, side 62)

"The merge" is the point where two fighter jets meet and the dogfight can begin. When two fighters fly towards each other, they will in practice fly head-on and pass at close range.

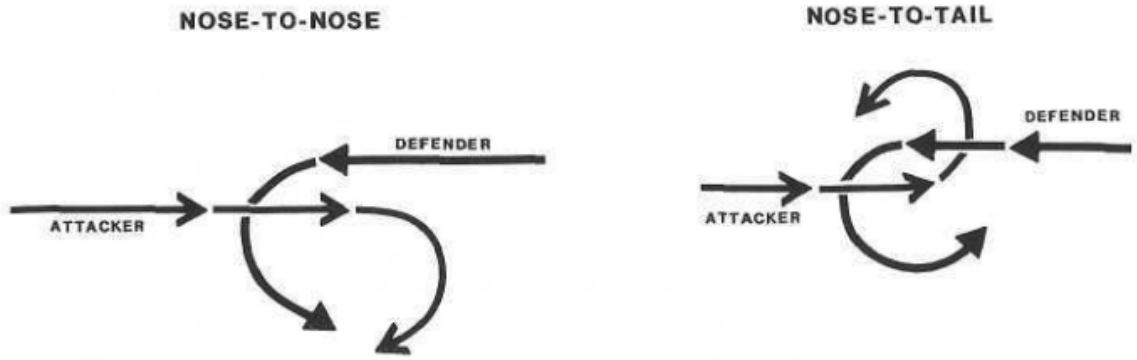


Figure 2-11. Turn Options

«Nose-to-nose and nose-to-tail turns are two options of fighters meeting in forward-quarter passes. Figure 2-11 graphically defines these maneuvers. As can be seen from this illustration, the names are fairly descriptive. In the first case, one fighter turns left, across the tail of its opponent, while the other turns right, away from its adversary, so that the two fighters again approach in a nose-to-nose fashion. In the second, each pilot chooses to cross the other's tail, resulting in a nose-to-tail relationship. In choosing the nose-to-nose turn, one pilot turns away from his opponent at the pass.» (Shaw, 1985, side 77–78)

Physics

Although aviation has an extensive body of regulations, it is the physical laws that are absolute and that all flight must conform to. The aim of this section is to provide background information on physics topics relevant to the investigation of the Partnair accident.

Shock Waves

Aircraft are designed to withstand very large forces, particularly with regard to severe turbulence. When an aircraft moves through an air mass with varying wind strength and direction, the lift on the wings will vary. Changes in lift result in "bumps" and "shaking" in the aircraft. To reduce the effects of turbulence, speed must be reduced.

Turbulence has been known to aircraft designers since the dawn of aviation, but the effects of supersonic speed were only experienced after Chuck Yeager became the first to break the sound barrier in October 1947. In the mid-1950s, the first fighter jets capable of flying faster than the speed of sound arrived. The Convair CV-240 flew for the first time in 1947, and a further developed version (CV-340) appeared in 1951. The Convair CV-580 is a CV-340 that was converted from piston engines to turboprops. (Convair CV-240 Family, Wikipedia)

Any design principles that make aircraft structures better protected against the effects of supersonic shock waves were most likely not known to the designers of the Convair CV-240, CV-340, and CV-580. The aircraft type was designed before supersonic-capable aircraft existed, and there was therefore little knowledge of shock waves from supersonic flight.

The energy in shock waves diminishes rapidly with distance. A small explosion, for instance, may be relatively harmless at a distance of several metres but can be lethal at close range.

In the same way, a supersonic shock wave may have entirely different consequences if the source is close than if it is further away.

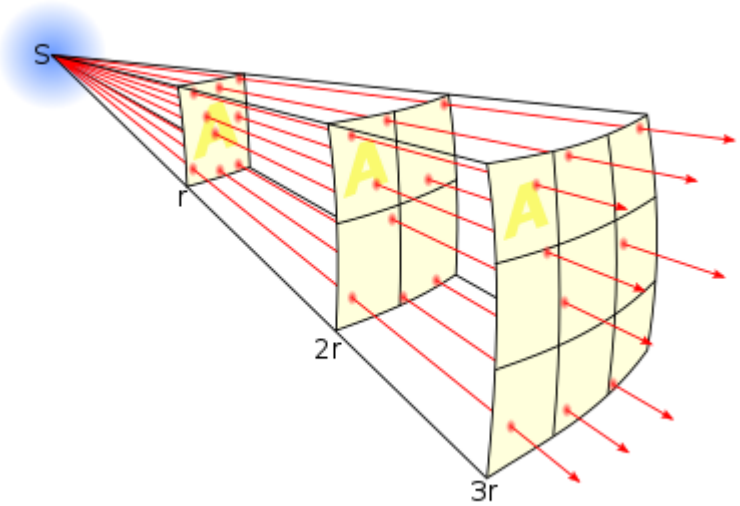
«Unlike solitons (another kind of nonlinear wave), the energy and speed of a shock wave alone dissipates relatively quickly with distance. When a shock wave passes through matter, energy is preserved but entropy increases. This change in the matter's properties manifests itself as a decrease in the energy which can be extracted as work, and as a drag force on supersonic objects; shock waves are strongly irreversible processes.» (Shock Wave, Wikipedia)

At a distance, an aircraft breaking the sound barrier sounds like rumbling thunder. At close range, however, it sounds like a double crack of a whip.

«There is a rise in pressure at the nose, decreasing steadily to a negative pressure at the tail, followed by a sudden return to normal pressure after the object passes. This "overpressure profile" is known as an N-wave because of its shape. The "boom" is experienced when there is a sudden change in pressure; therefore, an N-wave causes two booms – one when the initial pressure rises reaches an observer, and another when the pressure returns to normal. This leads to a distinctive "double boom" from a supersonic aircraft. … Duration of sonic boom is brief; less than a second, 100 milliseconds (0.1 second) for most fighter-sized aircraft and 500 milliseconds for the space shuttle or Concorde jetliner. The intensity and width of a sonic boom path depend on the physical characteristics of the aircraft and how it is operated.» (Sonic Boom, Wikipedia)

Inverse-Square Law

In this case, physical laws related to distance and energy transfer are absolutely essential: energy in the form of waves—in light, water, and air—diminishes with distance. This is because a given amount of energy is spread over an ever-larger area. In practice, this means that the closer one is to the energy source, the greater the amount of energy one receives. Halving the distance quadruples the energy.



«In science, an inverse-square law is any scientific law stating that the observed "intensity" of a specified physical quantity is inversely proportional to the square of the distance from the source of that physical quantity.» (Inverse-Square Law, Wikipedia)

This is crucial with regard to how close the F-16 was. If one assumes that the F-16 passed 2,000 feet away, the energy from a shock wave is only one quarter of what it is at 1,000 feet. Therefore, one cannot argue that a close pass at 2,000 feet is harmless and from this conclude that the F-16 could not have damaged the Partnair aircraft even if it flew closer. A pass with 100 feet of separation would deliver a transferred energy 400 times greater than a pass with 2,000 feet of separation.

Flutter

Flutter—undamped oscillations of the control surfaces—creates severe vibrations throughout the entire aircraft. It seems inconceivable that flutter would have arisen gradually on its own, without the pilots detecting it. Given that there is no damage to the aircraft's structure, flutter will not occur unless the speed is far above the aircraft's certified maximum speed.

«Control surfaces are designed so that flutter can never occur during normal operation. If the speed is increased beyond 'the critical flutter speed,' the control surface by definition begins to oscillate 'on its own.'» (Lind, 1999, p. 31)

To reach the speed necessary for flutter to develop in the control surfaces, the aircraft must be in a dive. If the Partnair aircraft entered an uncontrolled dive such that flutter developed and the control surfaces were torn apart, it is inconceivable that the aircraft was subsequently at 21,000 feet altitude as NATO's radar data indicates. An altitude loss of only 1,000 feet would not give the aircraft sufficient speed to develop flutter.

«It is clear therefore that the right elevator had moved up and down well beyond its limits for hundreds of cycles. … The oscillations had to have occurred over a long period of time, i.e. greater than ½ minute, because frequencies of even 4 or 5 per second would require more than 40 seconds to cause the hundreds of cycles revealed. It is therefore apparent that both the left and right elevators developed abnormal gyrations over a significant period of time, causing both to fail.» (Accident Investigation & Research, 1992, side 15–16)

If flutter begins to develop in the control surfaces, the first imperative is to reduce speed. That flutter occurred in level flight and continued for more than 40 seconds without the pilots reducing speed is entirely implausible. The only logical explanation is that the pilots could not reduce speed because the aircraft was in a dive resulting from a roll and loss of control.

Speed and Altitude

An F-16 fighter jet has enormously high engine power relative to the aircraft's weight. This enables it to achieve high speed even during climb or in level flight. For a passenger aircraft such as the Convair 580, however, there are limits to how fast the aircraft can fly straight and level, since the engines are dimensioned for what the aircraft can withstand. Cruise speed for the Convair 580 is close to the aircraft's maximum certified speed, and at that point maximum continuous power is used. This is somewhat lower performance than what is used

for take-off and climb, where a power setting is available that can only be used for a limited time period.

The aircraft is certified for a given speed, with a safety margin beyond that. If both the certified speed and the safety margin are exceeded, one enters a region where flutter can develop in the control surfaces. Reaching this speed requires more than what the engines can deliver in level flight—in other words: the aircraft must dive. It can be compared to rolling downhill on a bicycle; one loses altitude and gains kinetic energy.

This is important because the Partnair aircraft was flying at 22,000 feet. For flutter to develop in the control surfaces, the aircraft must have been in a dive and thus have lost several thousand feet in altitude. This is crucial when assessing altitude readings in radar data for the final part of the flight. It is physically impossible for the aircraft to have been flying at cruise altitude while simultaneously developing flutter—the aircraft must have lost significant altitude first.

Radar

In both civil and military contexts, radar is an invaluable tool. The civil air traffic service requires radar in order to separate aircraft from one another.

Primary Radar

The civil air traffic service depends on secondary radar, but primary radar constitutes an important supplement. Primary radar is based on radar reflections—it transmits a radar signal and registers what is reflected back. It requires no active cooperation from the aircraft.

«This type of radar (called a primary radar) can detect and report the position of anything that reflects its transmitted radio signals including, depending on its design, aircraft, birds, weather and land features. For air traffic control purposes this is both an advantage and a disadvantage. Its targets do not have to co-operate, they only have to be within its coverage and be able to reflect radio waves, but it only indicates the position of the targets, it does not identify them. When primary radar was the only type of radar available, the correlation of individual radar returns with specific aircraft typically was achieved by the controller observing a directed turn by the aircraft. Primary radar is still used by ATC as a backup/complementary system to secondary radar, although its coverage and information is more limited.» (Secondary Surveillance Radar, Wikipedia)

Secondary Radar

Secondary radar is the primary tool for civil air traffic services. It depends on the aircraft having a transponder that actively responds to interrogations from the ground station. The transponder responds with a transponder code and pressure altitude (Mode C). The aircraft's callsign is registered together with the transponder code in the radar system, which enables the air traffic controller to see position, altitude, and callsign on their screen.

If the transponder in the aircraft is switched off, this information will no longer be displayed on the radar screen. Depending on coverage, primary radar may still detect the aircraft and

show it as a point on the screen, but without altitude or identification. Without an active transponder, an aircraft will be virtually invisible to an air traffic controller. The military cannot rely exclusively on secondary radar, as military aircraft switch off their transponders on missions. They must therefore use primary radar.

«The need to be able to identify aircraft more easily and reliably led to another wartime radar development, the Identification Friend or Foe (IFF) system, which had been created as a means of positively identifying friendly aircraft from unknowns. This system, which became known in civil use as secondary surveillance radar (SSR), or in the US as the air traffic control radar beacon system (ATCRBS), relies on a piece of equipment aboard the aircraft known as a "transponder." The transponder is a radio receiver and transmitter pair which receives on 1030 MHz and transmits on 1090 MHz. The target aircraft transponder replies to signals from an interrogator (usually, but not necessarily, a ground station co-located with a primary radar) by transmitting a coded reply signal containing the requested information.» (Secondary Surveillance Radar, Wikipedia)

Transponder Code

«Air traffic control units use the term "squawk" when they are assigning an aircraft a transponder code, e.g., "Squawk 7421". Squawk thus can be said to mean "select transponder code" or "squawking xxxx" to mean "I have selected transponder code xxxx".

The transponder receives interrogation from the Secondary Surveillance Radar on 1030 MHz and replies on 1090 MHz.» (Transponder (Aeronautics), Wikipedia)

Airspeed

The accident investigation board assumed that the normal cruise speed for LN-PAA was 200 knots. They appear to have focused solely on the indicated airspeed recorded by the Flight Data Recorder, without accounting for the inaccuracy inherent in this recording. The accident investigation board noted that the speed decreased from 215 to 200 knots, without discussing the cause of the speed loss. Depending on weight and cruise altitude, a cruise speed of 200 knots may in some cases be normal, but the speed reduction after "top of climb" is not normal regardless of altitude and total weight.

To substantiate the premise that the airspeed was normal, the accident investigation board should have more closely examined whether the correct speed was recorded by the Flight Data Recorder, and why the speed was decreasing rather than remaining stable. The accident investigation board failed to do this.

«When the aircraft established itself at cruise altitude, the indicated airspeed increased from 185 KT and then decreased to 200 KT.» (The Accident Report, 1993, p. 38)

«At this point, the engines were probably set to cruise setting. Thereafter, the speed decreased until at approximately 32 min FDR time it stabilised at approximately 200 KT.» (The Accident Report, 1993, p. 106)

Another important observation is that the speed decreased from 215 knots down to 200 knots over a period of 3 minutes and 45 seconds. Any reduction in speed when setting the engines from "climb power" to "cruise power" occurs within a matter of seconds.

To support the claim that the aircraft was at cruise speed when the accident occurred, the accident report relies on Turbine Inlet Temperature (TIT), which is used in connection with adjusting the engines. Convair pilots are meticulous about using the throttle levers to fine-tune the temperature to 847 °C. The temperatures the accident investigation board read from the instruments show that the engines had a higher temperature than this when the instruments lost power. Rather than discussing this discrepancy, the accident investigation board chose to "round off" the values and conclude that the engines were set to "cruise power."

It is plausible that the throttle levers had been set to approximate "cruise power" shortly before the accident, without the crew having prioritised fine-tuning them as they normally would have done. In such a scenario, the instruments could show approximately normal "cruise power" values, despite the aircraft not having flown for long in stable cruise.

The following points should have been investigated more thoroughly by the accident investigation board before concluding that LN-PAA was at normal cruise speed when the accident occurred:

- Inaccuracy in the Flight Data Recorder's recording of airspeed
- Unexplained reduction in speed after "top of climb"
- TIT instruments with temperature readings deviating from fine-tuned "cruise power" settings

Acceleration

The airspeed indicator in an aircraft is based on measurement of dynamic pressure, created by the aircraft moving through the air, as well as the static pressure of the surrounding air. The speed displayed on the airspeed indicator is "indicated air speed" (IAS). In this document, only indicated airspeed is referenced, as pilots primarily use this for take-off speeds, cruise speed, and landing. The indicated airspeed is also what is recorded by the Flight Data Recorder (FDR).

With a heavily loaded car driving up a steep mountain road, the car will have relatively low speed, even at full throttle. This is a good analogy for how a flight progresses. When the hilltop is reached, it still takes some time at full throttle to achieve maximum speed. The higher the speed, the longer it takes to increase it further. Acceleration from 0 to 30 km/h happens relatively quickly, but from 150 to 180 km/h takes much longer.

"Top of Climb" (TOC) is the term used for when the "hilltop" is reached, and the aircraft levels off to increase speed to cruise speed. "Maximum Operating Speed" (VMO) is the maximum speed the aircraft is certified for. This speed limitation is so important that the airspeed indicator continuously shows what this speed is.

For many aircraft, cruise speed is close to the maximum speed (VMO). In practice, this means that after reaching "top of climb," the engine settings are maintained until cruise speed is reached, and then engine power is reduced slightly. By adjusting the engines to "cruise setting," the aircraft will stabilise at cruise speed on its own.

Cruise Speed for the CV-580

The image below is from an aircraft identical to LN-PAA, which is at a cruise altitude of 21,000 feet (flight level 210) and has a cruise speed of 212 knots. The maximum speed (VMO) at this altitude is 227 knots, which is indicated by the red-and-white striped pointer.

(VikingWings Part 1, 2020, tid 1:15:44)

The airspeed indicator, the artificial horizon, and the altimeter are three of the most essential instruments in the aircraft. Each pilot has these instruments positioned directly in front of them and uses them actively in all phases of flight. At "top of climb," the instruments are used to read when the correct altitude has been reached and when cruise speed has been achieved, so that engine power can be reduced to "cruise power." During cruise flight, the pilots continuously monitor the instruments to detect deviations in heading, altitude, or speed. Even small variations on a pointer can indicate the onset of a serious problem. Pilots are therefore trained to "scan" the instruments regularly, so that faults with the instruments or the aircraft's systems can be detected as early as possible.

In a video, a Nolinor captain demonstrates and explains the procedure when "top of climb" is reached. The speed increases before engine power is reduced slightly, and the aircraft stabilises at cruise speed. In this video, the aircraft ends up with a cruise speed of 212 knots. (VikingWings Part 1, 2020, tid 1:12:40)

In connection with changing engine settings, there is a need to "trim the aircraft." By adjusting the trim tabs, the aircraft will maintain heading and altitude without the pilot (or the autopilot) needing to apply force to the control surfaces. In another Nolinor video, the captain of a Convair CV-580 demonstrates the entire process from "top of climb" until "cruise power" is set and the aircraft is trimmed. The process of adjusting the engines and trimming the aircraft was completed in under one minute.
(Air-Clips, 2020, tid 1:40:30-1:45:35)

There are several videos showing flights with the Convair CV-580, and one will observe that the indicated airspeed varies with altitude and load weight. What is important to note is that the videos show the pilots using the same procedure at "top of climb": let the aircraft

accelerate to cruise speed, and then set "cruise power." Another important observation is that the pointer on the airspeed indicator remains completely steady when the aircraft is at cruise speed.

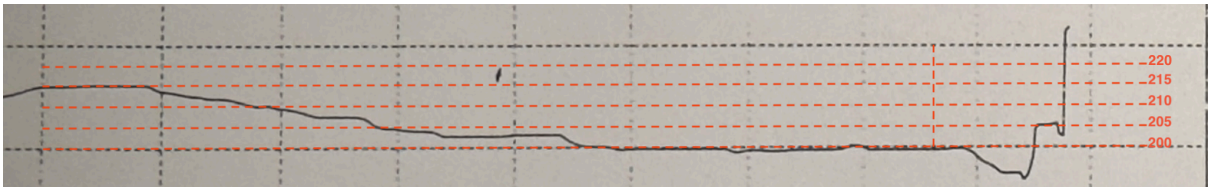
The exact cruise speed depends on the total weight and altitude. When the engines are set for "cruise power" and the control surfaces are trimmed, the speed will stabilise and remain stable, provided there is no severe turbulence.

LN-PAA's Cruise Speed

Data from the Flight Data Recorder (FDR) shows that LN-PAA reached its cruise altitude of 22,000 feet (flight level 220) at 22:40 FDR time. After that, the aircraft took approximately 4 minutes to reach a speed of 215 knots. One minute later, a reduction in speed occurs. It is reasonable to assume that the reduction occurred in connection with the engines being set to "cruise power." 215 knots is somewhat higher than what is shown in the videos, which may mean that the crew maintained "climb power" slightly longer than necessary, and that the aircraft therefore accelerated to a few knots above cruise speed.

There is a potential inaccuracy in the Flight Data Recorder system, specified as ±10 knots. (The Accident Report, 1993, p. 35)

Since the exact cruise speed for LN-PAA is not known, the process at "top of climb" must be taken into consideration, in addition to comparison with other similar flights. Given that 215 knots appears to be a slightly high cruise speed, and that a speed reduction occurs relatively shortly after it was achieved, this may indicate that the actual cruise speed was a few knots lower than 215. After a slight speed reduction, LN-PAA would then have had a cruise speed consistent with what is observed in available videos.

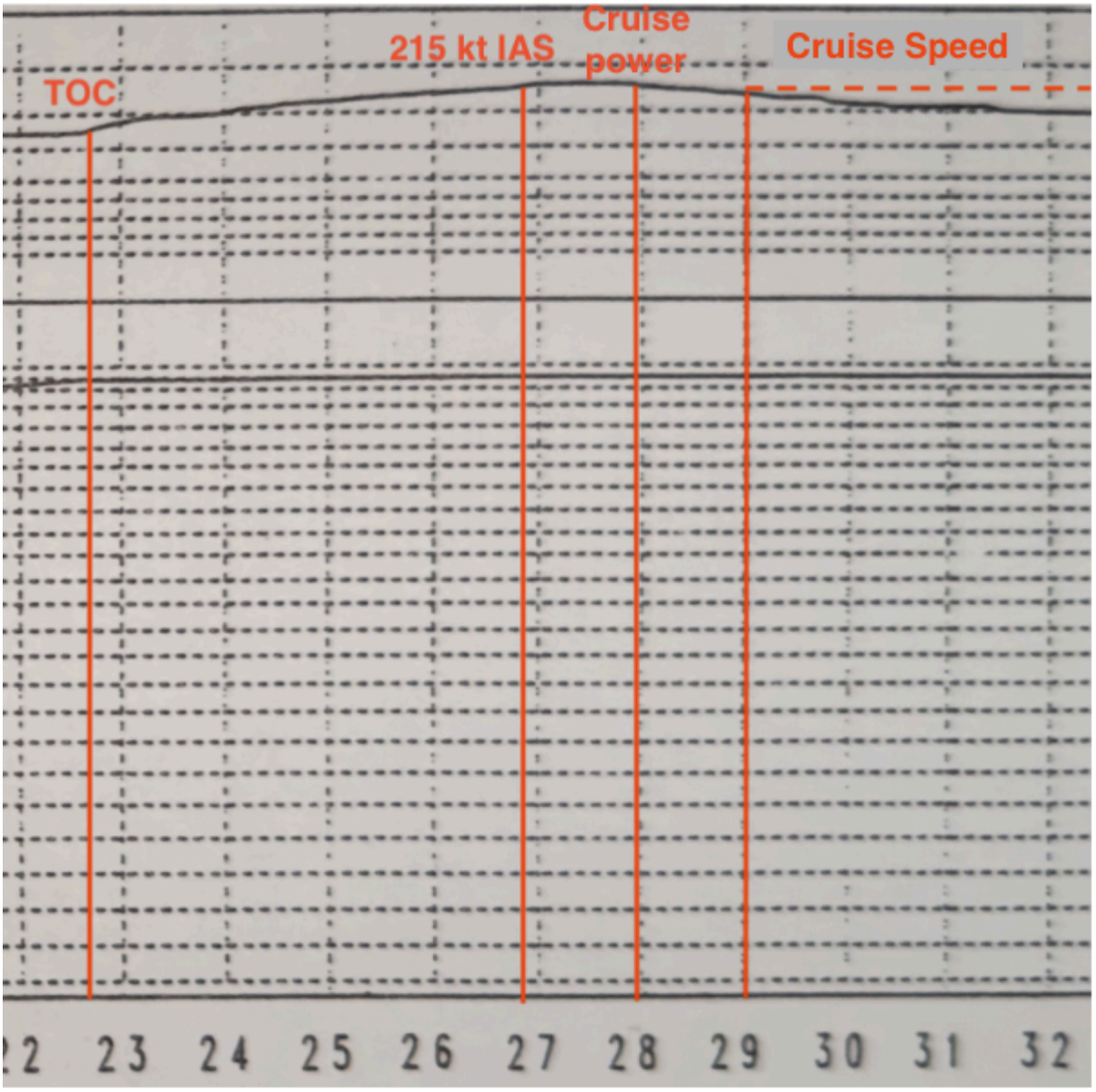


In the FDR printout, there are only markings for 200 and 225 knots. Horizontal dashed lines have been added to the FDR printout to clarify the approximate speed after "top of climb."

«When desired altitude is reached, climb power should be maintained until airspeed exceeds anticipated cruise value by approximately 5 knots. (Never exceed VMO). This procedure provides an airspeed "cushion" to allow for aircraft trim adjustments.»
(Pilot's Handbook Convair 580, 1977, side 18-8)

Taking into account what is stated in the aircraft's handbook, as well as the fact that LN-PAA achieved a speed of 215 knots after "top of climb," it is probable that LN-PAA's cruise speed in the FDR data would have been approximately 210 knots. This contradicts the premise of the accident report, which assumes that the aircraft's normal cruise speed on the day of the accident was approximately 200 knots.

The image shows the point for "top of climb" and when the highest speed (215 knots) was achieved. In addition, the point where the crew presumably set "cruise power" is shown, and the dashed line shows 210 knots, which would have been a plausible cruise speed on the accident flight.



Speed Premises

It is difficult to understand how the accident investigation board arrived at the conclusion that 200 knots was normal cruise speed for a Convair CV-580. In connection with the analysis of FDR data, airspeed is highly relevant—even small variations in indicated airspeed can provide important clues as to what has happened.

Interviewed pilots have confirmed that the cruise speed is around 200 knots, depending on load and cruise altitude, and the aircraft's documentation contains calculation diagrams showing cruise speeds in this range. It may therefore be tempting to believe that the accident investigation board used the Flight Data Recorder data as confirmation that the speed was normal during the final minutes, since it apparently was around 200 knots.

If one considers that the speed should have stabilised approximately at the peak of the curve and remained completely steady thereafter, it becomes easier to see that the accident investigation board's premise regarding cruise speed cannot be correct. A stepwise reduction over a relatively long period, followed by a speed with variations large enough to produce deflections on the airspeed indicator, is not consistent with normal cruise speed.

Speed Data from the Flight Data Recorder

The only known speed that can be used to calibrate the speed from the Flight Data Recorder (FDR) is the take-off speed. The FDR recorded when the aircraft began to climb, and this point is used to define where FDR time starts. The take-off speed is pre-calculated based on the total weight of the aircraft.

The Flight Data Recorder recorded approximately 130 knots at the moment of take-off, which is 10–15 knots higher than the expected speed of 110–115 knots.

This provides an indication that the indicated airspeed recorded by the Flight Data Recorder is higher than what was shown on the airspeed indicators in the cockpit. According to the specification for the Fairchild Flight Data Recorder, the accuracy for airspeed is specified as ±10 knots. (The Accident Report, 1993, p. 35)

Expected Speed

From the VikingWings videos, one can see the take-off speed (VR) for 53,000 pounds and 50,000 pounds respectively. With 20 degrees of flaps, the wing generates more lift than with 15 degrees, which results in a slightly lower take-off speed. The heavier the aircraft, the higher the take-off speed required, as more lift is needed to compensate for the weight.

Take-off speed (rotation speed) for the Convair CV-580 with 15 and 20 degrees of flaps, based on speed reference cards in the VikingWings videos.

Weight (LBS/pund)	15° flaps	20° flaps
50.000	110	106
53.000	112	109

In the weight and balance sheet for LN-PAA, a total weight of 24,768.7 kilograms was calculated. (The Accident Report, 1993, p. 28)

This corresponds to 54,606 pounds, and would likely have resulted in a take-off speed a few knots higher than for 53,000 pounds.

From the take-off speed diagram for the military version of the aircraft, one can see that 17° flaps would have required a take-off speed of 113 knots.

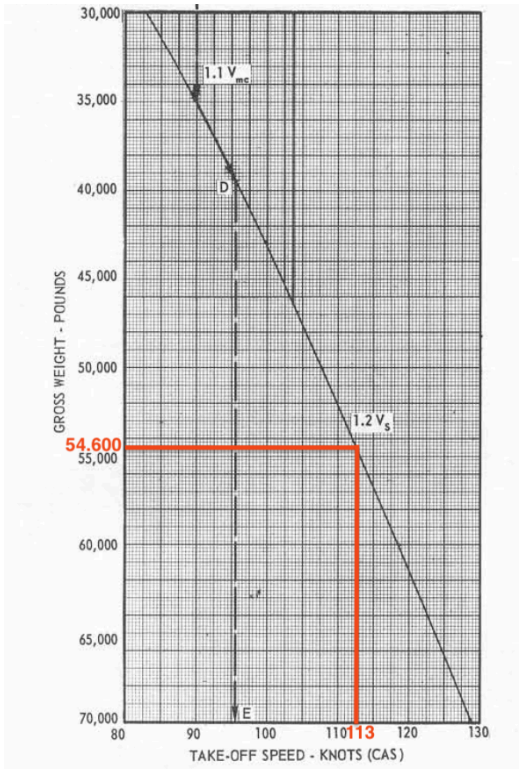


Figure C-3. Takeoff Speed — 17° Flap

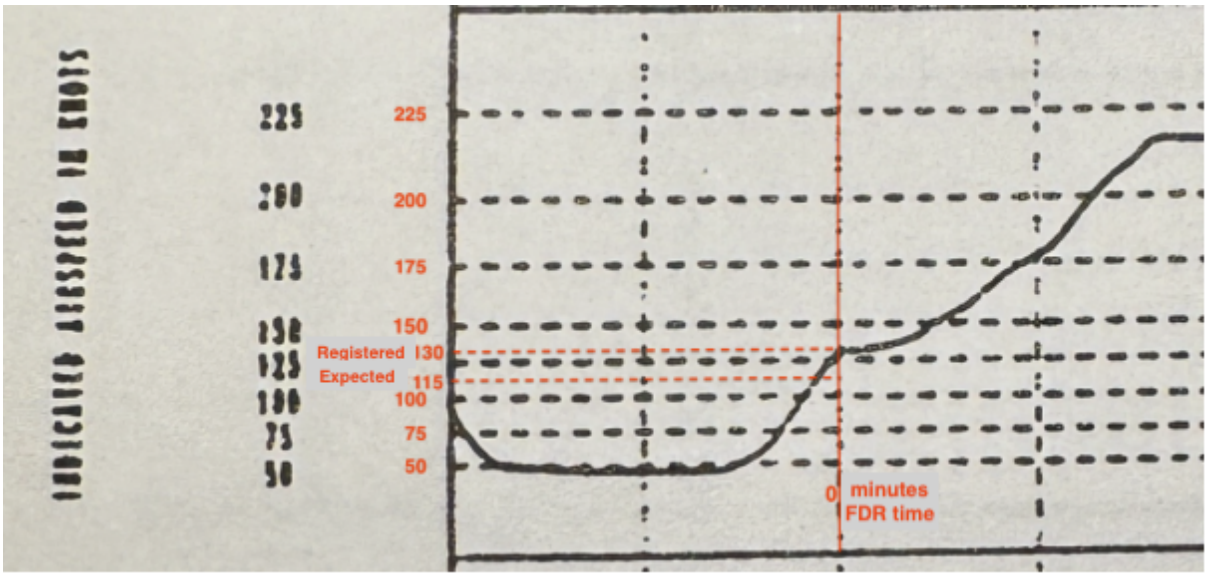
(Handbook YC-131C, 1955, p. 128)

(VikingWings Part 1, 2020, time 58:17) The image shows the speed reference card for 53,000 pounds.

(VikingWings Part 1, 2020, time 1:21:01) The image shows the speed reference card for 50,000 pounds.

Image of the reference card from LN-PAA, taken on the return trip from Canada in the summer of 1989.

Recorded Speed



The image shows the first four minutes of speed data recorded by the Flight Data Recorder (FDR). At the moment of take-off (0 minutes FDR time), the expected speed was approximately 115 knots, while the recorded speed appears to be approximately 130 knots.

Missing Calibration Profile for the Flight Data Recorder

The accident investigation board commissioned a report from Accident Investigation & Research (AIR), which includes, among other things, a detailed analysis of the Flight Data Recorder. In this report, the following is stated about the calibration profile:

"The Recorder's actual calibration template was not available for the A.I.R. analysis." (Accident Investigation & Research, 1992, p. 43)

By using a standard profile instead of the calibration profile for the specific Flight Data Recorder, an uncertainty arises in the values that were read. This uncertainty is not discussed in the accident investigation board's report.

The altitude data in the Flight Data Recorder is also not correct. Despite the pilots being assigned 22,000 feet as their altitude, and the aircraft's transponder recording an altitude of 21,900 feet (according to radar data), the reading from the Flight Data Recorder shows 22,500 feet. The aircraft's altimeters, autopilot, transponder, and Flight Data Recorder use the same pitot-static system to record pressure altitude, and there should therefore have been consistent altitude readings between all these components.

The Airspeed of LN-PAA

In order to establish what normal cruise speed was according to the Flight Data Recorder, it is necessary to compare with readings from other flights. In the AIR report, there is a table based on data from multiple flights, where cruise altitude is specified. These data show that the average speed was 212 knots when the aircraft was at cruise altitude (above 20,000

feet). The difference between 200 and 212 knots represents approximately 12% of the kinetic energy, and is in other words significant.

TABLE 6:- PARTNAIR CONVAIR 580, LN-PAA:-

FDR RECORDED ALTITUDE DOUBLE TRACE EVENT TIMING

FLIGHT # SINCE OVERHAUL	SEGMENT OF FLIGHT WITH DOUBLE TRACE (Minutes)			MAGNITUDE OF VIBRATION (Altitude parameter feet)		
	CLIMB	CRUISE	DESCENT	CLIMB	CRUISE	DESCENT
2	4.50	8.27	14.62	77 typical	77 typical	77 typical
10		14.81			55 to 66	
11	4.45	33.44	13.00	44 typical	44 typical	44 typical
13		52.36	4.24		55 to 110	55 typical
14		52.89			55 to 88	
15	1.48	38.02		44 typical	44 typical	
16	11.10	45.84	16.77	55 to 66	66 to 77	55 typical
18		19.57	1.67		55 to 66	55 typical
20	8.85	31.20		44 to 55	66 to 99	
22	14.72	25.90		55 to 77	66 to 77	
24	13.55	150.90		66 typical	66 typical	
25		43.14			44 to 66	
26	5.10	32.63	5.80	55 typical	55 to 88	55 typical
28	3.13	49.63		44 typical	66 typical	
31		1.92			55 typical	
33	21.19	13.16		77 typical	88 typical	

FLIGHT # SINCE OVERHAUL	SPEED RANGE DURING DOUBLE TRACE (Knots IAS)			ALTITUDE RANGE DURING DOUBLE TRACE (Feet MSL)	
	Vinitial	Vcruise	Vdescent	(Cruise Alt)	(Descent Alt)
* 2A *	157	213	164	22,228	9,845
* 2B *	157	213	164	9,845	7,897
10	169	212	207	21,362	21,362
11	184	215	224	20,526	12,956
13	192	212	212	22,684	22,684
14	190	212	211	21,655	21,655
15	183	218	204	20,588	20,588
16	185	219	204	20,614	17,852
18	201	225	203	20,526	19,419
20	179	206	206	22,363	22,363
22	173	206	204	22,658	22,658
24	187	203	203	23,526	23,526
25	172	196	196	22,395	22,395
26	183	211	220	22,658	18,156
28	180	258	255	10,465	10,465
31	173	227	227	19,714	19,714
33	170	215	205	22,500	22,500

* Note:- Test Flight #2 contained sectors of cruise flight at two differing altitudes *

(Accident Investigation & Research, 1992, Table 6)

If one assumes that the Flight Data Recorder recorded 10–15 knots higher indicated airspeed than the actual speed, this means that LN-PAA had 200–205 knots as its highest speed after "top of climb." Thereafter, the speed fell to 185–190 knots for the final minutes of the flight. This is clearly below normal cruise speed for LN-PAA.

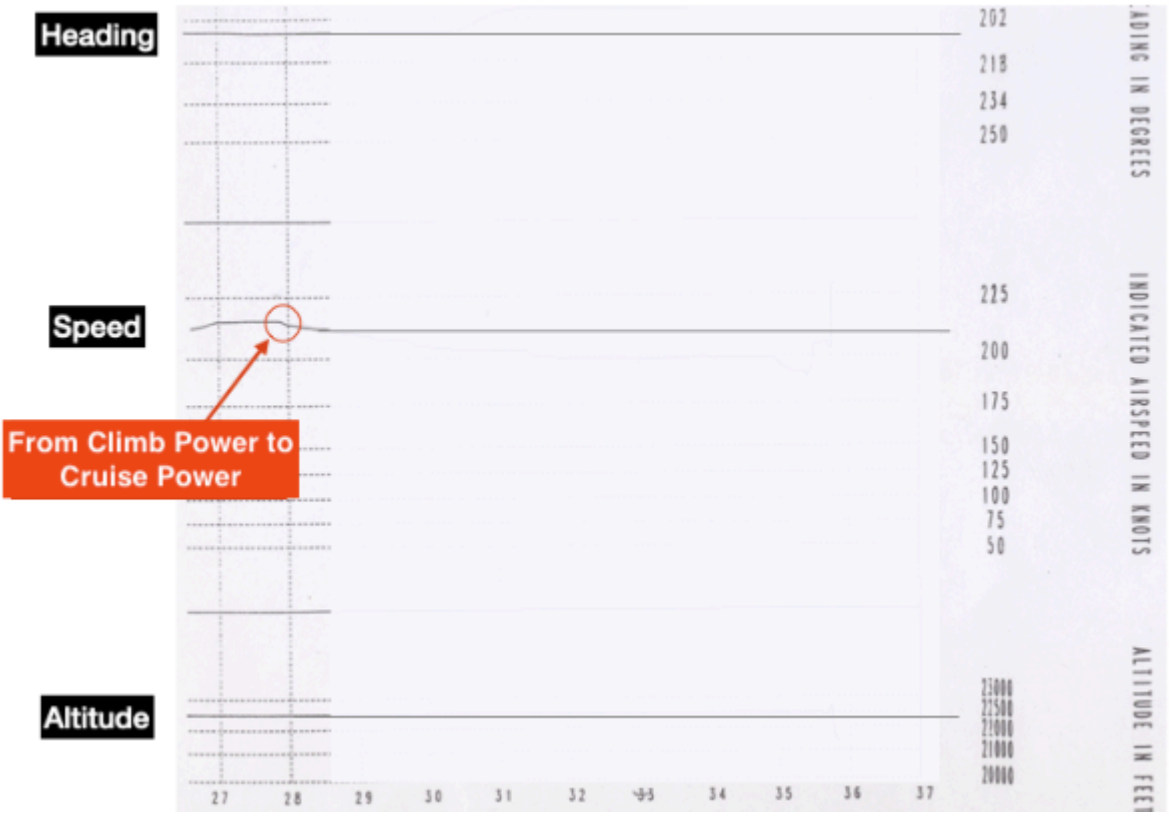
It seems unlikely that the accident investigation board attempted to verify the speeds that LN-PAA should have had during the different phases of the flight, and therefore missed essential information about whether the Flight Data Recorder actually recorded the true indicated airspeed. The precision of ±10 knots has not been examined further beyond its listing as a specification in the FDR documentation.

The low precision for speed in the Flight Data Recorder is significant because the accident investigation board's conclusion is partly built on the premise that the aircraft was maintaining normal cruise speed. Although there is some uncertainty regarding the speed, it is important to emphasise that it is the abnormal speed curve that is the most important indication that the aircraft was not at normal cruise speed. The cruise speed should have stabilised close to the highest speed, not decreased by 15 knots over time as LN-PAA's speed did.

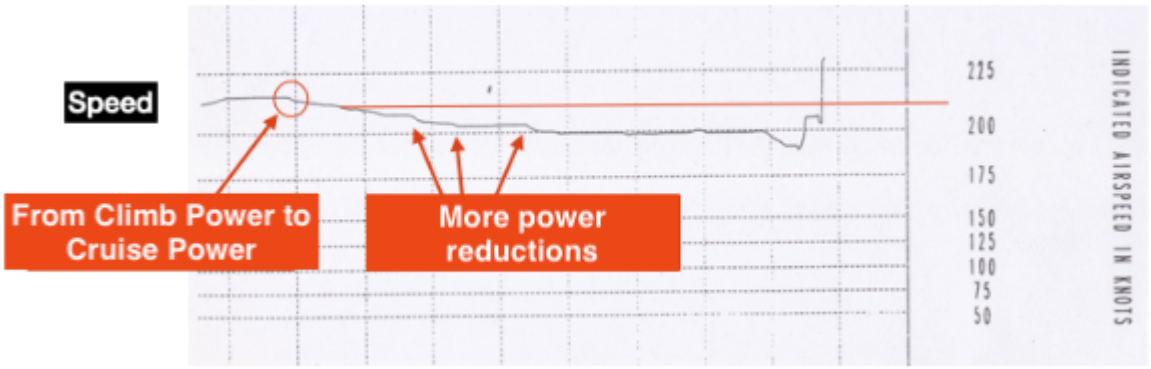
Abnormal Speed

After the aircraft reached its highest speed with climb speed, following level-off (top of climb), the crew set the engines to "cruise power," which resulted in a small reduction in speed of a few knots. After the speed stabilised, it should then have remained constant in the subsequent minutes. According to the speed values in the FDR, the speed should have decreased from 215 knots to approximately 210 knots when cruise power was set. Over the next three minutes, the speed decreases to approximately 200 knots. The actual speed, taking into account the correction for FDR misreading, was lower. If we assume a 15-knot correction of the speed, this would mean that after cruise power was set, the aircraft had an actual indicated airspeed of 195 knots. Although this may sound like little, a reduction of 10 knots would be significant considering that energy increases with the square of speed, and the same applies to drag. 10 knots at these speeds means a 10% reduction in engine power, which is significant in this context. $(1 + 10/195)^2 = 1.105$ (10%)

Pilots operate in accordance with the company's Standard Operating Procedures (SOP). Given that the costs of the aircraft are linked to the time it is airborne, it is standard practice to fly this aircraft type at maximum permitted continuous engine power, provided there are no other factors that would require a reduction in engine power. In any case, it is not normal to reduce engine power by 10% shortly after normal cruise speed has been achieved, given that nothing unusual had occurred.



FDR recording of heading, speed, and altitude as it would have been in a normal situation.



FDR recording of abnormal speed reductions.

Turbine Inlet Temperature (TIT) Indicator

The TIT indicator shows the temperature of the exhaust gas after the combustion chamber, on its way into the turbine.

In the Convair 580 handbook, the maximum permitted performance values for the engines are specified in °C TIT. It is worth noting that the maximum permitted temperature for "cruise power" is 847 °C. If these limits are exceeded, the engines may be damaged.

«Maximum Continuous: 932° Climb: 895° Cruise: 847°» (Pilot's Handbook Convair 580, 1977, 2-6)

«maximum cruise power of 847°» (Pilot's Handbook Convair 580, 1977, 4-1)

The accident investigation board examined both the analogue and digital components of the TIT instruments. The findings indicated that TIT showed higher values than the maximum permitted temperature of 847 °C, yet the accident investigation board nevertheless concluded that this was a normal temperature for cruise speed.

«Turbine Inlet Temperature (TIT) Indicators from both engines were recovered and examined. The indicators were of electromechanical type, with an approximately 2-metre-long magnetic tape that is positioned in accordance with the temperature indication. The tape is transferred alternately between two spools and remains in the position it held when the power supply to the instrument was cut off. … There was no visible mechanical damage that could cause deviation in the gauge reading. Digital reading gave 853 °C, analogue 850 °C. Of the servo-potentiometer tape, 62 cm was on the drive side and 126 cm on the opposite side. Comparative tests with an undamaged gauge of the same type showed that the distribution of tape between the two spools in the ratio 61/126 corresponded to an indication of 850 °C. This is normal temperature for engine setting at cruise speed." (The Accident Report, 1993, p. 50)

Pilots fine-tune engine settings based on TIT to remain as close to the maximum permitted performance as possible. When the examinations show a 3–6 °C deviation from 847 °C, it is natural to discuss what the cause of this deviation may be. One possible explanation is that the crew had reduced engine power but had not completed the fine-tuning. Another explanation may be that all significant speed changes throughout the sequence of events were caused by changes in engine settings, and that the crew set the throttle levers back to approximate "cruise power" before the power failure occurred. When the temperatures that the accident investigation board read from the instruments do not match normal values for "cruise power," this should have been discussed further—rather than making the erroneous claim that 850 °C is "normal temperature for engine setting at cruise speed."

Navigation

Prior to a flight, a navigation plan is prepared and submitted to the air traffic service. The plan serves as the basis for the route the aircraft is to follow, but changes can be made en route. Air traffic controllers may need to instruct pilots to alter heading and altitude for traffic management purposes, and pilots may request changes to heading and/or altitude if, for example, there is a need to fly around adverse weather.

When a passenger aircraft apparently deviates from its course shortly before an accident, there is reason to examine this deviation more closely. A change in heading should be attributable to one of the following causes:

- The navigation plan
- Instruction from air traffic control
- An approved request from the pilot
- Inattention
- Emergency

The navigation plan for LN-PAA called for no heading change when the first turn began. No instructions had been issued by the air traffic controller, and the pilots had not requested a change of heading. A pilot who discovers that the aircraft has drifted off course will correct this immediately, but no such correction was made by the crew of LN-PAA. Three left turns were made before the aircraft crashed, with no indication of correction.

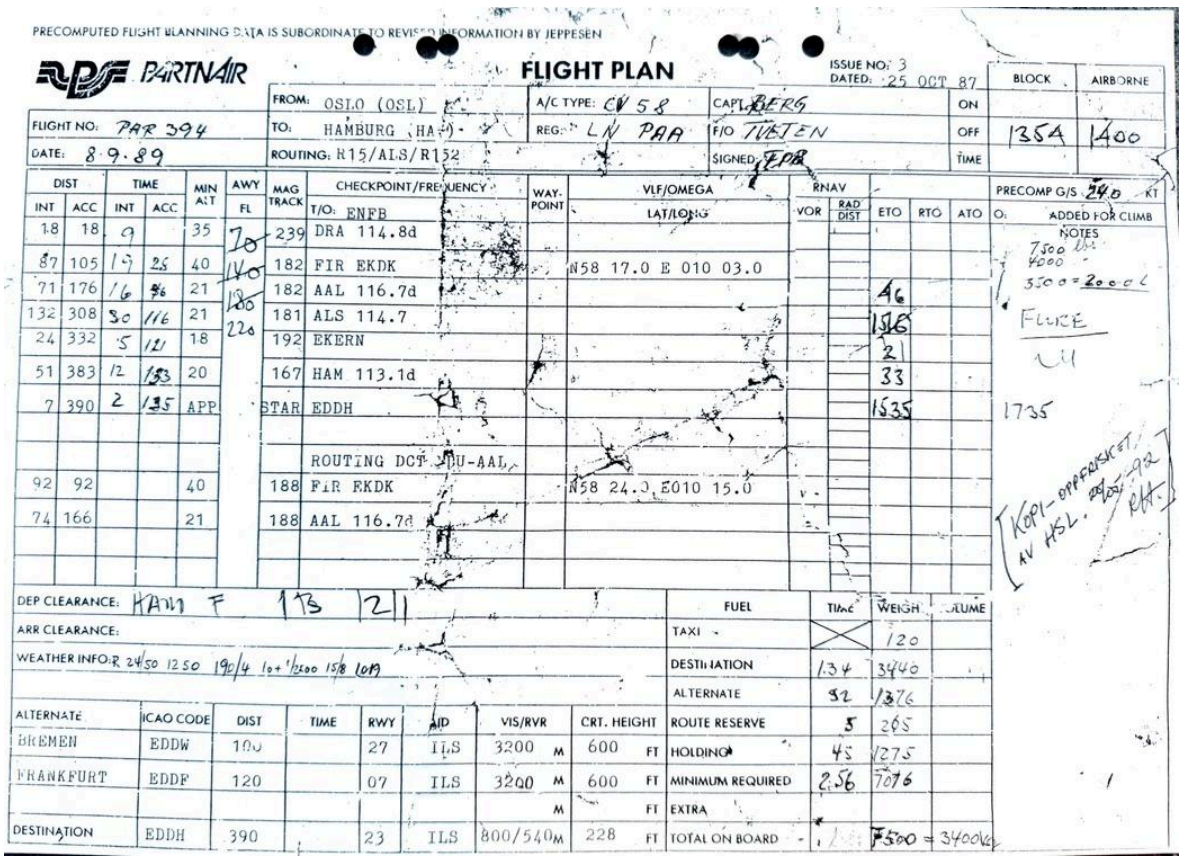
When it is not possible to understand the cause of LN-PAA's turns, or to see any indication that the crew attempted to correct the heading deviation, the accident investigation board should have regarded this as an indicator that the situation was outside the normal.

Background

Commercial flights are conducted in accordance with Instrument Flight Rules (IFR). This is a comprehensive regulatory framework in which both pilots and air traffic controllers have clearly defined responsibilities and tasks. In brief, the pilot is responsible for the aircraft and navigation, while the air traffic service is responsible for maintaining separation between aircraft and managing air traffic. An air traffic controller provides both information and instructions to pilots. If a pilot wishes to change heading or altitude, the controller must issue a clearance first. Normally, a controller will attempt to accommodate the pilot's request, provided it does not compromise safety or create problems for others.

The navigation plan for a flight is submitted to the air traffic service by the pilot or the airline. In this way, all controllers along the route receive information about the destination and the route the aircraft will follow. In modern aircraft, the entire route can be programmed into a Flight Management System (FMS), allowing the autopilot to fly the route primarily using GPS. In older aircraft, such as the Convair CV-580, there are no equivalent automation systems, which means the pilots must do more of the work manually.

An autopilot is not necessary for flying, but it is a very effective tool for reducing the pilot's workload. Maintaining correct heading and altitude requires significant attention, especially in turbulent air. When a pilot is "hand-flying" the aircraft, they will have less capacity for other tasks than when the autopilot is engaged.



PRECOMPUTED FLIGHT PLANNING DATA IS SUBORDINATE TO REVISED INFORMATION BY JEPPESEN

PARTNAIR — FLIGHT PLAN — ISSUE NO: 3 DATED: 25 OCT 87

FLIGHT NO: PAR 394 — DATE: 8.9.89

FROM: OSLO (OSL) — TO: HAMBURG (HAM) — ROUTING: R15/AL3/R152

A/C TYPE: CV 580 — REG: LN PAA — CAPT: BERG — F/O: TVETEN — SIGNED: FPB

	BLOCK	AIRBORNE
ON		
OFF	1354	1400
TIME		

DIST INT	DIST ACC	TIME INT	TIME ACC	MIN ALT	AWY FL	MAG TRACK	CHECKPOINT/FREQUENCY T/O: ENFB	WAY-POINT	VLF/OMEGA LAT/LONG	RNAV VOR	RNAV RAD DIST	ETO	RTO	ATO
18	18	9		35	70	239	DRA 114.8d							
87	105	19	25	40	140	182	FIR EKDK		N58 17.0 E 010 03.0					
71	176	16	46	21	180	182	AAL 116.7d					46		
132	308	30	116	21	220	181	ALS 114.7					1516		
24	332	5	121	18		192	EKERN					21		
51	383	12	133	20		167	HAM 113.1d					33		
7	390	2	135	APP		STAR	EDDH					1535		
							ROUTING DCT JU-AAL							
92	92			40		188	FIR EKDK		N58 24.0 E010 15.0					
74	166			21		188	AAL 116.7d							

PRECOMP G/S: 240 KT — O: ADDED FOR CLIMB

NOTES: 7500 lbs 4000 — 3500 = 2000 L — FLUKE — 1735 — KOPI-OPPDOSKET, AV HSL. 25/07-92 RH.

DEP CLEARANCE: HAM F 13 21

ARR CLEARANCE:

WEATHER INFO: R 24/50 1250 19c/4 10+ 1/2500 15/8 1019

FUEL	TIME	WEIGHT	VOLUME
TAXI		120	
DESTINATION	1.34	3440	
ALTERNATE	32	1376	
ROUTE RESERVE	5	205	
HOLDING	45	1275	
MINIMUM REQUIRED	2.56	7076	
EXTRA			
TOTAL ON BOARD		7500 = 3400kg	

ALTERNATE	ICAO CODE	DIST	TIME	RWY	AID	VIS/RVR	CRT. HEIGHT
BREMEN	EDDW	100		27	ILS	3200 M	600 FT
FRANKFURT	EDDF	120		07	ILS	3200 M	600 FT
						M	FT
DESTINATION	EDDH	390		23	ILS	800/540M	228 FT

Partnair 394, Navigation Plan, signed by Captain Finn Petter Berg.

Heading

The route went from Fornebu via Drammen VOR (radio navigation beacon), Aalborg VOR, and further southward towards Hamburg. The radar track shows that the aircraft followed the coastline southward while climbing towards cruise altitude.

The navigation plan recovered after the accident shows that Finn Petter Berg was the captain (CAPT) and Knut Tveten was the first officer (F/O). The form is signed by Berg (FPB). In the accident report, the accident investigation board assumed that Tveten was the captain, despite this navigation plan documenting the opposite. The captain normally sits in the left seat, and the error may be significant for interpreting who performed which actions in the cockpit. It is worth noting that the accident investigation board had access to this navigation plan, yet failed to identify the role assignment.

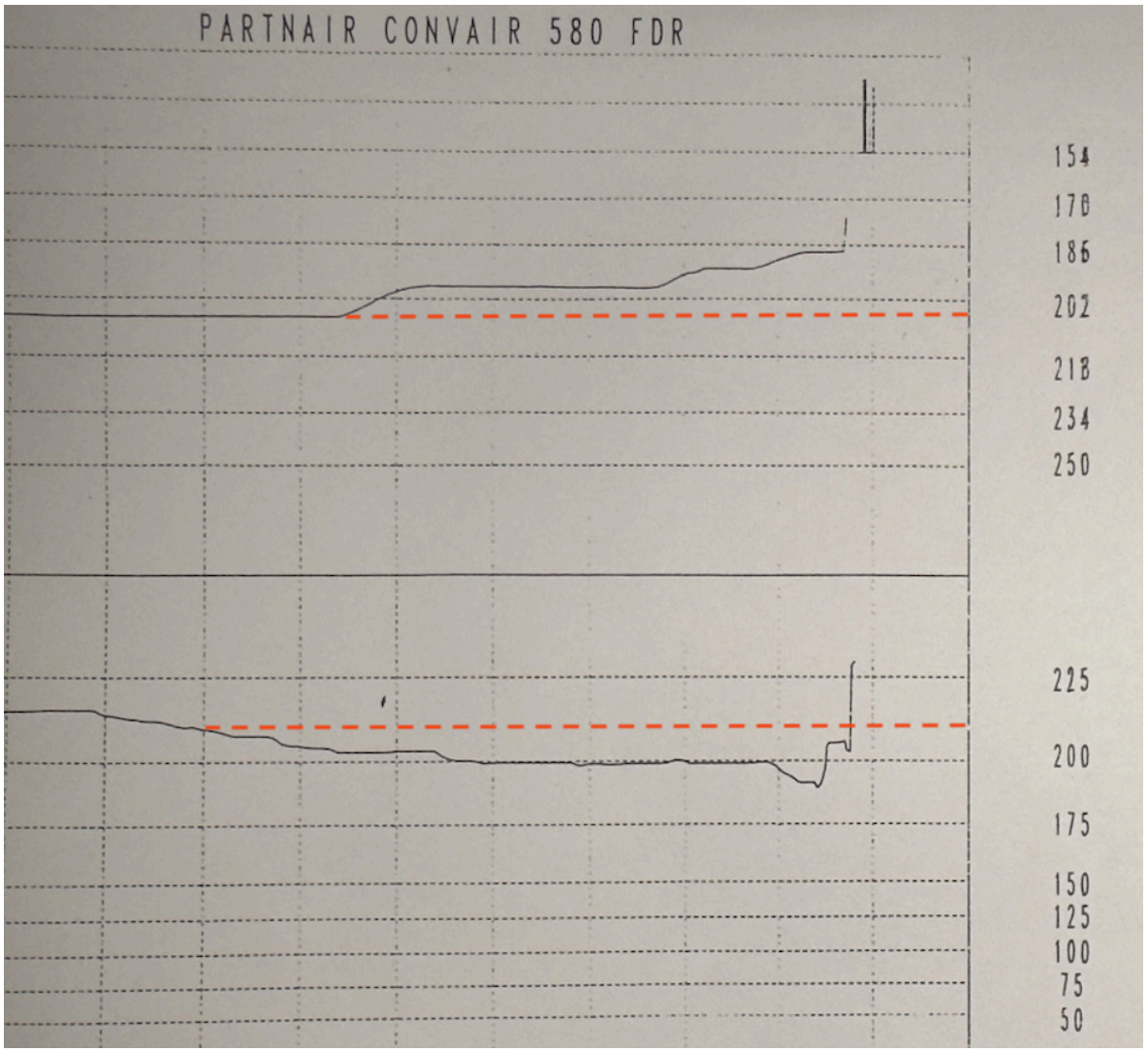
«Between 20:50 and 30:30 FDR time, the heading was approximately 208° M.» (The Accident Report, 1993, p. 39)

Most pilots choose to use the autopilot during this phase of the flight, and it is reasonable to assume that LN-PAA was flying with autopilot engaged.

Navigation Premises

The last recording of heading, altitude, and speed was made at approximately 35:45 FDR time, when a power failure occurred in the aircraft.

«At 30:30 FDR time, a heading change of 8.5° to the left was recorded. At 33:40 FDR time, the heading was again changed 5.5° to the left. One minute later, there was a further 5.5° heading change to the left.» (The Accident Report, 1993, p. 39)



Heading (top) and speed (bottom), with red dashed line indicating expected/normal situation.

It is worth noting that these "turns" cannot really be characterised as turns, but rather as gradual heading deviations. An autopilot normally turns at a standard rate of 3° per second. The first heading change of 8.5° occurred over approximately 40 seconds, which corresponds to approximately 0.21° per second—less than one-fourteenth of a normal

autopilot turn. Had the autopilot been engaged and commanded a heading change, the turn would have been completed in under 3 seconds, not 40. The gradual heading deviation is therefore a strong indication that the autopilot was not engaged when the aircraft began to drift off course.

«The change of direction to the left that occurred at 34:00 FDR time was, in isolation, not alarming, but it appears unmotivated after a period of stable flight parameters. It is, moreover, coincident with a speed change that also appears unmotivated. During the period immediately before 34 minutes after departure (FDR time), where the recorded flight parameters show very stable values, the commission believes the autopilot was engaged. Judging by the recorded values, altitude and heading had been selected as governing parameters.» (The Accident Report, 1993, p. 102)

LN-PAA received no request from air traffic control to change heading, and from a navigational standpoint it is difficult to understand why the crew would make heading changes that neither brought the aircraft back to the planned route nor towards Aalborg VOR. It is difficult to understand why the report does not question these heading changes, when there is apparently no reason for the crew to have chosen to alter the heading. When we additionally know that the aircraft ultimately "rolled" to the left, it seems probable that all three turns were unintentional.

The premise that the heading changes were not alarming because «the recorded flight parameters show very stable values» seems illogical. One cannot conclude that a turn is normal because it has been a while since the aircraft last turned.

Other data must be analysed to assess whether the heading changes were normal or anomalous. The heading changes do not appear to be rooted in navigational decisions. Data from the Flight Data Recorder for speed indicates that the aircraft was not at normal, stable cruise speed. In practice, this means that the only remaining parameter that can be interpreted as normal is the altitude. Altitude alone is not a sufficient basis for concluding that a turn is "not alarming."

«At approximately 35 min FDR time, a new change of direction to the left occurred, coinciding with a marked loss of speed.» (The Accident Report, 1993, p. 102)

«During the period 34 to 36 min FDR time, the vibrations assumed catastrophic dimensions and began to affect the aircraft's directional stability. The oscillations were no longer damped by the structure's rigidity; they became divergent, i.e. the displacement (amplitude) increased with each cycle. … The crew probably knew at this point that something was wrong in the tail, and activated the fire extinguisher for the APU. This caused the fuel supply to the APU to be shut off, but had no influence on the subsequent course of events.» (The Accident Report, 1993, pp. 106–107)

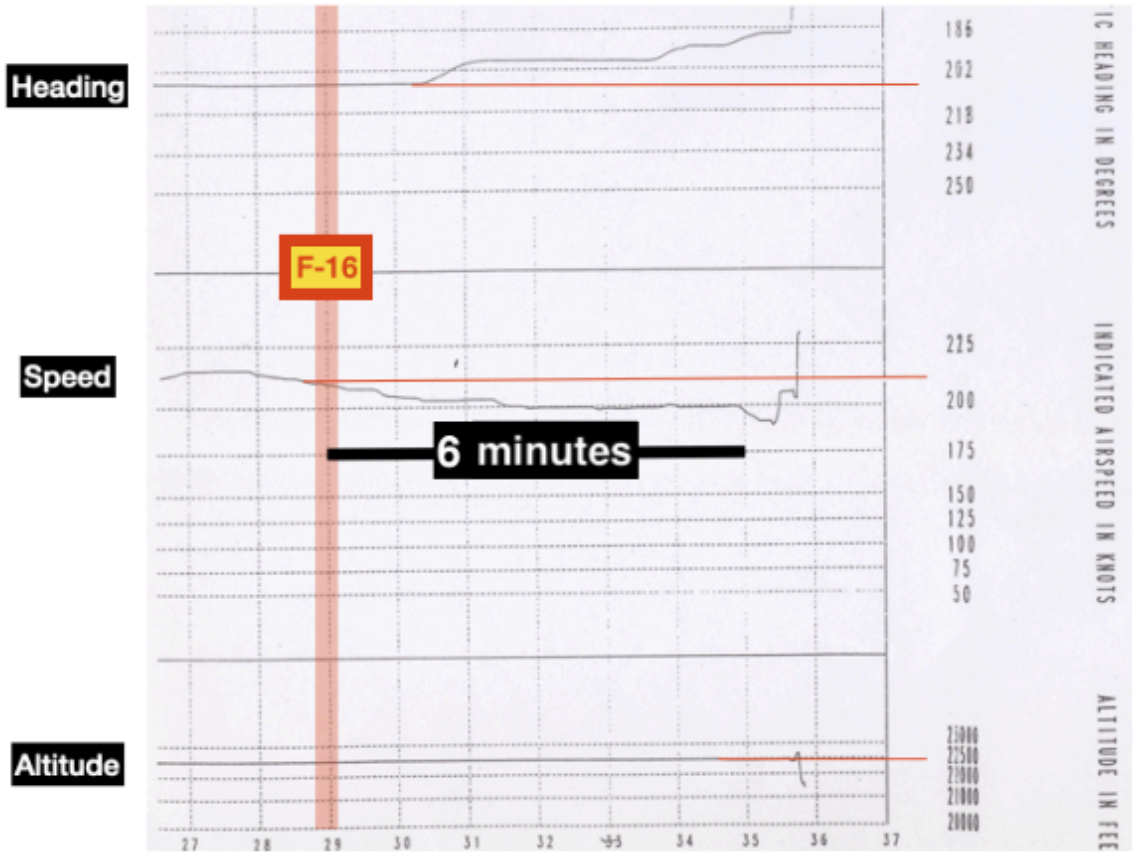
The accident investigation board appears to categorise the first turn as normal, the second as "not alarming, but unmotivated," and that it was only in connection with the final turn to the left that the autopilot was disengaged and the crew knew they had problems with the aircraft.

The pilots were trained to continuously monitor the aircraft's instruments and would in all probability have quickly detected deviations in heading or speed. The accident investigation board's conclusion appears to be built on a hypothesis that the pilots of LN-PAA detected neither deviations in the aircraft's speed nor heading—something that seems highly improbable given that the crew consisted of experienced pilots.

Flight Data Recorder

The accident investigation board stated in its report that the F-16 met the Partnair aircraft 9 minutes before the accident, but this is not correct. Nine minutes after the pass, the Partnair aircraft hit the water, but it was quite evident that the situation was critical and that the accident sequence began approximately 6 minutes after the pass. The deviations in expected speed coincide with the pass, which makes it highly probable that there is causality between the F-16 pass and what subsequently occurred.

«The Norwegian fighter jet, which met LN-PAA approximately 9 minutes before the accident, did not participate in the NATO exercise.» (The Accident Report, 1993, 1.17.5.3, p. 84)

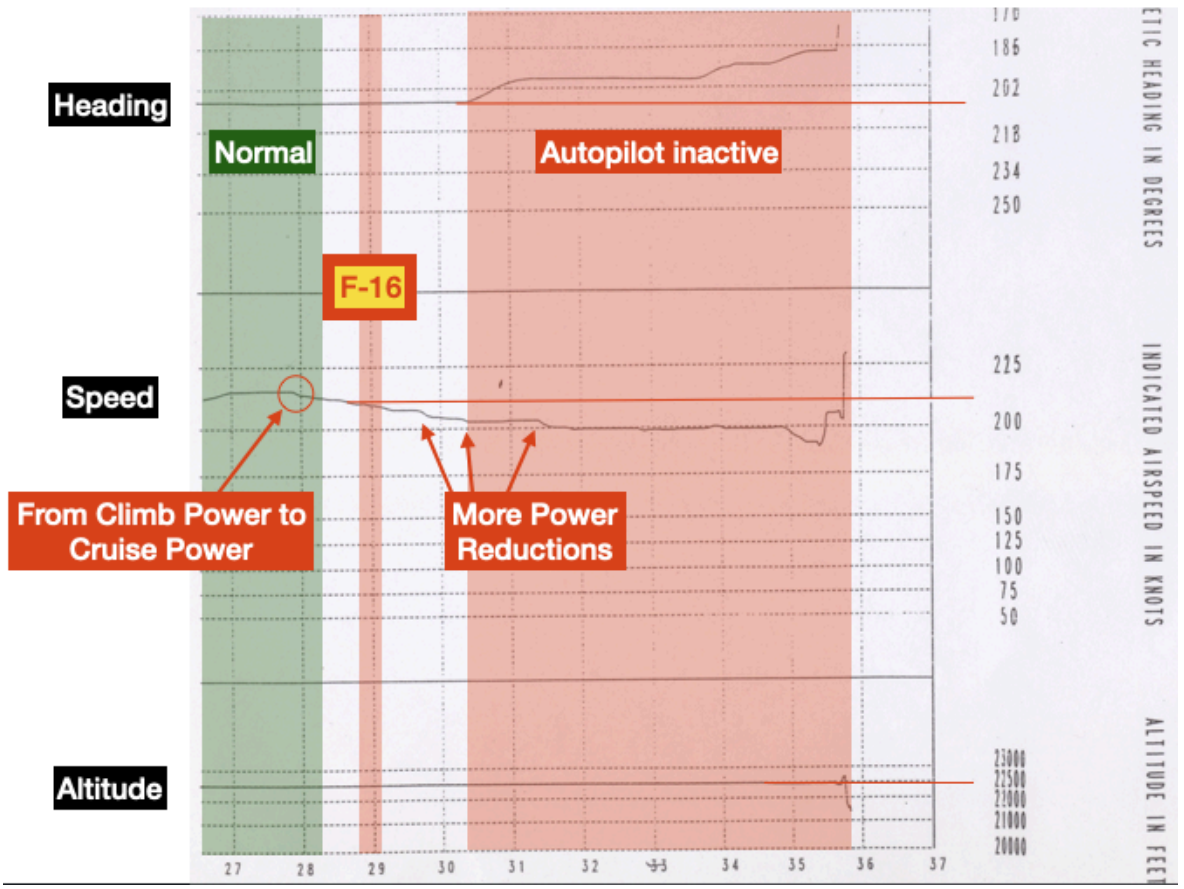


6 minutes from the F-16 pass until the situation becomes catastrophic.

Situational Analysis

Everything up until the F-16 pass appears, according to the FDR, to be normal. It is only when the F-16 passes that the deviations begin. It starts with stepwise speed reductions, as well as a heading deviation, which cannot have been carried out by the autopilot. There are speed reductions both before and after the first heading deviation.

This is of significant importance, as it coincides with a troubleshooting process where one change is made at a time—reduction in speed and deactivation of autopilot—and the effect is observed. This suggests a systematic troubleshooting process, not coincidence.



FDR analysis of emergency situation.

Hypothesis Regarding the Sequence of Events

The pass by the F-16 happens so fast, and directly from ahead, that the crew of the Partnair aircraft in practice had no opportunity to see the F-16. They would certainly have heard the supersonic shock wave striking the fuselage, and noticed that something happened to the aircraft. Physical damage to the rudder's trim tab could have produced vibrations and a tendency towards left yaw, meaning the aircraft rotates slightly to the left. The autopilot would have immediately corrected the heading deviation using the ailerons, but the pilots would have noticed if the aircraft was flying uncoordinated (at a sideslip), in addition to the autopilot signalling that it was applying corrective input.

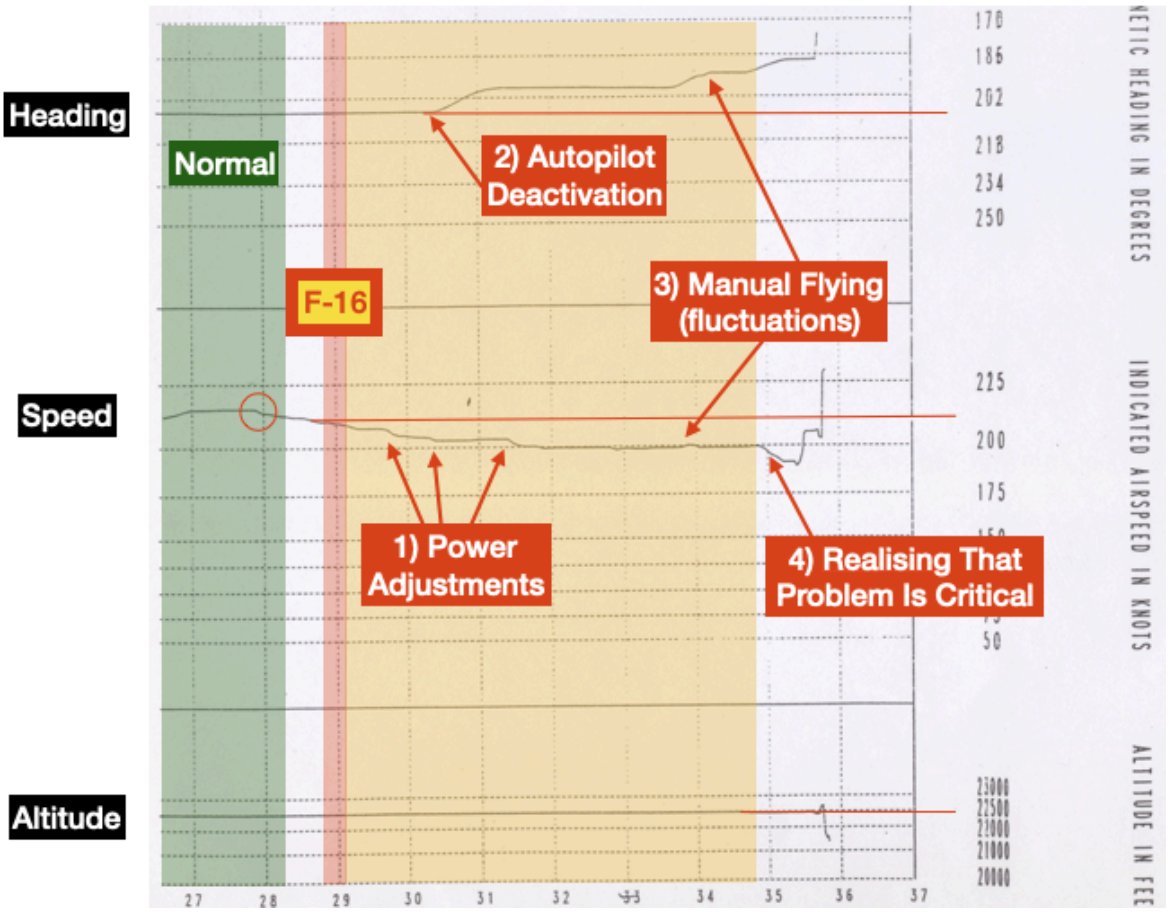
There is no doubt that the crew detected that something was wrong, but they cannot have understood what kind of damage had occurred or how serious it was. Having climbed at high engine power and then levelled off and adjusted the engines to cruise power, it is not logical that structural damage to the aircraft would suddenly occur. A far more probable scenario would be if a bang, vibrations, and yaw were the result of an engine-related problem. Had the pilots feared structural damage to the aircraft, they would have reacted entirely differently. They would have immediately reduced speed, initiated an "emergency descent," and notified air traffic control.

EMERGENCY DESCENT (Low Airspeed, Max. Drag)

CLOSE THROTTLES, REDUCE SPEED TO 173 KTS.
GEAR DOWN
FULL FLAPS AS SPEED PERMITS
DESCEND AT 148 KTS. MAX.

Checklist for "Emergency Descent (Low Airspeed, Max Drag)."

Towards the end of the sequence of events, at 35 minutes FDR time, a more pronounced reduction in speed is observed before it rises again. A possible interpretation of this is that it was only then that the pilots realised how serious the situation was. Something causes them to increase engine power significantly again, as within a few seconds the speed increases by approximately 15 knots. It appears that this speed increase triggered the actual accident sequence, as the aircraft rolled and entered a dive a few seconds later. The crew never managed to regain control of the aircraft. It dived towards the sea, speed increased, and eventually flutter developed in the control surfaces until they ultimately disintegrated. This sealed the fate of Partnair 394.



Flight Data Recorder analysis, where the yellow area indicates what the accident investigation board interpreted as normal.

The Accident Investigation Board's Interpretation of the Flight Data Recorder

«The change of direction to the left that occurred at 34:00 FDR time was, in isolation, not alarming, but it appears unmotivated after a period of stable flight parameters. It is, moreover, coincident with a speed change that also appears unmotivated. During the period immediately before 34 minutes after departure (FDR time), where the recorded flight parameters show very stable values, the commission believes the autopilot was engaged. Judging by the recorded values, altitude and heading had been selected as governing parameters.

The variations in altitude recorded during this period are within normal variations. In conjunction with radar data, the altitude recordings during this period contribute to aligning the various time measurements that have been made.

At approximately 35 min FDR time, a new change of direction to the left occurred, coinciding with a marked loss of speed. The indicated speed increase that began at approximately 35:45 FDR time is of a magnitude that is not real. This means that the measurement system for the FDR was at this point affected by error sources that are not present during normal operation. A relevant error source is abnormal flow conditions at the aircraft's intakes for static air pressure (static ports). Uncoordinated yaw and rapid pitch changes will produce such conditions, and may result in erroneous indications of speed and altitude.

Immediately before the FDR stopped, the heading parameter first showed approximately 3 seconds of turn to the right, then transitioned directly into a change of heading to the left in the order of 500° per minute. To understand the significance of this recording, the commission has relied on information from the manufacturer of this type of FDR. In four previous accident cases where corresponding types of recordings have occurred, there were either eyewitnesses or technical findings that confirmed the aircraft's movements. The eyewitnesses reported that the aircraft rolled at the time the FDR made the recordings in question.» (The Accident Report, 1993, p. 102)

It is very difficult to understand how the accident investigation board analyses the Flight Data Recorder in this manner. Even if they did not know that the speed values were misread—despite the fact that a 500-foot error in altitude should have provided an indication that there could also be errors in speed—they should in any case have seen that the speed graph itself did not look right.

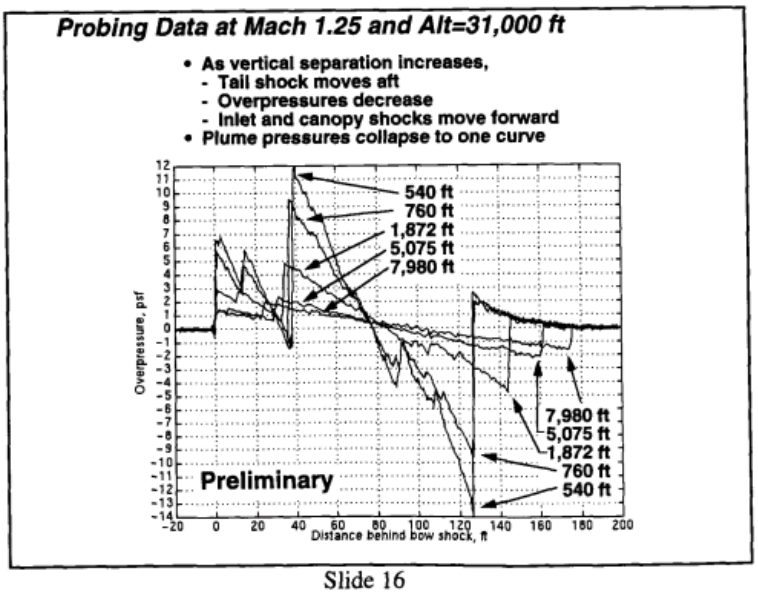
The speed was normal up until just after cruise power was set, but then it began to deviate. There is nothing unique about this aircraft type in this regard: it is entirely normal for aircraft that speed decreases slightly after cruise power is set, over the course of a few seconds, and that the speed then becomes approximately constant.

What the Flight Data Recorder shows is that an emergency arose shortly after the pass by the F-16. The accident report gives the impression that it was entirely out of the question that the F-16 could have had anything to do with the matter.

Shock Waves

NASA Experiment

In 1995, NASA published a document describing experiments with shock waves from a supersonic aircraft. They used an SR-71 (Blackbird) as the source of the shock wave, and had an F-16 fly just below (in the same direction) to take measurements of the supersonic shock wave.



Slide 16

«When the F-16XL aircraft probed within 1000 ft of the SR-71 aircraft, its pilot had several indications of crossing the shock waves. These indications include feeling the pressure changes within the cockpit, being slightly jostled by the shock waves, and hearing the SR-71 engines when aft of the tail shock. When probings were conducted at vertical separations greater than about 1000 ft, the pilot was unaware when the shock waves were penetrated.» (NASA, 1995, p. 5)

The measurements show that there is a very large difference in the pressure wave at 540 feet and 1,872 feet of separation respectively. (NASA, 1995, slide 16)

Flygtekniska Försöksanstalten (FFA)

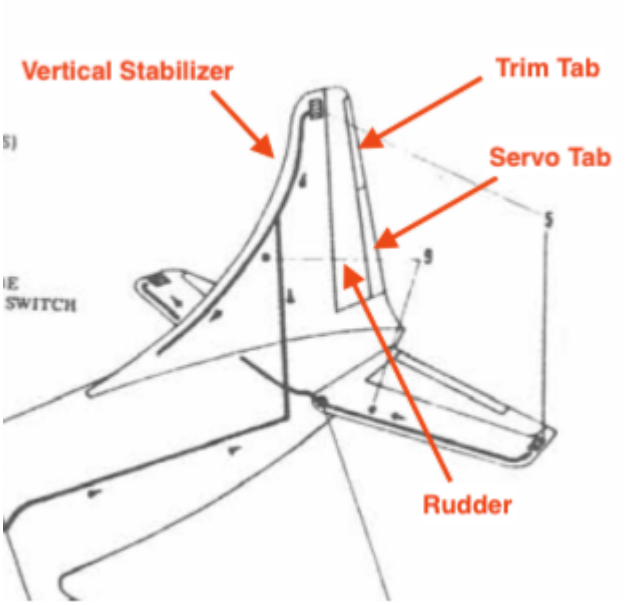
Ingemar A. Lind wrote in his report on the study of this issue concerning a close pass by an F-16 at supersonic speed:

«An experience from the study in Appendix 2 is that the transient load on the elevator due to the shock wave is quite high. For illustration purposes, it can be said to correspond to a sharp blow against the elevator's structure. A rough estimate points to a force of 8,000 N in the typical case.» (Lind, 1999, p. 45)

National Aerospace Laboratory (NLR)

The Ministry of Defence engaged NLR to assess whether a Convair CV-580 could be damaged in connection with a pass at 2,000 feet of separation. In connection with the calculations of whether the vertical fin could be set in motion by the shock wave, the following calculation is described:

«The area of the CV-580's vertical stabiliser is estimated to be equal to 107.48 sq ft (9.99 m²)[1] with which for the peak excitation force is found 2×150×9.99 = 2997 N.» (National Aerospace Laboratory, 2003, p. 27)



What is worth noting is that the entire vertical fin does not need to move for the control surface to be set in motion. The rudder consists of the rudder surface itself, as well as a smaller servo tab and a trim tab. Damage to the servo tab or trim tab can have catastrophic consequences even without the vertical stabiliser itself being damaged.

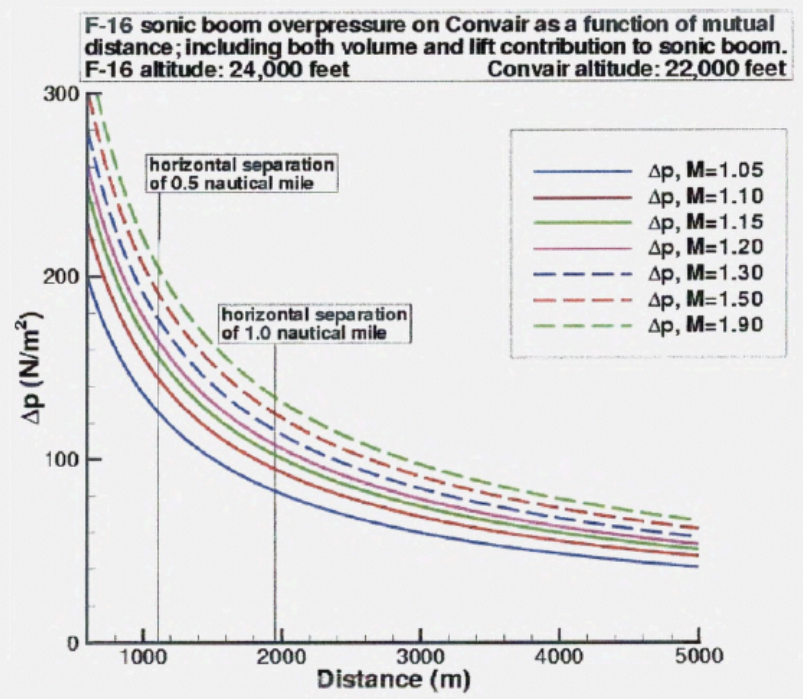
The NLR report takes CAR Part 4b as its starting point for calculating the loads that the various parts of the aircraft are designed to withstand. NLR does not, however, discuss what the individual control surfaces are designed to withstand, and has consequently not focused on the trim tabs either.

«Trimming tabs shall be designed to withstand loads arising from all likely combinations of tab setting, primary control position, and airplane speed, obtainable without exceeding the flight load conditions prescribed for the airplane as whole, when the effect of the tab is being opposed by pilot effort loads up to those specified in §4b.220 (a).» (Civil Air Regulations Part 4b, 1953, p. 14)

Pressure Calculation

The NLR report assumes a pressure of 150 N/m², but this is based on 2,000 feet of vertical separation and a horizontal separation of 0.5 nautical miles.

«Fig. 10 shows that, for the second stipulated Mach number of 1.1 and a horizontal separation of 0.5 nautical miles, the overpressure is in the order of 150 N/m². If Fig. 10, influences of Mach number and mutual distance variations are also shown on the sonic boom overpressure.» (National Aerospace Laboratory, 2003, p. 10)



«Overpressures produced by aircrafts flying supersonic at altitudes of less than 100 feet, creating between 20 and 144 psf (957.6 to 6,894.8 N/m2.) overpressure, have been experienced by humans without injury.» (National Aerospace Laboratory, 2003, p. 9)

The fact that humans have not been injured by a shock wave during a close pass does not mean that the hinges of a trim tab cannot be damaged by a corresponding shock wave. The entire conclusion of the NLR report is based on the premise that the vertical separation was 2,000 feet at the point of passing.

The figure shows graphs based on values that do not follow the inverse-square law. This is likely because a fixed vertical separation of 2,000 feet has been assumed, and the x-axis only shows horizontal distance. At 0 metres of horizontal separation, the pressure change from the shock wave, according to the graph, would be 200 N/m², and the absolute separation would be 2,000 feet.

By applying the inverse-square law, at 100 feet of separation—which is 1/20 of 2,000 feet—the pressure change would be $20^2 = 400$ times greater: 200 N/m² × 400 = 80,000 N/m².

Conclusion

The NLR report focuses on three areas: aerodynamics, structures, and flight safety. The aerodynamic calculations are based on the premise that the vertical separation was 2,000 feet. The assessment of the various structural components is based on a pressure change of 150 N/m². Reference is made to nine close passes between fighter jets and civilian aircraft,

where apparently no damage occurred to the aircraft. It is not clearly stated which of these close passes occurred at supersonic speed.

«As a result of the study in the three research areas as mentioned above, it is concluded by the multi-disciplinary team of NLR experts that the probability of the RNAF F-16 causing any damage to the Convair CV-580 is extremely small and can be excluded.» (National Aerospace Laboratory, 2003, p. 33)

By focusing solely on the breaking strength of the vertical fin, the NLR experts have overlooked the possibility that the trim tab and/or the servo tab were damaged in connection with the close pass. If the close passes referenced in the report were conducted at subsonic speed, this anecdotal evidence will not be relevant to a potential pass at supersonic speed.

If the premise of a vertical separation of 2,000 feet is false, the calculations in the NLR report are incorrect. It is unlikely that NLR would have reached the same conclusion had the starting point been a close pass with only a few hundred feet of separation at supersonic speed.

Near-Accident

Although there are no known accidents caused by a pass by another aircraft without physical contact, there have been many accidents and near-accidents related to problems with aircraft control surfaces. The Canadian accident investigation board investigated an incident involving a King Air where the control mechanism of the aircraft's rudder trim came loose. In this incident, it started with the crew noticing a slight vibration and a shallow turn. This is an example of how even damage to a trim tab can have major consequences for the aircraft.

«After approximately one hour of flight, while in level cruise at 11 500 feet asl, the crew experienced a slight vibration and a shallow uncommanded right turn. The aircraft was returned to level flight, the autopilot was selected off and a cockpit check was completed when another uncommanded but steeper turn to the right developed. The aircraft was once again returned to level flight and, as the vibration was continuing, a decision was made to land in North Bay due to its close proximity. During the descent, at approximately 8 500 feet asl, a severe vibration developed which violently shook the aircraft and rapidly moved the rudder and ailerons causing the hands and feet of the pilot flying to be displaced from the control wheel and rudder pedals. After approximately 30 to 45 seconds, the vibration stopped and control was regained. The descent was then continued at 140 knots, as the aircraft seemed controllable at this speed. However, to maintain coordinated flight, the crew had to hold approximately 2/3 left rudder. The remainder of the descent, approach and landing were uneventful and the aircraft landed safely. No injuries occurred. A maintenance recovery team was dispatched and examined the aircraft. They determined that the hardware connecting the rudder trim actuator push/pull rod to the rudder trim horn was missing. After replacement of the missing hardware and a free play check, the aircraft was ferried to Ottawa. The aircraft was returned to service after a severe turbulence check and non-destructive testing (NDT) of fittings in the empennage and wings.» (Transportation Safety Board of Canada, 1997)

Discussion

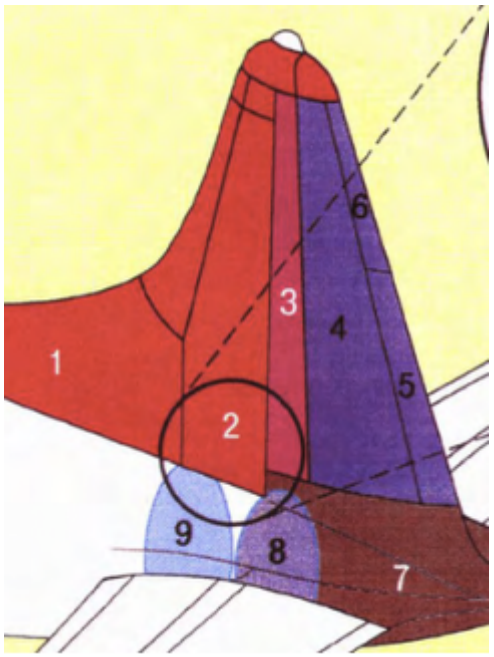
That a fighter jet at supersonic speed should be able to tear apart a passing passenger aircraft seems highly improbable. At a separation of 2,000 feet, the pressure wave from a supersonic pass would likely have limited ability to cause physical damage to an aircraft, although it would be audible inside the opposing aircraft.

After the accident report was published, information has emerged about radio communication between air traffic control and the F-16 pilot, as well as radar data, indicating that the F-16 passed LN-PAA at very close range. If this is the case, it should be reassessed whether a supersonic pass can be excluded as a cause, given that the separation between LN-PAA and the F-16 was much less than 2,000 feet.

In accordance with the inverse-square law, the energy in the shock wave increases dramatically at reduced distance:

Separation	**Factor vs. 2,000 feet**
500 fot	16×
250 fot	64×
125 fot	256×

To illustrate the same principle: standing 10 metres from an explosion, one receives only 1% of the energy compared with standing 1 metre away. Standing 20 metres away, the energy is reduced to 0.25%. For both explosions and supersonic shock waves, it is the change in distance that produces the greatest effect.



(Accident Investigation & Research, 1992, Figure 3)
Flight tab (5) and Trim tab (6)

According to Figure 3 in the accident report, the rudder is composed of the "tail rudder," "flight tab," and "trim tab." The gap between the vertical fin and the rudder is covered by "shroud doors." Together, these components constitute a significant portion of the area of the vertical structure, and are therefore exposed to a shock wave from a supersonic aircraft passing alongside the aircraft. Damage to one or more of the rudder components will alter the aerodynamic characteristics, resulting in the aircraft beginning to turn without input from the crew. At high speed, the tail structure is subjected to large aerodynamic forces. Structural damage would be able to develop and worsen the situation rapidly. In other words, even minor damage to the elevator or rudder can have catastrophic consequences.

The accident investigation board has devoted a large portion of the report to substantiating a hypothesis that the cause of the accident was vibrations in the aircraft's tail, which over time developed to catastrophic levels. This hypothesis is built on several sub-hypotheses with varying degrees of certainty. Up until 34 minutes FDR time, the accident investigation board considers that the pilots perceived the flight as normal, and discusses data from the Flight Data Recorder to a limited extent. The accident investigation board also refrained from speculating about what happened after the Flight Data Recorder ceased to record data. In practice, the accident investigation board has thus only defined the last two minutes of the FDR recording as an indication that something was abnormal.

The accident investigation board devotes approximately 10 pages (98–108) to providing an extremely detailed description of the damage that occurred, based on technical findings, and why the damage occurred. It may appear as though the accident investigation board concluded early on that "counterfeit parts" probably triggered the sequence of events, and subsequently explained all the technical findings in a manner that supports this hypothesis.

That vibrations developed over a long period and became so severe that the aircraft's tail section collapsed, without the crew detecting it, seems extremely improbable. The accident investigation board's hypothesis is that when the crew realised they were about to lose control of the aircraft, events unfolded so rapidly that they did not have time to react by pulling the throttle levers to idle.

«At approximately 35 min FDR time, a new change of direction to the left occurred, coinciding with a marked loss of speed. The indicated speed increase that began at approximately 35:45 FDR time is of a magnitude that is not real.» (The Accident Report, 1993, p. 102)

The FDR data and the description in the report indicate that approximately one minute elapsed from the final turn and the marked speed loss until the crew lost control. This is more than enough time to make changes with the throttle levers. It is entirely possible that the final speed reduction was caused by the crew attempting to reduce speed without it improving the situation, and that they subsequently increased engine power again. By concluding early on that the aircraft was maintaining normal cruise speed and that the engine settings were set to "cruise power," the accident investigation board has precluded any further interpretation of the airspeed as recorded by the Flight Data Recorder.

The pass occurred just under 6 minutes before the final, catastrophic accident sequence began. The report states that the F-16 passed approximately 9 minutes before, but this is not correct.

Despite an F-16 passing close to LN-PAA shortly before the accident sequence began, the accident investigation board has not discussed this further. Without interpreting the speed data from the Flight Data Recorder, it would be difficult to see the correlation between the F-16 pass and the point at which LN-PAA's airspeed dropped below normal cruise speed.

A hypothesis that damage occurred to the rudder during the F-16 pass, and that this damage developed to a catastrophic level over the course of 6 minutes of flight, fits better with radar and FDR data than the accident investigation board's hypothesis that vibrations caused by counterfeit parts triggered the accident.

APU

The aircraft's Auxiliary Power Unit (APU) has received much of the blame for the accident, as it is located in the tail and was in operation when the accident occurred. An APU is a turbine engine that drives an alternating current generator. When the fuel supply is shut off, the APU stops within a few seconds.

The accident investigation board's conclusion is built on the premise that the use of the APU on this flight was a decisive factor. It is not necessarily important to know exactly when the APU was stopped, but it is so central to the accident investigation board's causal hypothesis that there should be no remaining open questions surrounding it. There are contradictory findings regarding when in the sequence of events the APU was stopped, and the accident investigation board itself expresses doubt as to whether the APU could have been the initial cause of the damage to the tail section.

«During normal operation, the APU turbine rotates at over 40,000 RPM. If the friction led to vibration, it would have been high-frequency. It therefore seems improbable that the APU, with its defective forward mount, would be the initial cause of the large alternating loads to which the rest of the tail has been subjected.» (The Accident Report, 1993, p. 99)

«The forces to which the control surfaces were subjected overloaded the linkages between the cockpit and the control surfaces, causing them to fail.

The crew probably knew at this point that something was wrong in the tail, and activated the fire extinguisher for the APU. This caused the fuel supply to the APU to be shut off, but had no influence on the subsequent course of events.» (The Accident Report, 1993, p. 107)

«In the unit's turbine section, fragments of melted plastic were found. The plastic fragments were identified using IR spectroscopy and had the same composition as materials used in the cabin interior.» (The Accident Report, 1993, p. 68)

The accident investigation board's hypothesis is that the APU was stopped during the period 34–36 minutes FDR time, when the crew was in the process of losing control of the aircraft. This does not, however, reconcile with the fact that an APU takes only a few seconds to stop. If burnt plastic from the cabin interior was found in the APU turbine, it seems more probable that the APU was in operation when the aircraft broke apart. Alternatively, it may mean that the APU was stopped only seconds before the fuselage disintegrated.

Stopping an APU that was powering one of the aircraft's two alternating current systems seems unlikely if the crew was attempting to manage a power problem. If one is in the process of losing control of the aircraft, a pilot would naturally focus on the aircraft's primary flight controls and engine settings. In that case, it may mean that the pilots made no attempt to stop the APU, which means it was in operation when the aircraft disintegrated. This is consistent with the finding of melted plastic in the APU's turbine.

«The squib, which is intended to trigger the fire extinguisher for the APU, was found in a fired state. The charge is fired electrically. Tests have shown that an applied voltage of

approximately 15 V DC is sufficient to fire such a charge.»
(The Accident Report, 1993, p. 69)

The accident investigation board concludes that the fire extinguisher for the APU had been triggered, but does not explain how it could have been triggered without the aircraft having power on either the alternating current system or the direct current system. It would therefore have been natural to question whether the fire extinguishing mechanism could in fact have been triggered by the crew. The absence of electrical power and the finding of burnt plastic from the aircraft's interior weaken the accident investigation board's hypothesis that the crew activated the fire extinguisher.

«The technical findings show that the APU, after the forward mount had failed, remained in place and swung about the lateral axis. A large number of impact marks on the forward mount demonstrate this. Movement about the lateral axis was possible due to elasticity in the mounts that were still intact. "These oscillations must necessarily have affected the properties of other elements in the tail section."» (The Accident Report, 1993, p. 100)

«It is probable that the fact that the APU vibrated about the lateral axis is related to the oscillations in the elevator, although it cannot be established with certainty which of these two vibration sources initiated the reaction in the other.» (The Accident Report, 1993, p. 107)

It would have been interesting to know whether the impact marks occurred on the accident flight, or whether they developed over time when the aircraft flew in turbulence with the APU switched off. Gyroscopic precession is a physical phenomenon that causes a rotating object to resist changes in its position—in the same way that a spinning top remains upright as long as it is spinning. When flying straight ahead in stable flight, this effect will stabilise the APU about two axes while it is in operation. Given that the APU's shaft is mounted along the aircraft's longitudinal axis, this means the APU will resist movements about the lateral axis and the vertical axis. Only rotation about the longitudinal axis would be able to occur without the influence of gyroscopic precession. Without any further explanation of what is meant by the APU "remaining in place and swinging about the lateral axis," it is worth questioning whether this is even possible while the APU is in operation.

The Close Pass

Both the F-16 and LN-PAA were flying in accordance with Instrument Flight Rules (IFR). In practice, this means that the air traffic service is responsible for separating the aircraft from one another. For safety to be maintained, the pilots must adhere to their assigned altitude.

In 1989, civilian aircraft had no means of detecting other aircraft in the vicinity, and were therefore dependent on the air traffic service for information about any other traffic in the area. "Essential traffic" is air traffic that will come closer than the minimum separation prescribed by regulations, and which the air traffic controller is obliged to inform pilots about. In this case, the aircraft were separated in accordance with regulations by 2,000 feet of vertical separation, and the traffic was therefore by definition not "essential." The fact that the F-16 pilot nevertheless referred to LN-PAA as "essential traffic" on the radio is in itself an indication that the actual separation was far less than 2,000 feet.

The information that there were several fighter jets in the air simultaneously, and that they were flying just ahead of the Partnair aircraft, has not been mentioned by the accident investigation board. Since the crew of the F-16 was not informed by either Danish or Norwegian air traffic control about which aircraft they were encountering in the direction of Rygge military air station, confusion could naturally arise.

Radar data showing that the F-16 descended in altitude has been omitted from the report by the accident investigation board. The combination of the radio recording and the radar plot makes it probable that the close pass was not a coincidence.

Radio Communication

To fly in controlled airspace, as all IFR traffic does, pilots are required to be in contact with the air traffic service by radio. When an air traffic controller uses an aircraft's callsign, it means that the following message is intended for that specific aircraft. Since one can hear communications with other aircraft, pilots can form a mental picture of the traffic in the area.

A challenge with civilian and military aircraft in the same airspace is that civilian aircraft use VHF frequencies, while military aircraft use UHF. The air traffic service can use both VHF and UHF simultaneously. In practice, this means that civilian aircraft only hear the voices of pilots in other civilian aircraft, while military aircraft only hear other military aircraft. When the air traffic service transmits on VHF and UHF simultaneously, all pilots in the area hear what the controller says, regardless of whether the controller is addressing civilian or military aircraft. Without hearing both sides of the conversation, it is in many cases impossible to interpret which aircraft the radio communication concerns and where the aircraft is located.

The F-16 was on Copenhagen Control's UHF frequency when Partnair contacted the same controller on the VHF frequency. The F-16 pilot therefore did not hear Partnair report its altitude (flight level 220), but could only hear the controller's reply: «Partnair 394 good afternoon, radar contact, Copenhagen control.» Based on this information, the F-16 pilot had no way of knowing that the aircraft, which appeared to be coming from the same direction as Rygge, was LN-PAA.

Other Fighter Jets

Together with the Partnair aircraft, in Oslo Control's airspace, the military aircraft Viper 20 and Viper 71 were also en route to Aalborg. These were likely American F-16s that had participated in an exercise that day. The crew of the Norwegian F-16 likely had knowledge that there were other F-16s in the area. Viper 20 and Viper 71 had probably already passed over Denmark when the Norwegian F-16 (Norwegian 5007) took off from Aalborg.

F-16 Fighting Falcon

Many military aircraft have a nickname in addition to their official name. The F-16's nickname is "Viper."

«The F-16 was given its name of "Fighting Falcon" on 21 July 1980. Its pilots and crews often use the name "Viper" instead, because of a perceived resemblance to a viper snake as well as to the fictional Colonial Viper starfighter from the television program Battlestar Galactica, which aired at the time the F-16 entered service.» (F16 Fighting Falcon, Wikipedia)

Viper 20 and 71

At the same time as the Partnair aircraft was climbing towards its cruise altitude, two military aircraft were in the same airspace. These had the callsigns "Viper 20" and "Viper 71." Both were flying shortly after one another, but not in formation. During formation flight, only the formation leader communicates with air traffic control on behalf of everyone in the formation.

According to the radio log, Viper 20 and Viper 71 cross into Danish airspace at approximately 14:10. They are then approximately midway between Rygge and Aalborg, a flight that according to Norwegian 5007 took approximately 20 minutes.

«The undersigned flew on Friday 8 September 89 from Aalborg Air Station with take-off at 1420 Zulu. After one minute, the aircraft was established at FL 240 en route to Rygge. At approximately 1430Z, I detected an aircraft on the radar coming straight towards me—at approximately the same altitude. … Flew VFR into Rygge and landed at approximately 1440Z.» (Norwegian 5007, 1989, p. 1)

When Norwegian 5007 took off from Aalborg, Viper 20 and Viper 71 had likely already reached the Danish mainland.

Radio Log

Clearances and instructions from air traffic control must be read back by the pilot to confirm that the message has been understood and will be carried out. The readback functions as a contract between the controller and the pilot.

Military aircraft use UHF frequency, while civilian aircraft use VHF. What civilian aircraft say on the radio therefore cannot be heard by military aircraft, and vice versa. Air traffic control hears both military and civilian aircraft, and transmits on both VHF and UHF simultaneously so that all aircraft hear what the controller says.

The radio communications below are taken from Oslo Control (1989, pp. 1–2) and Copenhagen Control (1989, p. 1). The purpose is to show the timing of relevant events, and irrelevant parts of the communication have therefore been omitted.

Tid	**Stasjon**	**Message**	**Explanation**
14:04	Oslo Control	Partnair 394 is cleared direct Aalborg	The Partnair aircraft receives clearance to fly direct to Aalborg
14:04	Partnair 394	Roger - direct Aalborg	The crew confirms the clearance
14:08	Oslo Control	Viper 71 - you are cleared direct to Aalborg - AAL	Viper 71 receives clearance to fly direct to Aalborg. They are certainly not at the same altitude as Partnair.
14:08	Viper 71	(svar på UHF)	Viper 71 likely reads back the clearance.
14:09	Oslo Control	Viper 20 cleared direct AAL	Viper 20 also receives clearance to fly direct to Aalborg.
14:09	Viper 20	(svar på UHF)	Viper 20 likely reads back the clearance.
14:10	Oslo Control	Viper 71 - contact Copenhagen Control - frequency 293.250	Viper 71 is told to change frequency to Copenhagen Control as the aircraft is about to enter Danish airspace.
14:10	Viper 71	(svar på UHF)	Viper 71 likely replies: "say again"
14:11	Oslo Control	293.250	The controller repeats the frequency

			that Viper 71 is to switch to.
14:11	Viper 71	(svar på UHF)	Viper 71 likely reads back the frequency
14:11	Oslo Control	Viper 20 - also contact Copenhagen on 293.250	Viper 20 and 71 must have been flying relatively close to each other since they both receive instructions to change frequency at the same time.
14:11	Viper 20	(svar på UHF)	Viper 20 likely reads back the frequency
14:22	Oslo Control	Partnair 394 - radar services terminated. You will enter Danish airspace two minutes from now. Contact Copenhagen 124.55	The Partnair aircraft is told to change frequency. This is not the same frequency as the Viper aircraft since they used UHF radio and civilian aircraft use VHF radio.
14:22	Partnair 394	124.55 - bye	The frequency is read back as confirmation that they will contact Copenhagen Control.
14:23	Partnair 394	Copenhagen - Good afternoon - Partnair 394 maintaining flight level two two zero	The Partnair aircraft calls Copenhagen Control and reports that they are established at flight level 220 (22,000 feet)
14:23	Copenhagen Control	Partnair 394 - Good afternoon - Radar contact	The controller confirms that he/she can see the Partnair aircraft on the radar.

(Oslo Control, 1989)

The Pass

After the encounter with LN-PAA, a confrontation arises between the F-16 pilot and the air traffic controller. In the recording of the radio communication, the F-16 pilot is heard saying:

«You knew you had that airliner coming straight at us here?» After a response from the controller, the F-16 pilot continues: «Just confirm that you had him, pretty essential traffic.»

Norwegian 5007 was a two-seat F-16 with a crew of two qualified F-16 pilots. According to the Armed Forces, the pilot in the back seat had no assigned responsibilities on the trip from Aalborg to Rygge, but as a qualified F-16 pilot and instructor, he was part of the crew. He testified in the lawsuit Partnair brought against the state, and also claimed in the documentary that the F-16 maintained its assigned altitude. (Wisting, 2023)

The radio recording between the F-16 pilot and the air traffic controller clearly shows that the F-16 pilot was agitated. That he would react to an aircraft 660 metres (2,000 feet) below his own altitude seems entirely incomprehensible. The only logical explanation is that the F-16 and LN-PAA passed each other at very close range. The sharp criticism directed at the air traffic controller suggests that the F-16 pilot believed he should have been informed about the civilian, opposing passenger aircraft that the controller had on his radar screen.

The recording of radio communication between the F-16 pilot and the air traffic controller is not discussed in the accident report. The fact that two military aircraft, likely F-16s from Rygge, were flying towards Aalborg at the same time as the Partnair aircraft has been completely omitted. In this way, the accident investigation board bypassed everything that could have put the spotlight on the Armed Forces.

Motivation

A central question is why the F-16 crew apparently departed their assigned altitude and flew towards LN-PAA. The answer may lie in the fact that they believed they were encountering a colleague.

The F-16 crew likely knew that other F-16s—probably American aircraft that had participated in an exercise—were en route to Aalborg in the opposite direction. When the F-16's radar detected a target in the direction of Rygge, the crew may have assumed that this was one of those aircraft. Among fighter pilots, it is not uncommon to carry out a close pass of another fighter—a "stunt" that both parties are trained for and prepared to handle. In such a scenario, a close pass would have been considered harmless by the crew, since they expected that the pilot of the opposing aircraft was a colleague accustomed to such encounters in the air.

The problem was that the target on the radar was not an F-16, but the Partnair aircraft LN-PAA—a civilian passenger aircraft with 55 people on board. Neither the Danish nor the Norwegian air traffic controller informed the F-16 crew that the civilian aircraft was in the area, and the F-16 pilot could not hear Partnair's radio conversation with the controller since it took place on VHF. The misidentification thus became catastrophic.

Since the F-16 is equipped with its own radar, this may have given the crew a false sense of security that they had the situation under control—which may have made it easier to break the safety rule of maintaining their assigned altitude. Given that the F-16 pilot switched off the aircraft's transponder, the aircraft would in practice have become invisible in the radar system of the civilian air traffic service.

When the F-16 pilot says on the radio «You knew you had that airliner coming straight at us here?», the controller replies: «Norwegian 5007 will you confirm that you are flight level 240.»

The controller's question may suggest that he did not have an up-to-date altitude reading on his radar screen, but perhaps only a prediction from the radar system. If the F-16's transponder had been switched off, the controller would only have had the last known altitude to rely on.

The Merge

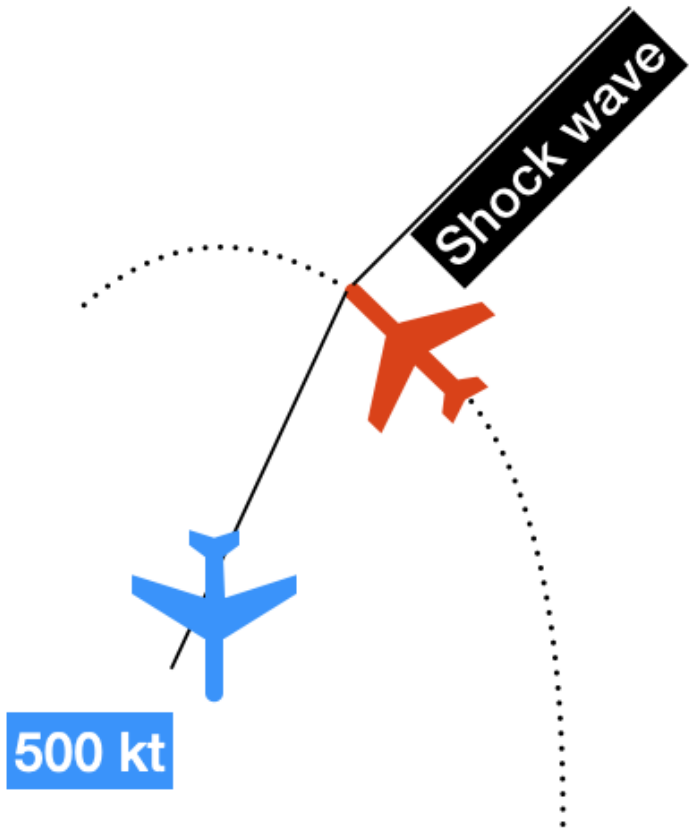
In military aviation, "the merge" is the moment when two opposing aircraft pass each other. The pilot identifies an oncoming aircraft, and as the aircraft pass each other, the pilot turns to get in behind the other aircraft. This is a standard manoeuvre that all fighter pilots train for.

The AWACS video shows the F-16 turning to the left after passing the Partnair aircraft—consistent with the initiation of such a manoeuvre. The F-16 pilot likely assumed that the Partnair aircraft was the last of the fighter jets coming towards him on the same route, and acted accordingly.

Speed and distance

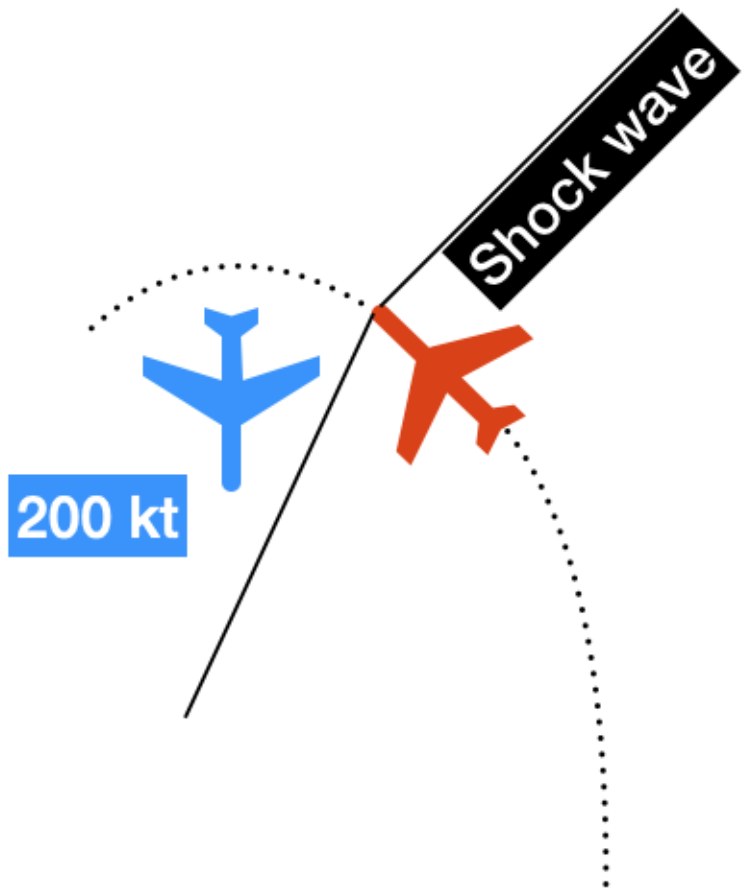
At speeds exceeding 1,000 km/h, there is no time to think and analyse. The pilot acts on reflexes ingrained through training. The timing for when the turn is initiated, and how hard one turns, is based on experience with opposing aircraft moving at a speed comparable to one's own.

When the opposing aircraft is a fighter jet at 500 knots, both aircraft are moving rapidly away from the point of passing. When the F-16 pilot begins the turn, the opposing aircraft has already covered a considerable distance. The result is that the turn occurs at a relatively large distance from the other aircraft.



Merge against a fighter jet at 500 knots—large distance at the turn.

When the opposing aircraft is instead a propeller aircraft at 200 knots, the situation changes dramatically. The pass itself is experienced almost identically—the closure rate is still enormous. But after the pass, the Partnair aircraft is moving at only one-third the speed of a fighter jet. When the F-16 pilot initiates the turn based on trained timing, the distance to the Partnair aircraft is substantially shorter than it would have been against a fighter jet. The result is that the F-16 turns in much closer behind the Partnair aircraft than the pilot had anticipated.



Merge against a propeller aircraft at 200 knots—much closer at the turn.

The pilot has no opportunity to correct. Everything happens too fast. Before the pilot can react to the distance being less than expected, the F-16 has already passed.

The Shock Wave Strikes from the Side

When the F-16 turns behind the Partnair aircraft, the shock wave from the F-16 is directed at the Partnair aircraft's side. At speeds near the speed of sound, the shock wave propagates nearly perpendicularly from the F-16. As the F-16 passes behind and to the side of the Partnair aircraft, the shock wave strikes the Partnair aircraft's fuselage and tail control surfaces from the side.

The fact that the shock wave strikes from the side has two important consequences: the entire length of the aircraft's fuselage is exposed to the pressure change, and the rudder—which stands vertically on the tail—is struck head-on. When the F-16 additionally passes at the same altitude as the Partnair aircraft, the shock wave strikes the tail control surfaces directly, without any dampening angle from above or below.

The most vulnerable part of the tail structure is the rudder's trim tab—a small surface mounted on the rudder. The trim tab is naturally not designed to withstand forces as great as the rest of the rudder, since it is only intended to help fine-tune the position of the control surface. If the trim tab is knocked out of position or physically damaged by a shock wave, it could trigger large aerodynamic forces that may be catastrophic.

The combination of an unexpectedly close pass and a shock wave striking the rudder's trim tab directly from the side, at the same altitude, constitutes a direct threat to the weakest part of the aircraft's tail structure.

Emergency

Pilots train extensively on detecting and managing faults with the aircraft's systems, and they are evaluated annually in a simulator. Detecting faults early requires continuous monitoring of the instruments. If one receives an indication that something is abnormal, it is important to attempt to understand what the problem is before concluding what must be done, so as not to end up making matters worse.

When a fault situation arises during flight, the pilots must identify the cause and take the necessary measures to reduce risk, as well as assess whether the flight can continue as planned or must be aborted. Some situations arise from acute problems, while in other cases the severity is not immediately apparent. An engine failure is easy to detect, and the pilots are in no doubt about what they must do. If, on the other hand, one experiences a reduction in engine performance, or for instance an indication of fluctuating oil pressure, it may be the beginning of a problem that develops into something serious.

Vibrations

All pilots have learnt that if structural damage to the aircraft occurs, speed must be reduced as soon as possible to minimise the load on the aircraft structure. If vibrations arise in engines or control surfaces, it is important to determine whether the vibrations are related to specific speeds or engine settings. If the vibrations do not quickly subside, most pilots will reduce speed considerably and find a suitable landing site.

Performance Loss

A performance reduction in one engine does not necessarily mean there is a serious problem, but it must be investigated. A reduction in the performance of the left engine will cause the aircraft to begin turning to the left, as the thrust is no longer symmetrical. The autopilot will automatically correct the turn, but the pilots will be able to detect that something is wrong because the speed decreases and the aircraft begins to fly uncoordinated. The cause of the speed reduction would in that case be that the total thrust is reduced, and that the use of control surfaces to correct the heading causes increased drag.

Priorities

«Aviate, Navigate, Communicate» is the order of priorities for pilots. The most important thing is to maintain control of the aircraft (aviate). Once control is established, one can formulate a plan for where to fly and navigate in the correct direction. At the bottom of the list is communicating with the air traffic service.

It may sound illogical not to send a distress call first, but in practice there is very little an air traffic controller can help with if the pilot is unable to control the aircraft or navigate to an airport. If no distress call has been received in connection with an aircraft accident, it means either that events unfolded very rapidly, or that the pilots chose not to send a distress call because they were occupied with more important tasks.

The Lead-Up to the Accident

The accident investigation board has based its conclusion on the premise that the accident came suddenly and unexpectedly to the pilots, while simultaneously claiming that the cause was vibrations that had intensified over time. The problems are said to have been impossible to notice or to have produced any indication on the instruments, otherwise the crew would have detected them on this and previous flights. The main argumentation for this is that the aircraft appeared to be flying normally—something previous chapters have shown was not the case—and that no distress call was transmitted.

A far more probable scenario is that the crew detected that the aircraft was developing an unwanted turn to the left, but misunderstood the cause and believed it was related to the left engine rather than the rudder. By the time they realised there was damage to the aircraft's control surfaces, the damage had already developed to catastrophic proportions.

Without recordings from a Cockpit Voice Recorder, it is very difficult to establish with certainty what the pilots were thinking and doing prior to the accident. When one combines data from the Flight Data Recorder (FDR) and radar plots with knowledge of how the crew was trained, it is unlikely that the pilots of LN-PAA were unaware of problems with the aircraft right up until the final sequences, as the accident investigation board has assumed.

Pilots use checklists during the various phases of flight to ensure that nothing important is overlooked or forgotten. In addition to the normal checklists, pilots also have emergency checklists, which describe each step to be taken in a given emergency situation—for example, checklists for engine fire and engine failure.

Without cockpit audio recordings, it is difficult to know which checklists the crew of LN-PAA used. Instead, one must rely on knowledge of what pilots have been trained to do, as well as the context of the particular flight, in order to form a picture of the crew's pattern of actions.

Speed Loss After "Top of Climb"

After the aircraft had reached "top of climb" and built up speed, the pilots set the engines to "cruise power." Despite the fact that cruise speed should have stabilised, it gradually declined. During this phase of the flight, the airspeed indicator and the Turbine Inlet Temperature (TIT) are two essential instruments. It is highly probable that the crew quickly perceived that the aircraft was not stabilising at the expected cruise speed, but was gradually losing airspeed. Based on an expected cruise speed of 210 knots indicated airspeed, this means the crew became aware of the problem at approximately 29 minutes FDR time.

Autopilot and Troubleshooting

If problems arise with the control surfaces, the most important action would be to reduce speed and then disengage the autopilot in order to feel the movements of the control surfaces and the aircraft through the controls. An autopilot can mask the effects of structural damage—vibrations and tendencies towards rotation about one of the aircraft's axes become difficult to detect when the autopilot is engaged. The autopilot has no control over

the engines, and if one receives an indication of an engine problem, it would not necessarily be natural to disengage the autopilot immediately.

Given that the crew had recently adjusted the engines, and that the result was declining airspeed, it would be natural to suspect that the problem was engine-related. It is reasonable to assume that the crew attempted to adjust the engines to compensate for the speed loss, but this is difficult to read directly from the FDR data. The only thing one can rely on is that the engine settings, at some point before the accident, were set such that the Turbine Inlet Temperature was 850–853 °C instead of 847 °C, which would have been the expected temperature for "cruise power."

If the autopilot is using the control surfaces to correct for forces about the vertical axis (yaw), this will produce a deflection on the slip indicator in the aircraft. After having troubleshot the engine instruments, it would be natural to disengage the autopilot to see whether it was the cause of the reduced speed. If the autopilot was fighting against a tendency to turn left—which would have been the consequence of a performance reduction in the left engine or increased drag on the left side—the aircraft would have immediately begun to turn left when the autopilot was disengaged.

The Three Heading Deviations

The first of the three heading deviations to the left occurs approximately 1 minute and 30 seconds after the aircraft's speed dropped below the expected cruise speed. It seems probable that the heading deviation resulted from the autopilot being disengaged, as this is a natural step in the troubleshooting process. Since the speed did not drop dramatically to well below 200 knots, it seems unlikely that the crew suspected structural damage. If at this stage they still suspected a problem with the left engine, it seems logical that the crew corrected the heading deviation with aileron input to the opposite side.

It is impossible to know in hindsight what the crew was thinking, what sounds they heard, what movements in the aircraft they felt, and how they reasoned together to understand what was wrong. What seems entirely obvious is that they must have understood they had a problem, and that they were working to manage the situation. The fact that the crew did not react by reducing engine power and airspeed can be interpreted as meaning that they did not understand the aircraft had sustained structural damage. When the first indications arose, there was no way for the pilots to understand how little time they had before the situation became catastrophic.

The Flight Engineer in the Cockpit

Since the accident investigation board's hypothesis is that the crew did not know the aircraft had problems until it was too late, they have also not discussed what impact it had that there was a flight mechanic together with the pilots in the cockpit.

That the problem arose just after the engines had been adjusted from "climb power" down to "cruise power," and that declining airspeed was the most visible indicator, makes it natural to suspect that the problem was engine-related. When one additionally has a technician with

in-depth knowledge of the engines present, this may have reinforced the focus on the problem being engine-related.

Given that the aircraft was approaching Denmark, where there were several alternative landing sites, and the pilots apparently had control of the aircraft, it is understandable that they attempted to maintain altitude and speed—given the assumption that the left engine was the root of the problems.

Radar Echoes of Wreckage

In addition to the detailed radar plots from Skagen radar, the accident report contains radar data from Sweden showing that over the course of half an hour, parts from the aircraft descended towards the sea surface. Maps of the wreckage area show where the various parts of the aircraft were recovered. Without collating the information, it is difficult to obtain a clear picture of what happened and when. This chapter contains images from the accident report with annotations to make it easier to see the connection between the different data sources.

The accident investigation board's hypothesis is that shroud doors between the control surfaces and the stabilisers were shattered early in the accident sequence, while the aircraft was still at cruise altitude, and that the honeycomb material from these shroud doors is what was observed on radar. This hypothesis is central to the accident investigation board's conclusion that vibrations in the tail section developed over time.

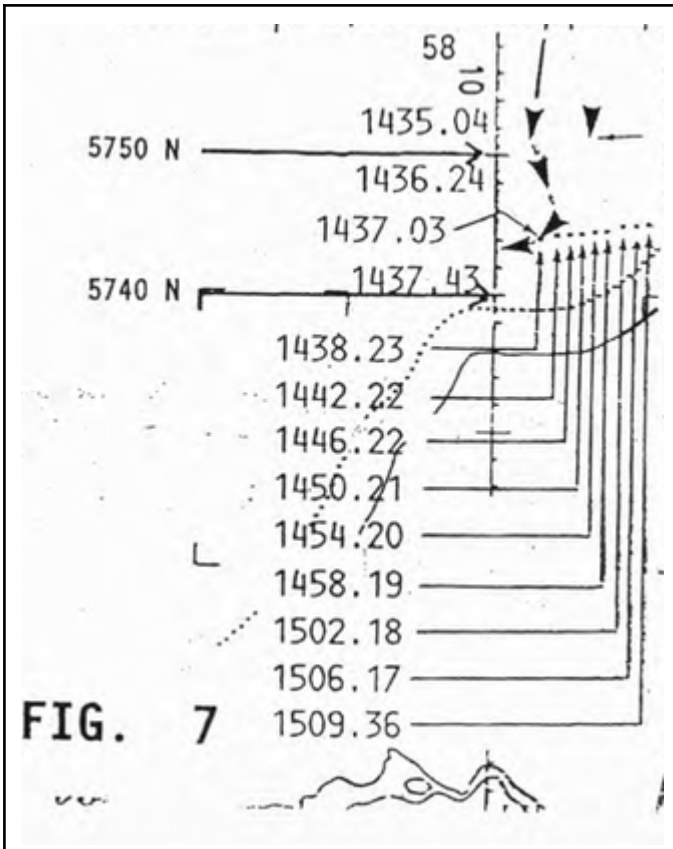
An analysis of radar data and physical calculations shows, however, that the objects registered on radar separated from the aircraft in the very last phase of the accident—when the tail section collapsed and the pressure cabin ruptured—and not in an early phase of the accident sequence.

Swedish Radar Data

The Swedish Armed Forces delivered radar data to the Swedish accident investigation board, which forwarded them to the Norwegian accident investigation board on 11 October 1989. The document describes the observations from the Swedish west coast radar film.

The Swedish document establishes that the aircraft was at approximately 5,000 metres altitude (approximately 16,400 feet) until approximately 14:37:40, based on rough calculations from which radar stations detected and lost the target. Furthermore, a radar echo is described that is assumed to originate from objects that separated from the aircraft:

«Appendix 2 shows the movement of a radar echo that is assessed to have consisted of objects that separated from the accident aircraft while it was still at a minimum altitude of 5,000 metres.» (Forssberg, 1989, p. 2)



(The Accident Report, 1993, Figure 7)

The object was visible on the west coast radar film for just over 31 minutes and drifted approximately 14.5 km eastward with the wind. When it disappeared from the radar, the altitude is estimated to have been approximately 400 metres, with a rate of descent of approximately 2.5 metres per second.

The fact that the Swedish assessment states «a minimum altitude of 5,000 metres» (approximately 16,400 feet) is consistent with the aircraft already having lost several thousand feet from its cruise altitude of 22,000 feet (6,700 metres) before the objects separated. This is consistent with an accident sequence in which the aircraft first entered a dive and lost 5,000–7,000 feet in altitude before the tail section collapsed.

Descending Object

From radar data, it is difficult to know whether one object was registered or whether there were several. For simplicity, «the object» is used here, while in reality there may have been many objects.

To understand what the radar data shows, it is essential to establish when the object left the aircraft. The Swedish radar data shows that the aircraft passes a given point at 14:37:03. At approximately the same location, radar data shows the object in the air 80 seconds later (at 14:38:23). This means that the object left the aircraft further to the west and was then carried back eastward by the wind.

The Swedish radar data covers the entire flight and is not as precise as the plot from Skagen radar. Based on the Swedish radar film, approximately 80 seconds elapse from the aircraft passing until the object is registered back at approximately the same point. Using the plot from Skagen radar, which has higher resolution, the corresponding time is approximately 93 seconds.

Calculation of Separation Time

By calculating the distance the object has travelled, it is possible to estimate approximately when the object detached from the aircraft.

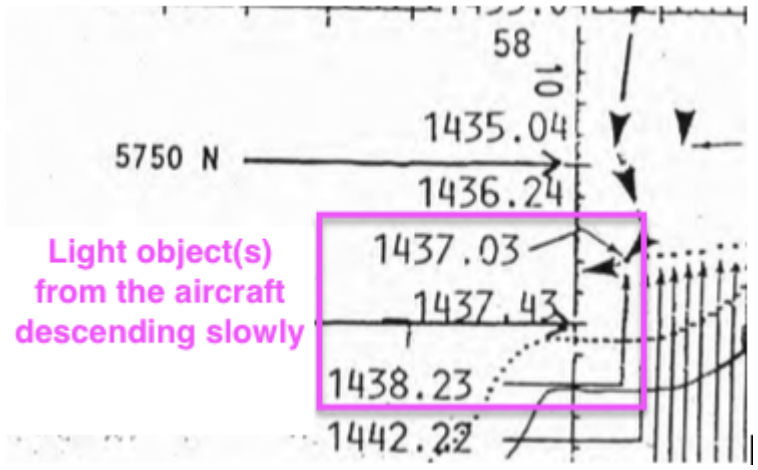
Assumptions

At the time of the accident, there was a 70-knot wind from 260° at the altitude the aircraft was at. The object has therefore moved at a ground speed of 70 knots in approximately the opposite direction to the aircraft after it separated.

Based on performance data (Pilot's Handbook Convair 580, 1977, p. 4-7), a Convair 580 will have an average true airspeed of approximately 300 knots at 22,000 feet altitude. Given that the final portion of the flight was heading almost directly into the wind, the ground speed would have been approximately 230 knots.

The calculation is based on the principle that the total time—from the aircraft passing the reference point until the object is observed back at the same point—equals the sum of the aircraft's flight time forward and the object's drift time back with the wind:

Flight time + drift time = 80 seconds



Calculation at 230 knots ground speed (normal cruise speed)

Parameter	Value
Wind eastward (wreckage)	70 knop = 36,0 m/s
Aircraft ground speed westward	230 knop = 118,3 m/s
Flight time before separation	**19,0 seconds**
Drift time back	62,4 seconds
Sum	**81,4 seconds**

Calculation at 130 knots ground speed (dive with reduced ground speed)

If the aircraft was in a dive, the velocity vector points downward rather than forward. The horizontal component—ground speed—can thus become substantially lower than during normal cruise, even though the aircraft's speed through the air increases.

Parameter	Value
Wind eastward (wreckage)	70 knop = 36,0 m/s
Aircraft ground speed westward	130 knop = 66,9 m/s
Flight time before separation	**28,0 seconds**
Drift time back	52,0 seconds
Sum	**80,0 seconds**

Calculation at 330 knots ground speed (dive with increased ground speed)

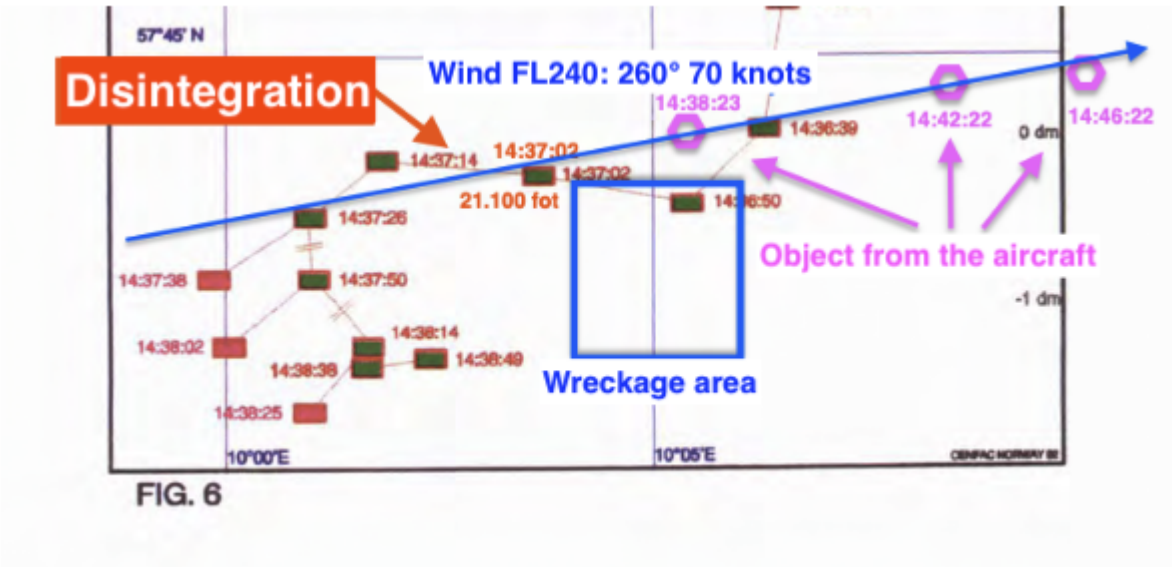
Depending on the dive angle, ground speed may also be higher than normal, if the aircraft is not diving steeply but accelerating in a shallow descent.

Parameter	Value
Wind eastward (wreckage)	70 knop = 36,0 m/s
Aircraft ground speed westward	330 knop = 169,8 m/s
Flight time before separation	**14,0 seconds**
Drift time back	66,0 seconds
Sum	**80,0 seconds**

Result

Depending on the aircraft's ground speed in the final phase, the objects detached between 14 and 28 seconds after the aircraft passed the reference point. Based on the Skagen radar plot, this corresponds to a time between approximately 14:37:04 and 14:37:24. Regardless of which ground speed is assumed, this time window coincides with the final radar registrations of the aircraft—and not with an early phase of the accident sequence.

The calculations above are based on the radar plot from Skagen, which is a NATO radar. There is reason to question the accuracy of these data, which is discussed further in a later chapter. The most important point, however, is that the Swedish civilian radar independently confirms the same picture: the objects separated from the aircraft too late to have originated from an early phase of the accident sequence. The point at which the aircraft departs controlled flight is also visible on the Swedish radar. Had the objects detached at cruise altitude—early in the process—they would have appeared on the Swedish radar at a substantially earlier time and further north than where they were actually registered.



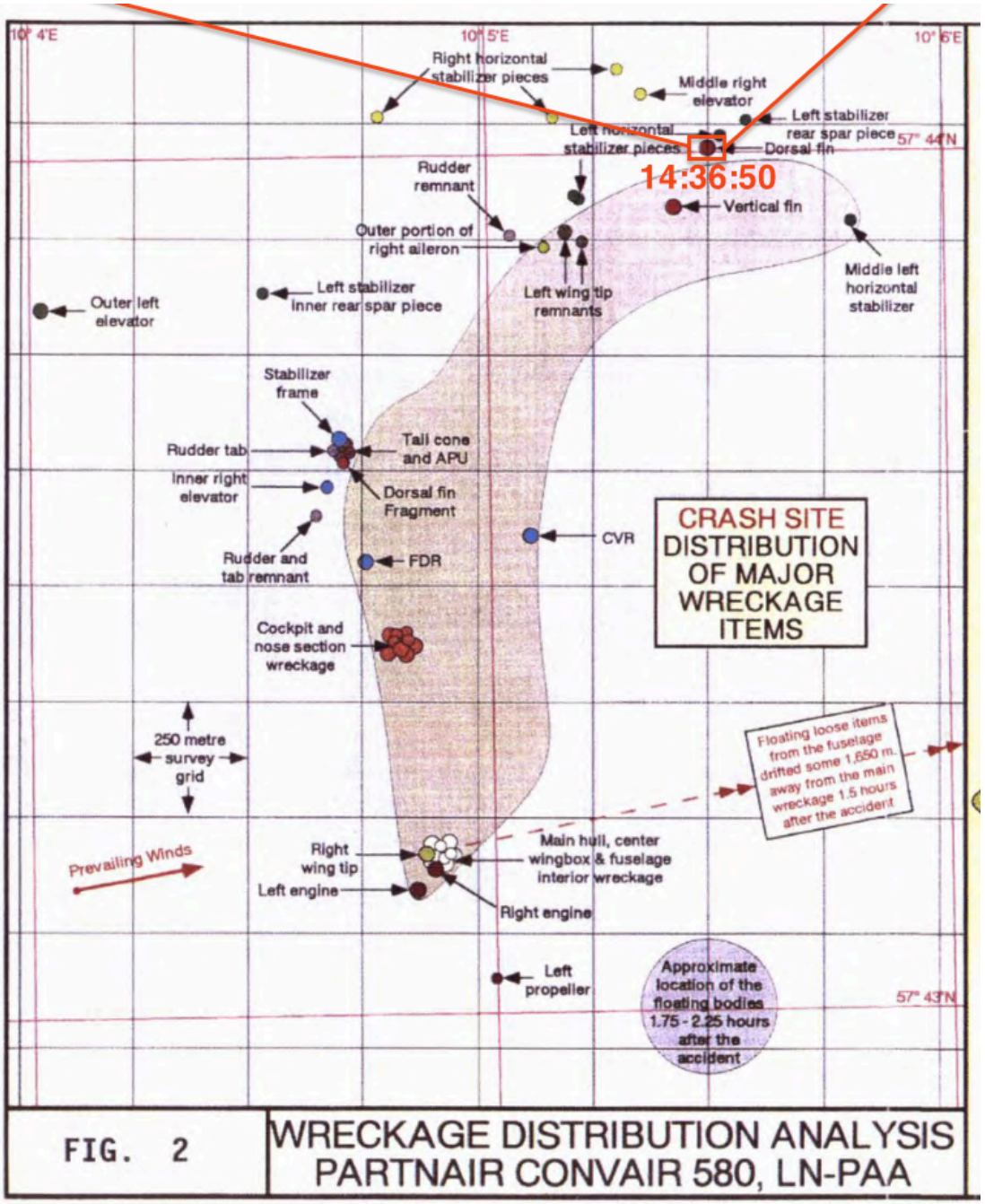
(The Accident Report, 1993, Figure 6) Skagen radar data with annotations.

The Wreckage Area

When the aircraft broke up in the air, air resistance brought the aircraft's forward motion to a halt in a short time. This is visible in the radar data, which shows the aircraft moving less forward after the time of the accident than previously. According to the accident report, horizontal surfaces in the tail broke off, and the aircraft then entered a manoeuvre with so much negative g that the wings broke:

«The technical findings and radar data provide several indications of the subsequent course of events. In broad terms, stability about the lateral axis was also lost when horizontal surfaces in the tail broke off. After this, the aircraft entered a manoeuvre with so much negative g that the wings broke.» (The Accident Report, 1993, p. 108)

Data from Skagen radar indicates that the final radar registration was at 14:38:49.



(Accident Investigation & Research, 1992, Figure 2)

Altitude Indication in Radar Data

Radar data from Skagen shows a Mode C registration of 21,100 feet at 14:37:10. A Mode C registration requires that the aircraft's transponder transmitted pressure altitude information. The accident investigation board has concluded that the transponder at this point was receiving power from the aircraft's 12-volt battery.

There are, however, strong physical arguments that this altitude indication cannot be correct:

Assertion 1: The Time Conflict

In free fall from 22,000 feet, it takes approximately 1 minute and 40 seconds to reach the sea surface. The Partnair aircraft hit the sea surface at approximately 14:39—approximately two minutes after it was allegedly at 21,100 feet. The fuselage did not, however, fall straight down, but flew through the air with wings that still provided aerodynamic lift in varying directions depending on the fuselage's orientation. The radar track confirms that the aircraft did not fall vertically. It is therefore not physically possible that the aircraft was at 21,100 feet at 14:37:02 and hit the sea surface two minutes later.

Assertion 2: The Tail Section Must Have Broken After a Dive

For flutter to develop in the control surfaces, a speed far exceeding normal cruise speed is required. Such a speed can only be achieved through a dive with significant altitude loss. According to an expert assessment from a person with intimate knowledge of the aircraft type—as a mechanic, pilot, and instructor—an altitude loss of 5,000–7,000 feet over approximately one minute would likely provide sufficient speed for flutter to develop.

After flutter has destroyed the control surfaces, it is not physically possible for the aircraft to maintain altitude. The elevator contributes to giving the horizontal stabilisers negative lift in order to keep the aircraft's nose up. Without this negative lift, the nose-heavy aircraft will pitch downward.

The aircraft therefore cannot have been at 21,100 feet at 14:37:02, since at this point it had already been through a dive with several thousand feet of altitude loss and subsequent collapse of the control surfaces.

Conclusion Regarding Altitude Data

The aircraft was in a dive and descending after having lost control. The tail control surfaces eventually collapsed, and at that point there was no return—it is physically impossible for the pilots to bring the aircraft back up to altitude without functioning control surfaces. Radar data from Skagen showing 21,100 feet at 14:37:02 therefore cannot have been real.

The Swedish radar analysis supports this:

«Our data does not contain any altitude measurements. Rough assessments of the aircraft's altitude have, however, been possible based on where different radar stations detected and lost the target. Up until approximately 1437.40, the aircraft was still at approximately 5,000 metres altitude. (It was then visible on a radar in south-eastern Sweden.) As shown in the

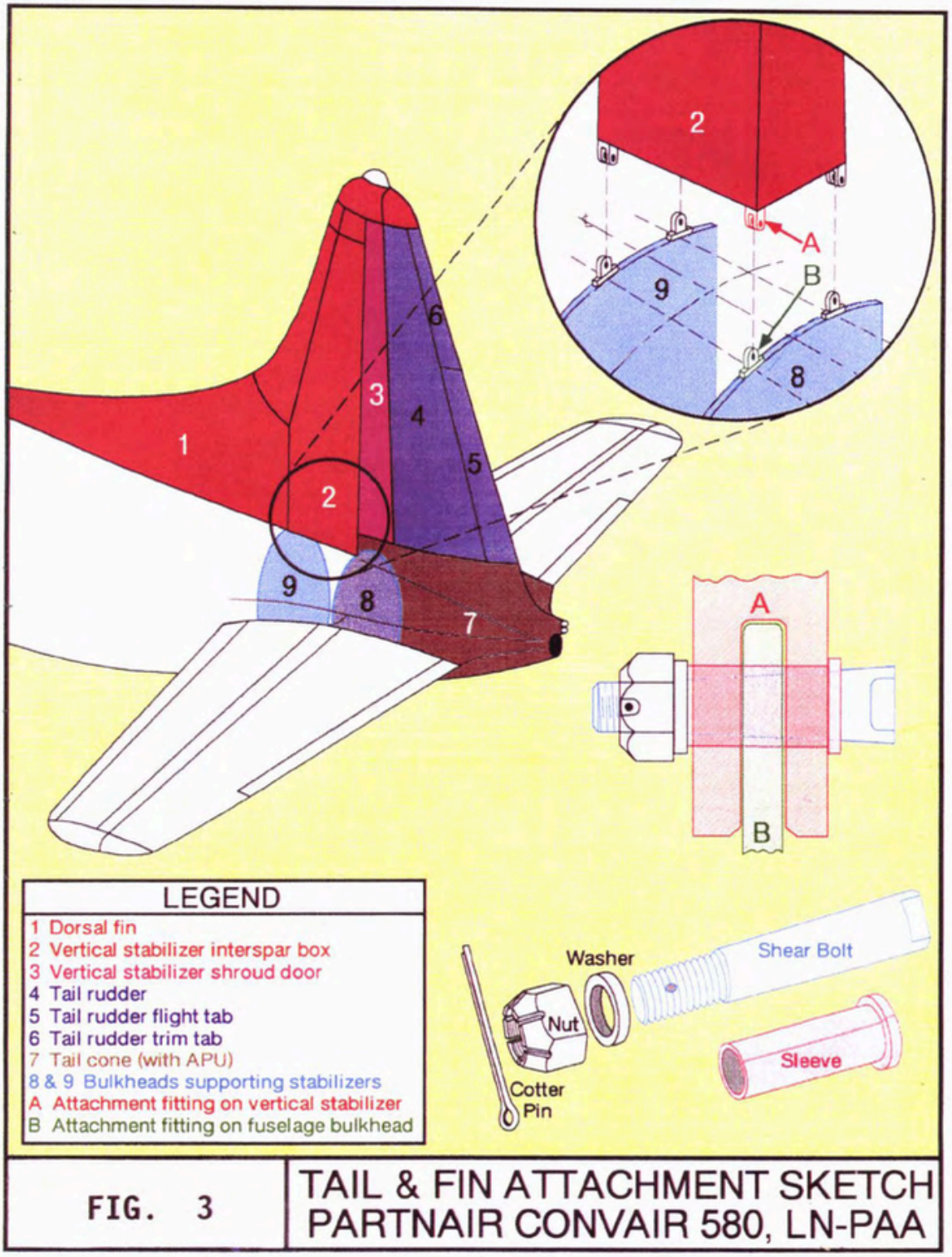
sketch, the last presentation on the west coast radar occurred at 1437.43. The aircraft is therefore assessed to have plunged steeply into the sea.» (Forssberg, 1989, p. 2)

Swedish radar thus estimates the aircraft's altitude at approximately 5,000 metres (16,400 feet) at 14:37:40—only 38 seconds after Skagen radar allegedly registered 21,100 feet. This contradiction confirms that the altitude indication from Skagen cannot have been correct.

Objects Observed by Civilian Radar

The accident investigation board's hypothesis is that shroud doors from the tail section detached early in the accident sequence, while the aircraft was at cruise altitude, and that the honeycomb material from these panels explains the radar echoes. There are several problems with this hypothesis.

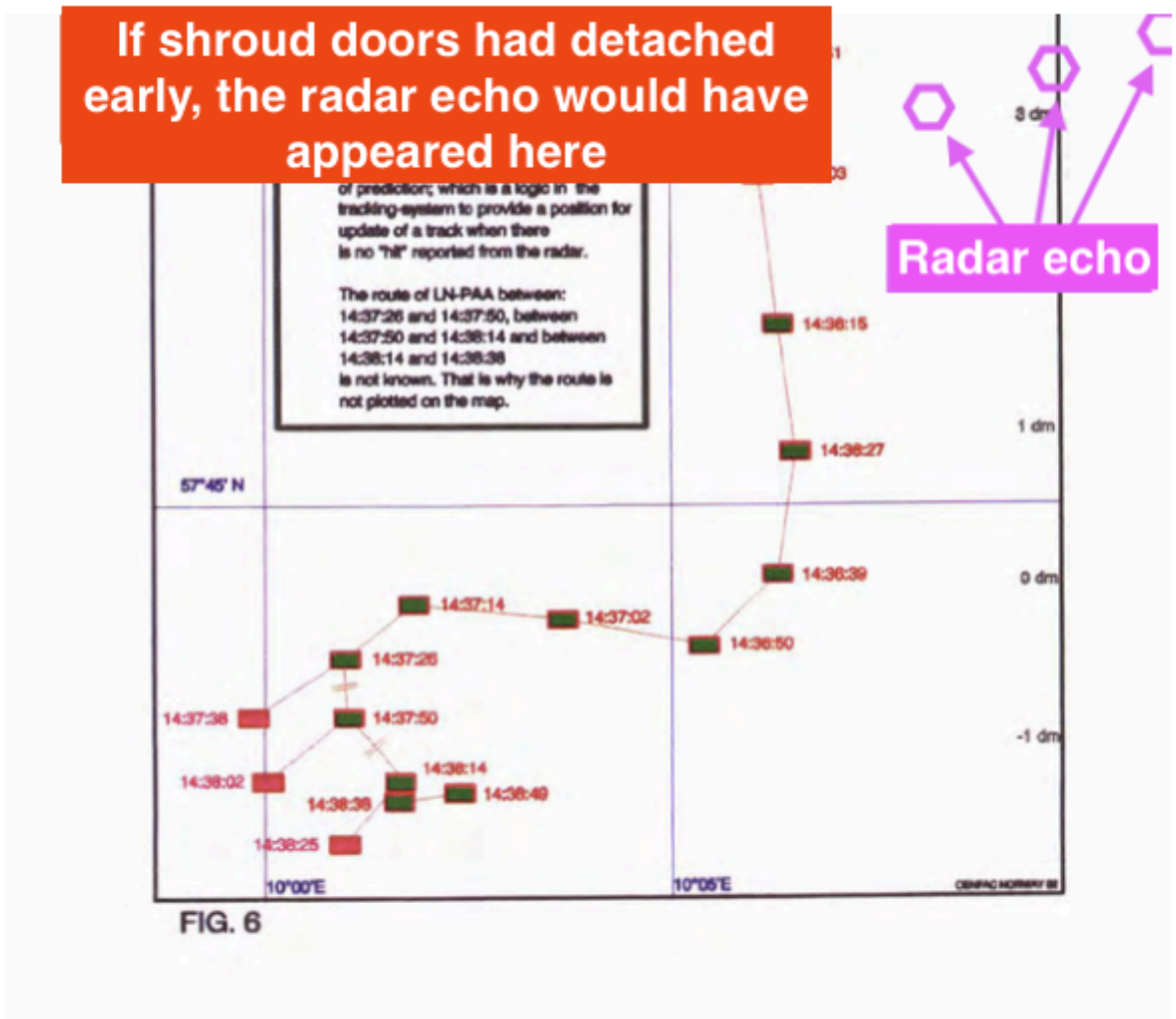
The radar beam from a civilian primary radar of the 1980s requires a reflective area of approximately 100 square centimetres or greater for reliable detection. The shroud doors are relatively small, and when they break into smaller pieces and fall rotating downward, it is very unlikely that they would produce continuous radar reflections. Radar reflection can in theory be based on many small objects in proximity to one another that collectively produce a reflection, but for this purpose the shroud doors are too small for fragments of them alone to explain the observed radar reflections.



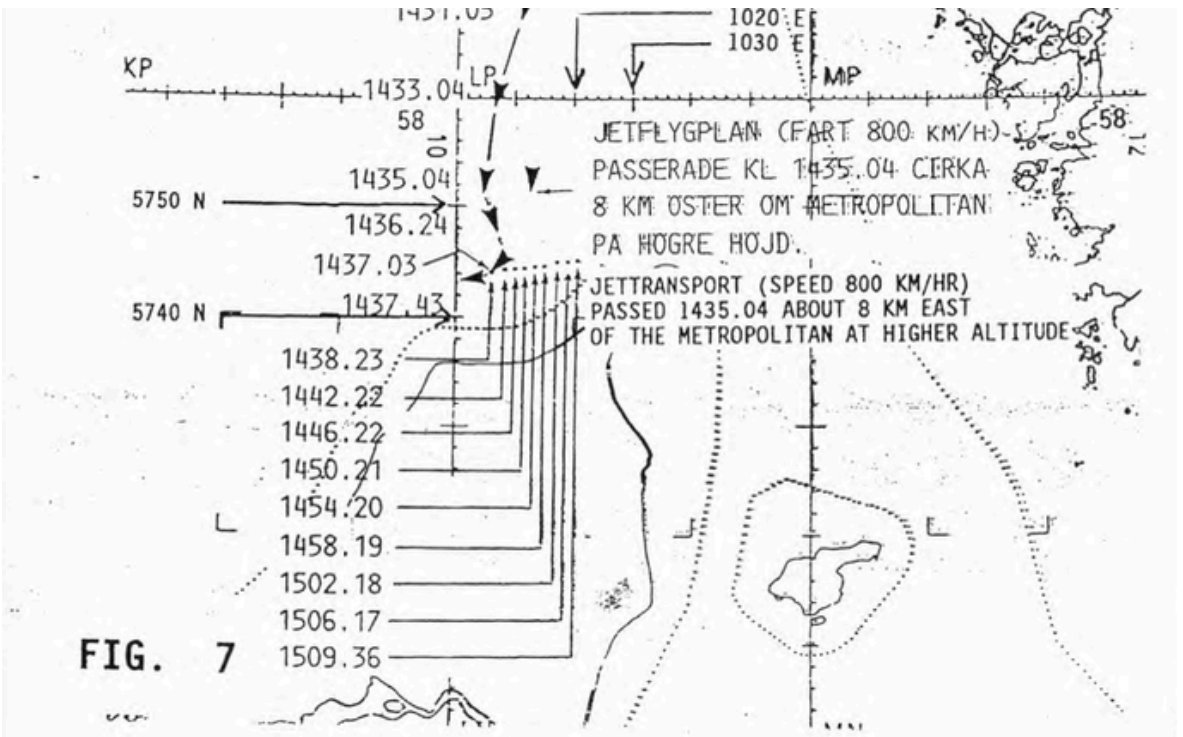
(Accident Investigation & Research, 1992, Figure 3) Shroud doors (number 3 in the diagram)

The only logical explanation is that the radar reflections are caused by wreckage from both the inside and outside of the aircraft when the tail section broke off and the pressure cabin ruptured. The catastrophic decompression caused objects from the inside of the aircraft to be ejected in addition to the fuselage itself breaking apart. Thousands of parts of varying size and radar-reflective properties were scattered throughout the altitude range—the lightest parts drifted with the wind and took a long time to reach the sea surface. The parts that spread vertically collectively produced clear primary radar reflections and were registered by both Swedish and Danish radar.

Had the shroud doors actually detached in an early phase of the accident sequence—while the aircraft was still at cruise altitude and cruise speed further north—the radar echo would have appeared at an entirely different location than where it was observed. The radar plot shows, however, that the objects appear at a position that coincides with the calculated time of the aircraft's final disintegration.



(The Accident Report, 1993, Figure 3) Skagen radar data annotated.



(The Accident Report, 1993, Figure 7) Wreckage registered by Swedish radar.

«The starting point was that the object must have been small and very light. It must also have had excellent reflection properties for radar-transmitted energy. The object was registered for 2,473 seconds (41 minutes and 13 seconds). … Because this "honeycomb" was the only material on the aircraft that could satisfy the requirements for low weight per unit area and perfect reflection of radar energy, HSL concludes that the object registered by Swedish radar and Aalborg approach radar was one or more pieces of "honeycomb" from the vertical fin's shroud doors.» (The Accident Report, 1993, pp. 81–82)

Aalborg Approach Radar

The radar at Aalborg and Copenhagen registered an apparently stationary object in the air above the accident site.

«The approach radar at Aalborg airport was also used to search for LN-PAA. The controller and his assistant observed an apparently stationary object at position radial 360° 16 NM from Sindal airfield. … It was also of interest that Copenhagen ACC radar registered "something" 40 NM north of Aalborg at 1445. This coincides with the position of the object registered by the approach radar at Aalborg airport.» (The Accident Report, 1993, p. 80)

The Aalborg report describes the observation in detail:

«At approximately 1455 UTC, LLyt (OF) received an inquiry from the Control Centre (ACC) as to whether a transponder track of an aircraft could be observed on LLyt's radar, last seen 30 NM north of Aalborg, estimated to be over Aalborg; transponder code 1211. The transponder track could not be observed on LLyt's radar. At this point, OF and RN were only attempting to observe transponder tracks. Approximately two minutes later, LLyt (RN)

received the same request from ACC, after which LLyt also began observing for primary radar tracks. Immediately, OF and RN observed a stationary primary radar echo approximately one NM outside the 40 NM radar distance ring, due north of Sindal airfield, which corresponds to a position 16 NM on radial 360 relative to Sindal airfield. As the weather caused many rain showers on the radar, with the possibility of confusing primary radar echoes and rain, all showers were removed from the radar using the rain filter. The primary echo 16 NM north of Sindal was not diminished, and remained the size of a primary echo from an aircraft. In the area surrounding this primary echo, no other primary echoes, stationary or moving, were observed. The observation continued until 1520 UTC. The time at which the primary echo disappeared is not known. The minimum altitude at which LLyt's radar could detect primary echoes at the position 16 NM north of Sindal was, on that particular evening, approximately 2,000 feet. This was established through overflights of the area.» (Nielsen, 1989, p. 2)

The report shows that the controllers at Aalborg observed a stationary object on the radar in the vicinity of the accident site immediately after they began looking for primary radar echoes. Primary radar relies solely on reflected radar beams and is not dependent on an active response from a transponder, as secondary radar is. The object was visible on the radar from when the observation began, at approximately 14:57, until 15:20.

Shroud Doors and the Accident Investigation Board's Hypothesis

The accident investigation board claims that the rudder deflected beyond its normal travel in both directions, struck the shroud doors, shattered them, and released honeycomb that produced the radar echoes:

«The technical investigations have shown that the rudder deflected beyond its normal travel in both directions. As a result, the rudder's balance weights struck the shroud doors, shattered them, and released honeycomb that was part of the structure of the shroud doors. The investigation has established that only this material, sheets of aluminium honeycomb, could have produced the radar echo that was observed by Swedish radar and by the approach radar at Aalborg airport. On the exterior of the aircraft, there were no other materials or composite structures that could satisfy the criteria with respect to density, geometric shape, and reflection value. The radar observations show that honeycomb was released at high altitude, most probably already at cruise altitude. When the aircraft is in motion at cruise speed, the forces required to give the rudder full deflection are so great that it is not possible to transmit them through the control system. The oscillations can therefore not have been initiated by the crew or the autopilot, or by a fault in the control linkages or transmission system.

For the rudder to have made such deflections while the aircraft was at cruise speed, it must have been subjected to abnormal aerodynamic forces, possibly combined with mechanically transmitted forces from the vertical stabiliser (tail fin).» (The Accident Report, 1993, p. 100)

«It is the commission's view that the oscillations in the fin reached a level where the rudder was affected both aerodynamically through disturbances in the airflow, and that mechanical

forces were transmitted through the rudder hinges. This effect set the rudder into oscillations that the rudder's balance weights eventually did not have the capacity to dampen. When the shroud doors were shattered, the conditions were further worsened by the increase in turbulence in the gap between the rudder and the fin.» (The Accident Report, 1993, p. 101)

The Aircraft Manufacturer's Assessment

The accident investigation board received a response from Convair, the aircraft manufacturer, regarding experience with damage to shroud doors. The response paints a substantially different picture from what the accident investigation board assumed:

«In regard to the yaw produced by a failure of the shroud panels, we have no test data available. We have, however, gone through our correspondence files from 1952 through the present time. This search showed that we have received reports from the operators telling us of delaminated shroud panels both on the vertical and the horizontal stabilizers. In one case a horizontal stabilizer shroud panel was completely delaminated for a length of two feet. This panel was replaced. None of these reports contained any mention of adverse flight control conditions resulting from the delamination. We have issued repair limits for delamination of these panels and published it in our 440 Structural Repair Manual.

In only one instance was any mention made as to the reaction of the airplane to a problem such as this. This incident was a case where the horizontal stabilizer shroud panel hinge pin had backed out of the hinge for a distance of 30 inches, leaving the end of the shroud panel loose. The report stated that the end of the panel protruded into the airstream causing heavy control forces. Convair subsequently issued service bulletin 640(340D) S.B. No. 55-1 to improve the method of retention of the hinge pins. A copy of the first page of this bulletin is enclosed for your information.

In addition the above our file search revealed several cases of torn balance curtains. We have also issued repair information for rips and tears in the curtains. No specific limitations were given except that if the repairs caused the control forces to feel high, the curtain must be replaced. Since we found no reports of a massive failure or loss of a shroud panel, we cannot comment specifically on the effect of such a failure. It is apparent, however, that the normal in-service delamination that have been experienced in the past did not result in an airplane control problem to the extent that it was considered reportable to Convair.» (General Dynamics, 1991, pp. 1–2)

Convair's own review of correspondence spanning nearly 40 years shows that delamination of shroud doors has occurred on both vertical and horizontal stabilisers—in one case over a length of two feet—without any problems with the aircraft's handling being reported. The accident investigation board has apparently assumed that the destruction of the shroud doors in itself dramatically worsened the situation, but this stands in contrast to Convair's experience data.

Military Radar

The wreckage was registered by both Swedish and Danish civilian radar. Military radar in the area would most likely also have registered the same observations, but no radar data has been received from the Armed Forces, and there are no statements regarding what their primary radar observed after the accident.

Conclusion

The accident investigation board has overlooked elementary logical flaws that should have been discussed:

1. **Flutter requires a dive.** Flutter cannot have developed in the control surfaces without the aircraft being in a dive, given that the control surfaces were intact at cruise speed. Damage due to a close pass has been excluded by the accident investigation board, which has concluded that the F-16 was never in the vicinity of the Partnair aircraft.
2. **A dive means altitude loss.** The aircraft must have lost many thousands of feet to achieve speeds that produce flutter, and therefore cannot have been at cruise altitude (21,100 feet) as Mode C radar data shows at 14:37:02.
3. **The radar echo shows late separation.** The calculations show that the objects registered by Swedish radar separated from the aircraft in the final phase of the accident—at the calculated time of disintegration—and not in an early phase. Had the shroud doors fallen off while the aircraft was at cruise altitude further north, the radar echo would have appeared at an entirely different location.
4. **Convair's experience data.** The manufacturer's own review shows that delamination of shroud doors has never resulted in reported handling problems, which weakens the hypothesis that destruction of shroud doors in itself dramatically worsened the situation.

An erroneous altitude indication via Mode C cannot be explained away by the radar system's prediction logic. This is the clearest evidence that there are errors in the radar data for the accident sequence.

A more probable hypothesis is that damage occurred in the rudder and developed to become catastrophic. The shroud doors were likely knocked loose midway through the accident sequence, but not while the aircraft was at cruise altitude. The aircraft dived, and as it rapidly lost altitude, flutter developed due to overspeed. When the tail section disintegrated, the pressure cabin ruptured and thousands of parts were ejected. It is this wreckage that was observed by Swedish and Danish radar.

It is difficult to understand why the accident investigation board overlooked these logical flaws. The simplest explanation is that they concluded early on that the cause was play in hinges and unhardened bolts that caused vibrations, and that they subsequently only interpreted observations and findings in a manner that supported this conclusion.

Radar Data

Radar data is essential in the investigation of aircraft accidents. In the Partnair case, the radar data has been decisive for the accident investigation board's conclusions and for the outcome of the subsequent lawsuits between Partnair and the state.

Despite the fact that, in theory, large quantities of radar data should have been available from multiple radar stations, surprisingly little data exists. The radar data that has been presented bears the hallmarks of post-processing, contains inexplicable errors and contradictory information, and has been delivered in multiple versions with mutual discrepancies. It is not possible to use the available radar data to prove exactly how close the aircraft were to each other, but it is possible to establish that the data has been altered.

Background

There are primarily two aspects that radar data can help illuminate:

1. When the Partnair aircraft began to deviate from its heading, cruise speed, and altitude
2. Whether other aircraft in the area were close enough to have been able to affect the Partnair aircraft

The accident investigation board concluded that everything appeared normal almost right up until the Partnair aircraft disappeared from radar, and that no other aircraft were close enough to have been a contributing factor. In subsequent lawsuits between Partnair and the state, regarding whether the F-16 caused the accident, the state prevailed based on the radar data evidence.

That the radar data is correct and has sufficient resolution are fundamental premises for being able to use radar data as evidence.

Radar Technology

The principle behind primary radar is relatively simple: a radio signal is transmitted and an antenna receives the reflected signal. By measuring the time from when the signal is transmitted until the reflection is received, the distance can be calculated. The radar head rotates continuously and registers the bearing (azimuth) and range to the aircraft.

It is not possible to determine exact altitude using primary radar. This is the reason civilian aviation primarily uses secondary surveillance radar (SSR). This radar transmits a signal that is received by the transponder in the aircraft, and the transponder responds with information in return. In 1989, Mode A (identifier/squawk code) and Mode C (pressure altitude) were in use. In addition to bearing and range, the secondary radar thus provided a four-digit ID and precise altitude measurement from the individual aircraft's transponder.

For military purposes, one naturally cannot rely on information transmitted from a transponder in an aircraft, and therefore there is far more extensive use of primary radar for

military purposes than in the civilian context. A 3D radar is a primary radar that scans the sky with a narrow radar beam so that the radar can also calculate the aircraft's altitude. The Partnair aircraft was within the coverage area of the Armed Forces' 3D radar at Eigersund, but no data from this radar has been presented in this case.

Stereographic Projection

Position data from the radar sources in this case is based on stereographic projection. In order to plot the positions on a map or calculate speed, the data points must be converted to latitude and longitude. The projection algorithm takes the radar station's coordinates as its centre, and the positions in the raw data are given in "data miles," which are then converted to metres before being transformed into geographic coordinates.

NATINADS

«The NATO Integrated Air Defense System» (NATINADS) is a network of radar stations and control centres. Mågerø and Skagen radar were part of this network. Neråsen wrote on 13 September, in a letter regarding radar data from Mågerø radar:

«Please note that all data is based on information that is automatically transferred from Danish radar to Lstn Måkerøy.» (Neråsen, 1989, p. 1)

In practice, this means that radar data from Skagen and Mågerø may consist of information from radar stations other than solely the station from which the printout originates.

Radar Sources

«HSL has had access to information from the following sources: Oslo ACC radar, the military radar at Måkerøy, the military radar at Skagen in Jutland, radar data from Skagen transferred to Måkerøy, a NATO AWACS aircraft circling north of Zealand approximately 120 NM (220 km) from the accident site, two radar stations in the Swedish Armed Forces, the approach radar at Aalborg airport, Copenhagen ACC radar.» (The Accident Report, 1993, p. 78)

To construct a picture of where the Partnair aircraft and other aircraft were moving, the accident investigation board has had multiple sources to draw upon. The accident investigation board early in the process dismissed the possibility that the F-16 may have influenced the sequence of events, and thus had no need to prove that the F-16 had flown close to the Partnair aircraft.

The radar data that has been relied upon provides no evidence of a close pass, but neither does it provide evidence that a close pass did not take place. The data from the NATO radars is apparently unreliable and incomplete. From Swedish military radar, and civilian radars in Norway, Sweden, and Denmark, no data is available that can be used to verify the accident investigation board's conclusions.

Actual radar data that can be plotted on a map comes from only three sources: AWACS, Skagen, and Mågerø. The AWACS data for the F-16 contains only 9 coordinates, and none

of them shows the point of passing. The Skagen data has been delivered in two different versions with mutual discrepancies. The Mågerø data is based on a simulation.

Radar source	Type of data	Comment	Value as evidence
Oslo ACC radar	Unknown	Not discussed in the accident report	Unknown
Måkerøy	Data dump	Simulated data, which does not show the actual situation	None: not real data
Skagen	Data dump	Data dump with many errors, apparently showing physically impossible situations	None: not real data
Skagen transferred to Måkerøy	Data dump	Same data as Skagen, thus not a separate data source	None: not real data
AWACS	Data dump and sketches	9 points for the F-16, but no data points at the time of passing	Low: too little data
Swedish radar	Sketches and descriptions of recordings from radar screen	Only 1 of 2 sketches is appended to the report. One sketch shows parts from the Partnair aircraft.	Low: missing base data
Aalborg radar	Report with description	Observation of a stationary object 41 NM north of Aalborg	None: missing data
Copenhagen ACC radar	Description	The report refers to "something" being seen 40 NM north of Aalborg	None: missing data

Timeline of Radar Data Delivery

Despite the fact that the Armed Forces knew that the F-16 passed the Partnair aircraft, and had Norwegian, Danish, and American radar data showing the pass, the Armed Forces initially denied that there was any aircraft other than a Braathens in the area. Only three weeks after the accident did the Armed Forces deliver radar data showing the F-16 in the area.

Five months after the accident, the Armed Forces delivered a complete radar dataset for the Partnair aircraft, while there are only fragments of radar data for the F-16. None of the datasets from Mågerø or Skagen can be direct data dumps from the radar systems; they bear clear signs of having been post-processed.

Two and a half years later, when the accident investigation board was in the process of finalising the report, the Armed Forces delivered a new version of the radar data. This dataset also contains major errors and corresponds neither with the first dataset nor with reality.

Date	From	To	
13.09.1989	Richard Nielsen, Air Traffic Service Aalborg Airport	The accident investigation board	Observation of a stationary object above the accident site between 14:55 and 15:20.
13.09.1989	Bjørn Neråsen	The accident investigation board	«Hereby transmitted are all data that the Air Force Station Måkerøy can contribute regarding the above-mentioned accident.» (Neråsen, 1989, p. 1). Every third plot from the simulated Mågerø data is appended to the letter.
19.09.1989	Nato Airborne Early Warning Force, Geilenkirchen, NATO Air Base	Kontroll og Varslingsgruppen ATEN: O-afdelingen Denmark	AWACS data plot of the F-16, Partnair, and Braathens. (The appended dataset consists of 9 points for the F-16, and is missing approximately 3.5 minutes around the time of the pass.)
19.09.1989	Bjørn Neråsen	The accident investigation board	«In accordance with the agreement between Rygnestad, the Accident Investigation Board, and Johannessen, Lstn Måkerøy, hereby transmitted are data on other aircraft movements in the area near the time of the accident. As the appendix shows, only one – 1 – aircraft movement in the vicinity of the accident site has been registered. It is Braathens SAFE BRA 405 from ENFB to EKBI.» (Neråsen, 1989, p. 1)
22.09.1989	The Civil Aviation Authority	The accident investigation board	«Hereby transmitted is an audio tape copy of the conversation between Oslo ACC and M5007 on 8.9.89.» ("Letter Regarding Audio Tape Copy," 1989, p. 1)
26.09.1989	Danish accident investigation board	The accident investigation board	Barvik collects printout of radar data from Skagen radar at the accident investigation board in

			Denmark.
27.09.1989	Bjørn Neråsen	The accident investigation board	«Hereby transmitted is the plotted track for PARTNAIR's aircraft and the F-16 on the opposite heading.» (Neråsen, 1989, p. 1)
28.09.1989	F-16 pilot	The accident investigation board	«At approximately 1430Z, I detected an aircraft on the radar coming straight towards me—at approximately the same altitude.» (Norwegian 5007, 1989, p. 1)
11.10.1989	Olle Forssberg	The accident investigation board	Sketches produced based on radar data from military radar stations in Sweden.
07.02.1990	Sigve Barvik	The accident investigation board	Dataset from Måkerøy and Skagen.
19.08.1992	Sigve Barvik	The accident investigation board	New version of dataset from Skagen radar.

Data Volume and Quality

Potential Data Volume

At both Mågerø and Skagen, there were three radar heads: two 2D radars and one height-finding radar. Only radar data from the 2D radars is available, not from the height-finding radar. The rotation speed of the Skagen radar was 5 revolutions per minute. Mågerø's radar heads rotated 6 times per minute. The AWACS aircraft's radar head rotated 6 times per minute.

If one were to draw upon the raw data from Skagen, Mågerø, and AWACS, there would have been approximately 980 data points for Partnair and 560 for the F-16 from the five radar heads. In order to study deviations and establish the precision of the measurements, it is important to have as much data as possible. The five radar heads collectively registered the aircraft 28 times per minute. Even when studying only a small segment of the flight, there should potentially be very good radar data coverage for both the F-16 and the Partnair aircraft.

Aircraft	**Flight time**	**Skagen x 2**	**Mågerø x 2**	**AWACS**	**Total**
Partnair	35 min	350	420	210	**980**
F-16	20 min	200	240	120	**560**

Available Data Volume

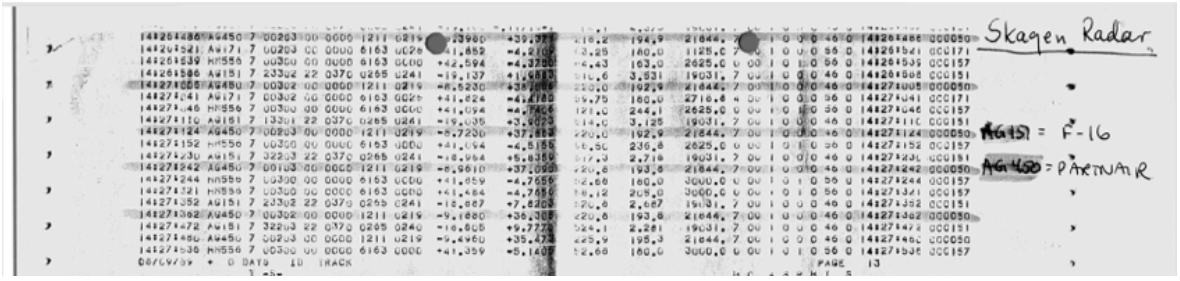
Raw data is available from Skagen, Mågerø, and AWACS. The total data volume is very small relative to the number of registrations the radars made. For Skagen and Mågerø, the raw data covers only a period of five minutes. In other words, it is not possible to use raw data to verify all the post-processed radar data documents, since these cover a larger time span.

Fly	Skagen	Mågerø	AWACS	Total
Partnair	23	21	69	**113**
F-16	24	19	9	**52**
Braathens	13	16	66	**95**

Raw Data Versus Post-Processed Data

Radar data exists in two types of documents. One type appears to be printouts from the tracker in the radar system, while the other appears to have been post-processed by humans. In 1989, it was not as straightforward to exchange data between systems as we are accustomed to today. It is therefore reasonable to assume that the transfer of data from the radar system to a word processor was based on a manual process.

While with machine-based, digital data transfer one would expect zero errors, there is a high probability of typographical errors where humans have manually transferred data from one system to another.



Example of raw data from Skagen radar.

TRACK DATA PRINTOUT OF TRACK AG151. F-16 to Rygge

DATE 08 SEP 89, SKAGEN RADAR

SYST TIME HH:MM:SEC	TRACK NUMBR	T Q	ACTIV 123CC	M1	MOD2	SIF/IFF 3/A	3/C	X.POS DATA M	Y.POS DATA M	SPEED DM/HR	HDGNG DEGRE	HIGHT FEET	OK
14:27:11.0	AG151	7	13301	..	....	0265	----	-19,035	+3,9023	514,0	3,125	24100	3/C
14:27:23.0	AG151	7	32203	..	....	0265	0241	-18,984	+5,8359	517,3	2,718	24100	3/C
14:27:35.2	AG151	7	23302	..	....	0265	0241	-18,887	+7,8203	520,8	2,687	N/M	
14:27:47.2	AG151	7	32203	..	....	0265	0240	-18,805	+9,7770	524,1	2,281	24000	3/C
14:27:59.2	AG151	7	23302	..	....	0265	0240	-18,477	+11,723	524,9	3,812	N/M	
14:28:11.2	AG151	7	32203	..	....	0265	0241	-17,785	+13,758	528,4	7,625	24100	3/C
14:28:23.4	AG151	7	23302	..	....	0265	0241	-17,152	+15,617	528,8	10,31	N/M	
14:28:35.6	AG151	7	32203	..	....	0265	0241	-16,574	+17,508	530,8	11,43	24100	3/C
14:28:47.5	AG151	7	23302	..	....	0265	0241	-15,805	+19,453	536,2	14,03	N/M	
14:28:59.5	AG151	7	32203	..	....	0265	0241	-15,207	+21,348	538,0	14,75	24100	3/C
14:29:11.5	AG151	7	31103	..	....	0265	0241	-14,496	+23,297	544,1	15,71	24100	3/C
14:29:23.6	AG151	7	23302	..	....	0265	0241	-13,887	+25,152	541,7	16,18	N/M	
14:29:35.6	AG151	7	32203	..	....	0265	0241	-13,367	+27,000	540,8	15,81	24100	3/C
14:29:47.5	AG151	7	23102	..	....	0265	0241	-12,719	+28,926	541,7	16,18	N/M	
14:29:59.6	AG151	7	32003	..	....	0265	0241	-12,027	+30,855	543,8	16,90	24100	3/C
14:30:11.5	AG151	7	23302	..	....	0265	0241	-11,461	+32,813	546,1	16,43	N/M	
14:30:23.4	AG151	7	32203	..	....	0265	0241	-11,145	+34,637	538,8	15,09	24100	3/C
14:30:27.6	AG151	7	32203	..	....	0265	0241	-11,145	+34,637	538,8	15,09	24094	MC
14:30:32.7	AG151	7	32203	..	....	0265	0241	-10,281	+36,576	604,6	15,15	22687	H/F

TRACK RAPPORTERING OVER TIL MAKERØY RADAR

14:30:42.6	AG151	7	32303	..	....	0265	0241	-10,016	+38,203	594,2	14,03	24844	H/F

Example of post-processed radar data for the F-16.

The raw data from the radar systems contains data for multiple aircraft. The position data is based on stereographic projection. In the documents with the post-processed radar data, data for the different aircraft has been separated, and position data has been converted to latitude and longitude. There are also instances where radar data from different radar stations has been merged into one document.

It is natural to assume that the post-processed radar data is based on the raw data printouts, and that they therefore contain exactly the same data. The raw data contains information from both primary and secondary radar, and there is no information suggesting that other radar sources were used as the basis for the post-processed documents. All discrepancies between the raw data and the post-processed radar data are therefore important, as they may indicate transcription errors or that unknown radar sources have been used.

Identifying Radar Sources in the Raw Data

Based on the different rotation speeds of the radars, Mågerø radar data can be identified by the fact that the radar heads registered the aircraft every 10 seconds. Skagen's radar heads took 12 seconds per revolution.

The printouts from the radar systems at Skagen and Mågerø have the same format. In a cover letter accompanying post-processed radar data, there is a description of what the various columns in the data printouts mean, but not all columns are described.
(Barvik, 1992, p. 7)

Column title	Column description	Comment
SYST TIME	Timestamp	
TRACK NUMBER	Track identifier	
TRACK Q	Indication of how recently the track was updated	
AIF ACT 123CC	Quality indicator for how old the secondary radar data is	3 = fresh data, d0 = old data. The middle of the 5 digits concerns "mode 3/A and 3/C"
SIF CODES	Data received from the transponder in the aircraft	Mode 1 and 2 are for military aircraft only. Mode 3/A (ident/squawk) and 3/C (pressure altitude) are also used by civilian aircraft.
X POS. / Y POS.	Position, stereographically projected	The position is calculated using the relevant radar station's position as origin, regardless of which radar station the information comes from.
SPEED DM/HR	Speed in "data miles" per hour	1 DM = 6,000 feet. DM/1.012 = knots
HDG. DEG.	Heading between data points	The radar system calculates the heading based on the change in position. The values may have been "smoothed" by the radar system by using averages from multiple measurements.
HEIGHT FT.	Altitude in feet	
HT STALE	Indication of how recently the altitude was measured	0 = updated last scan, 7 is the highest value, indicating a long time since the data was updated
CONS ADD		Unknown meaning
AUTO/MAN		Likely: binary value for "automatic" versus "manual." 0=auto, 1=man
SIM/LIVE		Likely: binary value for "simulation" versus "live." 0=sim, 1=live
REM/LOC		Likely: binary value for "remote" versus "local." 0=remote, 1=local
MASS R		Unknown meaning
IDENT		Unknown meaning
SEC ID		Unknown meaning
SIM. TIME	Simulerings-tidspunkt	In the dataset, this always has the same value as system time
TRACK SLOT		Likely numeric track number in the local tracker

Of particular interest are the binary values (0/1) that describe where the data comes from.

By studying the raw data from Mågerø, one can see that data at 10-second intervals is marked with "1" in the "rem/loc" column, which indicates that remote=0 and local=1. It is reasonable to assume that the other binary columns, "auto/man" and "sim/live," are coded in the same way. Since radar data was distributed through NATO's NATINADS network, there is a need to distinguish data registered by the local radar station from data that came from another station.

Plot	System time	Interval	3/C-	Speed	Heading	Height	Stale	Rem/Loc
2	14:28:08.0		0000	200.3	195.2	21 750	7	1
8	14:28:17.0	9	0000	200.3	195.2	21 750	7	1
14	14:28:27.6	10.6	0000	200.3	195.2	21 750	7	1
21	14:28:37.8	10.2	0000	200.3	195.2	21 750	7	1
28	14:28:47.5	9.7	0000	200.3	195.2	21 750	7	1
34	14:28:57.8	10.3	0000	200.3	195.2	21 750	7	1
40	14:29:07.8	10	0000	200.3	195.2	21 750	7	1

Example from the Mågerø data showing the Partnair aircraft at 10-second intervals.

For the F-16, the Mågerø data appears to consist of two measurements made by Mågerø radar, before the interval changes to 12 seconds and the rem/loc value changes from 1 to 0. This indicates that the radar data for the F-16 comes from a radar station other than Mågerø.

Plot	System time	Interval	3/C-	Speed	Heading	Height	Stale	Rem/Loc
3	14:28:12.2		0000	509.1	9.125	18 750	7	1
9	14:28:20.2	8	0000	509.1	9.125	18 750	7	1
16	14:28:30.3	10.1	0241	634.7	18.71	24 937	0	0
26	14:28:42.3	12	0241	611.4	18.4	24 937	0	0
31	14:28:54.5	12.2	0241	616.9	17.9	25 031	0	0
38	14:29:06.5	12	0241	615.9	17.59	25 031	1	0
45	14:29:18.4	11.9	0241	629.3	17.21	25 219	0	0

Example from the Mågerø data showing the F-16 with changing intervals and rem/loc values.

Radar Analysis

A primary radar measures bearing and distance to objects, while secondary radar additionally receives identification numbers and altitude measurements from the aircraft's transponder. The tracker in the radar system filters out noise from the measurements, follows aircraft over time, and calculates the aircraft's speed and heading. In 1989, some radar stations were still analogue, while others had transitioned to digital technology. Data analysis from an analogue radar system typically had to be done by observing the radar data on a screen, while the digital systems also made it possible to export the data as numerical values.

Different radars have different precision in their measurements, depending on the distance between the radar station and the aircraft. The radar systems at both Mågerø and Skagen consisted of multiple radar heads with primary, secondary, and a dedicated height-finding radar. Data from all the radar heads was collated by the tracker and formed the basis for the printouts. Noise in the radar data has already been filtered out, and the collation of data from multiple radar heads provides measurements with relatively high precision.

To be able to use radar data to establish exactly where two aircraft were in relation to each other, multiple complete, correlating datasets from objective sources are needed. In this case, the Armed Forces are not an objective source, and there is therefore a need to scrutinise the radar data with particular care and to use other sources to verify it. Radar data from Sweden could not be used to establish exact distance, because at the point of passing, the aircraft were so close that the points merged on the radar screen and were therefore not recorded in the footage.

Apart from the sketches delivered by the Swedish Armed Forces, it appears that only the Armed Forces/NATO delivered radar data to the accident investigation board. The radar data has major errors and deficiencies, particularly regarding the movements of the F-16 aircraft, and shows physically impossible situations. The only thing that can be established with certainty is that radar data has been altered after recording, and it is therefore not possible to use it as evidence for where the aircraft were in relation to each other.

Data Basis

Mågerø, Skagen, and AWACS were all connected in NATO's radar network (NATINADS) and continuously exchanged radar data with one another. Radar operators could see radar data from a number of stations on their screens, and these radar data were stored on tape for later playback.

The accident investigation board has had access to printouts from Mågerø, Skagen, and AWACS. Sweden delivered sketches of the Partnair and F-16 aircraft tracks, but these were based on photographic recordings of the radar screen every 40 seconds and contained no altitude information. A track based on 40-second intervals will not be able to register frequent heading changes, and the tracks will potentially show a straighter line than the aircraft's actual movements.

On Danish civilian radar (Aalborg and Copenhagen), a stationary object was observed after the accident. This coincides with the observations from Swedish radar, which the accident investigation board has established originate from parts of the aircraft drifting eastward with the wind.

The entire flight of the F-16, Partnair, and Braathens aircraft was registered by the radars at Mågerø, Skagen, and AWACS. Given that Mågerø and Skagen each had two radar heads with rotation periods of 10 and 12 seconds respectively, the aircraft were registered every 5–6 seconds by each station. There are many hundreds of data points for each of the aircraft in NATO's radar datasets, but only a small fraction of this has been delivered.

The quality of the radar data is very low. The AWACS printout shows positions with built-in uncertainty that produces a "zigzag track." There are large quantities of blank or static values in the data from Mågerø and Skagen. There is a lack of consistency between the two stations, but even within each individual dataset there are inconsistent values.

Data printouts from all available radar stations should have been presented to the accident investigation board immediately after the accident. Since radar data is in practice merely an export of measurements made by a radar system, nothing more than this data export should have been required. In connection with the Partnair accident, radar data with a series of errors has been presented, and some of the datasets have been presented in multiple versions—something that should have been entirely unnecessary.

Data Printouts from Mågerø and Skagen

The most contemporaneous radar data from Mågerø and Skagen dates from shortly after the accident. On 13 September, radar data was transmitted from Mågerø to the accident investigation board, but this consists of only a few points with coordinates and timestamps.

N A T O U N C L A S S I F I E D

C A R D ********			*** C O N V E R T E D P O I N T ***	XOCT, YOCT****
-004.9492	-052.5350	14:28:080	581728N0101725E	0
-005.6875	-054.4260	14:28:378	581535N0101603E	0
-006.1875	-056.2970	14:29:078	581346N0101507E	0
-006.9336	-058.1560	14:29:381	581153N0101345E	0
-007.5664	-060.6330	14:30:184	580928N0101233E	0
-008.3200	-062.6520	14:30:480	580728N0101111E	0
-008.6910	-064.5080	14:31:183	580538N0101030E	0

(Neråsen, 13.09.1989, p. 3)

The radar data that Neråsen sent to the accident investigation board apparently originates from the Mågerø printout, since the timestamps and coordinates are identical. It is worth noting that only every third point for the Partnair aircraft was included in Neråsen's

transmission—only position and timestamp—so it is natural to question whether this really was «all data that the Air Force Station Måkerøy can contribute.» (Neråsen, 1989, 13 September, p. 1)

Plot	System time	Interval	Track Number
2	14:28:08.0		AG450
8	14:28:17.6	9.6	AG450
14	14:28:27.6	10.0	AG450
21	14:28:37.8	10.2	AG450
28	14:28:47.5	9.7	AG450
34	14:28:57.8	10.3	AG450
40	14:29:07.8	10.0	AG450
44	14:29:17.9	10.1	AG450
51	14:29:28.1	10.2	AG450
58	14:29:38.1	10.0	AG450
72	14:29:58.2	20.1	AG450
79	14:30:07.9	9.7	AG450
85	14:30:18.4	10.5	AG450
88	14:30:28.6	10.2	AG450
94	14:30:38.6	10.0	AG450
99	14:30:48.0	9.4	AG450
104	14:30:58.1	10.1	AG450
109	14:31:08.1	10.0	AG450
114	14:31:18.3	10.2	AG450
117	14:31:28.6	10.3	AG450
128	14:31:38.5	9.9	AG450

Partnair at approximately 10-second intervals in the Mågerø dataset.

In Neråsen's cover letter, it also states: «Please note that all data is based on information that is automatically transferred from Danish radar to Lstn Måkerøy. The sortie has track number AG 450 in our computer.» (Neråsen, 1989, 13 September, p. 1)

This cannot be correct, since the Skagen radar had 12-second intervals, while the radar heads at Mågerø took 10 seconds per revolution.

On 19 September, Neråsen transmitted additional radar data from the Mågerø dataset. In the cover letter, it states: «As the appendix shows, only one – 1 – aircraft movement in the vicinity of the accident site has been registered. It is Braathens SAFE BRA 405 from ENFB to EKBI.» (Neråsen, 1989, 19 September, p. 1)

Only after VG revealed that there was an F-16 in the air over the Skagerrak did Neråsen transmit radar data showing the F-16:

«Hereby transmitted is the plotted track for PARTNAIR's aircraft and the F-16 on the opposite heading.» (Neråsen, 1989, 27 September, p. 1)

The F-16 pilot submitted his report to the accident investigation board on 28 September, the day after Neråsen sent the radar data.

The data printout from Skagen radar was collected at Flyvestation Skagen on 26 September 1989 by Sigve Barvik, on behalf of the Norwegian accident investigation board.

MÅKERØY RADAR
BLÅTT

SYST TIME HH:MM:SSS	TRACK NUMBER	Q	TACT 123CC	SIF 1-	SIF 2---	SIF 3/A-	SIF 3/C-	STEREOGRAPHIC X POS. DM	STEREOGRAPHIC Y POS. DM	SPEED DM/HR	HDG. DEG.	HEIGHT FT.	HC TO NS LAD	ASUMP/ADE	SIMULAT/ANE	RMIOR	MISSLE/VC	SEC TARGET	SIF. TIME HH:MM:SSS	TRACK SLOT
14:28:000	HM556	7	00300	00	0000	6163	0000	+46.891	-90.730	24.56	180.0	3000.0	0	00	1	0	1	0	56	0	14:28:000	000060
14:28:080	AG450	7	00000	00	0000	0000	0000	-4.9492	-52.535	200.3	195.2	21750.	7	00	1	0	1	0	46	0	14:28:080	000041
14:28:122	AG151	7	00000	00	0000	0000	0000	-11.203	-67.363	509.1	9.125	18750.	7	00	1	0	1	0	46	0	14:28:122	000110
14:28:126	HM556	7	00300	00	0000	6163	0000	+46.891	-90.891	24.56	180.0	3000.0	0	00	1	0	1	0	56	0	14:28:126	000060
14:28:137	AG571	7	00000	00	0000	0000	0000	-1.8438	-35.961	277.6	180.0	0.0000	7	00	1	0	1	0	40	0	14:28:137	000172
14:28:139	AG601	7	00000	00	0000	0000	0000	+26.016	-33.961	137.0	180.0	0.0000	7	00	1	0	1	0	40	0	14:28:139	000173
14:28:141	AG212	7	00000	00	0000	0000	0000	-29.063	-39.828	193.8	135.0	0.0000	7	00	1	0	1	0	40	0	14:28:141	000174
14:28:176	AG450	7	00000	00	0000	0000	0000	-5.0273	-52.973	200.3	195.2	21750.	7	00	1	0	1	0	46	0	14:28:176	000041
14:28:202	AG151	7	00000	00	0000	0000	0000	-10.766	-66.262	509.1	9.125	18750.	7	00	1	0	1	0	46	0	14:28:202	000110
14:28:204	HM556	7	00300	00	0000	6163	0000	+47.156	-91.379	24.56	180.0	3000.0	0	00	1	0	1	0	56	0	14:28:204	000060
14:28:214	AG571	7	00000	00	0000	0000	0000	-1.8438	-36.582	277.6	180.0	0.0000	7	00	1	0	1	0	40	0	14:28:214	000172
14:28:214	AG601	7	00000	00	0000	0000	0000	+25.016	-34.160	137.0	180.0	0.0000	7	00	1	0	1	0	40	0	14:28:214	000173
14:28:215	AG212	7	00000	00	0000	0000	0000	-28.859	-40.156	193.8	135.0	0.0000	7	00	1	0	1	0	40	0	14:28:215	000174
14:28:276	AG450	7	00000	00	0000	0000	0000	-5.3047	-53.703	200.3	195.2	21750.	7	00	1	0	1	0	46	0	14:28:276	000041
14:28:301	HM556	7	00300	00	0000	6163	0000	+47.156	-91.520	24.56	180.0	3375.0	0	00	1	0	1	0	56	0	14:28:301	000060
14:28:303	AG151	7	32303	22	0370	0265	0241	-9.8480	-65.168	634.7	18.71	24537.	0	00	1	0	0	0	46	0	14:28:303	000110
14:28:303	AG571	7	00300	00	0000	1261	0000	-2.8438	-38.063	277.6	180.0	0.0000	7	00	1	0	1	0	40	0	14:28:303	000172
14:28:305	KK577	7	00303	00	0000	6413	0122	-23.449	-1.3242	197.6	253.5	12537.	0	00	1	0	0	0	40	0	14:28:305	000177
14:28:307	AG601	7	00300	00	0000	7171	0000	+23.766	-33.023	137.0	180.0	0.0000	7	00	1	0	1	0	56	0	14:28:307	000173
14:28:313	AG212	7	00300	00	0000	1273	0000	-29.781	-41.734	193.8	135.0	0.0000	7	00	1	0	1	0	46	0	14:28:313	000174
14:28:378	AG450	7	00000	00	0000	0000	0000	-5.6875	-54.426	200.3	195.2	21750.	7	00	1	0	1	0	46	0	14:28:378	000041
14:28:408	HM556	7	00300	00	0000	6163	0000	+47.156	-91.738	24.56	180.0	3375.0	0	00	1	0	1	0	56	0	14:28:408	000060

Data printout from Mågerø, September 1989.

Leveres fra: Flyvestation Skagen
Leveres til: Haverikommisionen
Ind- og udleveringsseddel — Indlevering / Udlevering
361190
Dato: 26.09.89.
Lager nr. | Benævnelse: 3 sider Dataudskrift - TRACK HISTORY | Godkendt | Korrekturlæst og bogført | Mængde | Vedlegning | Linie nr.
nr. 04013 - 04015
Reference: Flystyrt i Tannisbuot 1989
Udstedere underskrift
Ovennævnte forsyningsgenstande kan: indleveres / udleveres
Dato
Sted
For modtagelsen af ovennævnte forsyningsgenstande kvitteres:
Egne Lager for Havarikommisjonen i Oslo
VFB275a(71) (575.5010)
7530-22-400-0051

Skagen Radar
uden moder C
med Blinde indikator
Printet på Skagen 26/9-89
til Egne Lager

The data printout from Skagen radar was collected at "Flyvestation Skagen" on 26.09.1989, by Sigve Barvik, on behalf of the Norwegian accident investigation board.

Source of Radar Data

That the F-16 radar data delivered from Mågerø in September 1989 originates from Skagen radar is an essential detail. The registrations made by the radar heads at Skagen were transferred via NATINADS to Mågerø. If one compares printouts with F-16 data from Skagen and Mågerø, each individual registration must be identical. This is not the case—none of the registrations are identical. There are two possible reasons: the data originates from other radar sources, or it is wholly or partially synthetic.

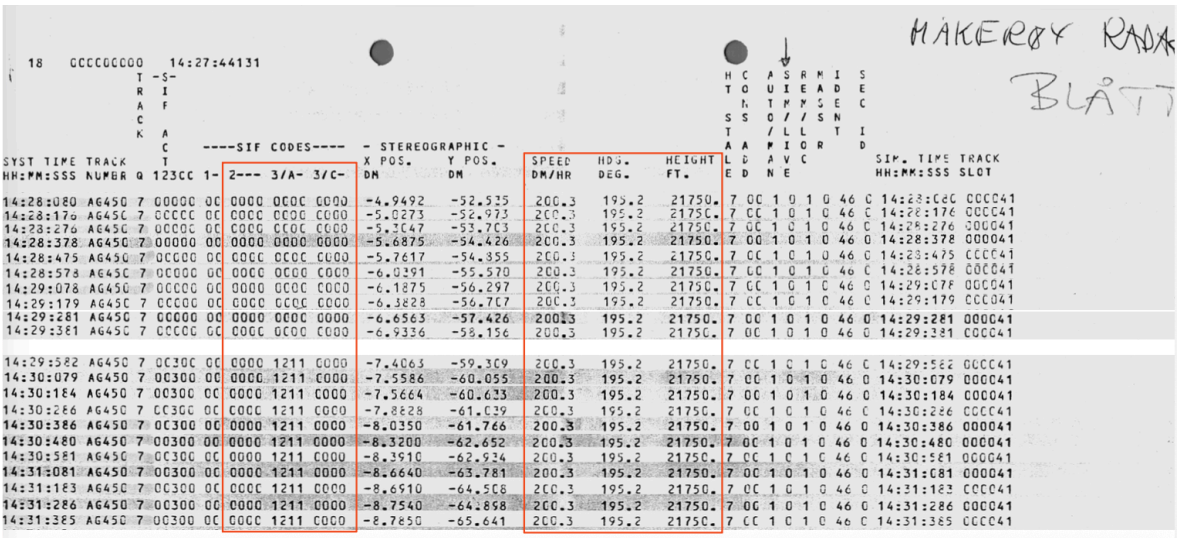
Plot	System time	Interval	Track Number
3	14:28:12.2		AG151
9	14:28:20.2	8.0	AG151
16	14:28:30.3	10.1	AG151
26	14:28:42.3	12.0	AG151
31	14:28:54.5	12.2	AG151
38	14:29:06.5	12.0	AG151
45	14:29:18.4	11.9	AG151
52	14:29:30.5	12.1	AG151
62	14:29:42.3	11.8	AG151
68	14:29:54.3	12.0	AG151
75	14:30:06.3	12.0	AG151
82	14:30:18.3	12.0	AG151
89	14:30:30.3	12.0	AG151
96	14:30:42.3	12.0	AG151
100	14:30:54.2	11.9	AG151
106	14:31:06.1	11.9	AG151
111	14:31:18.1	12.0	AG151
118	14:31:30.1	12.0	AG151
131	14:31:42.2	12.1	AG151

F-16 at approximately 12-second intervals in the Mågerø dataset (cannot originate from the radar heads at Mågerø).

Static Values for the Partnair Aircraft

For Partnair, it is in practice only time and position that change in the Mågerø data, while speed, heading, and altitude are completely static. The transponder values for altitude (3/C) are missing, despite the aircraft's transponder functioning. In connection with the pass by the F-16, one line of data is missing, and after this, the identification (3/A) from the aircraft's transponder is registered.

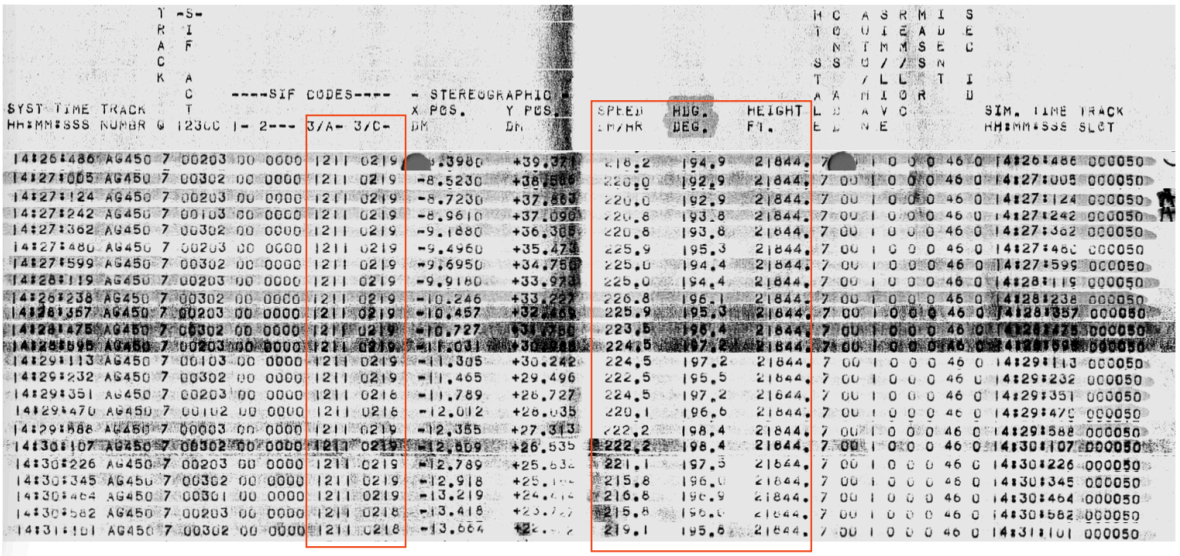
The tracker in the radar system calculates speed and heading based on changes in position between each registration. By performing the corresponding calculation, it is confirmed that the static values for speed and heading are not real.



SYST TIME TRACK HH:MM:SSS	NUMBER	Q	123CC 1-	2---	3/A-	3/C-	X POS. DM	Y POS. DM	SPEED DM/HR	HDG. DEG.	HEIGHT FT.	SIM. TIME TRACK HH:MM:SSS SLOT
14:28:080	AG450	7	00000 00	0000	0000	0000	-4.9492	-52.535	200.3	195.2	21750.	14:28:080 000041
14:28:176	AG450	7	00000 00	0000	0000	0000	-5.0273	-52.973	200.3	195.2	21750.	14:28:176 000041
14:28:276	AG450	7	00000 00	0000	0000	0000	-5.3047	-53.703	200.3	195.2	21750.	14:28:276 000041
14:28:378	AG450	7	00000 00	0000	0000	0000	-5.6875	-54.426	200.3	195.2	21750.	14:28:378 000041
14:28:475	AG450	7	00000 00	0000	0000	0000	-5.7617	-54.355	200.3	195.2	21750.	14:28:475 000041
14:28:578	AG450	7	00000 00	0000	0000	0000	-6.0391	-55.570	200.3	195.2	21750.	14:28:578 000041
14:29:078	AG450	7	00000 00	0000	0000	0000	-6.1875	-56.297	200.3	195.2	21750.	14:29:078 000041
14:29:179	AG450	7	00000 00	0000	0000	0000	-6.3828	-56.707	200.3	195.2	21750.	14:29:179 000041
14:29:281	AG450	7	00000 00	0000	0000	0000	-6.6563	-57.426	200.3	195.2	21750.	14:29:281 000041
14:29:381	AG450	7	00000 00	0000	0000	0000	-6.9336	-58.156	200.3	195.2	21750.	14:29:381 000041
14:29:582	AG450	7	00300 00	0000	1211	0000	-7.4063	-59.309	200.3	195.2	21750.	14:29:582 000041
14:30:079	AG450	7	00300 00	0000	1211	0000	-7.5586	-60.055	200.3	195.2	21750.	14:30:079 000041
14:30:184	AG450	7	00300 00	0000	1211	0000	-7.5664	-60.633	200.3	195.2	21750.	14:30:184 000041
14:30:286	AG450	7	00300 00	0000	1211	0000	-7.8828	-61.039	200.3	195.2	21750.	14:30:286 000041
14:30:386	AG450	7	00300 00	0000	1211	0000	-8.0350	-61.766	200.3	195.2	21750.	14:30:386 000041
14:30:480	AG450	7	00300 00	0000	1211	0000	-8.3200	-62.652	200.3	195.2	21750.	14:30:480 000041
14:30:581	AG450	7	00300 00	0000	1211	0000	-8.3910	-62.934	200.3	195.2	21750.	14:30:581 000041
14:31:081	AG450	7	00300 00	0000	1211	0000	-8.6640	-63.781	200.3	195.2	21750.	14:31:081 000041
14:31:183	AG450	7	00300 00	0000	1211	0000	-8.6910	-64.508	200.3	195.2	21750.	14:31:183 000041
14:31:286	AG450	7	00300 00	0000	1211	0000	-8.7540	-64.858	200.3	195.2	21750.	14:31:286 000041
14:31:385	AG450	7	00300 00	0000	1211	0000	-8.7850	-65.641	200.3	195.2	21750.	14:31:385 000041

Partnair, Mågerø – static values.

In the dataset from Skagen, there are apparently normal registrations from the Partnair aircraft's transponder. Speed and heading show even but varying values. The altitude measurement is static, which the radar system also indicates with the "HT STALE" value set to 7.



SYST TIME TRACK HH:MM:SSS	NUMBER	Q	123CC 1-	2---	3/A-	3/C-	X POS. DM	Y POS. DM	SPEED DM/HR	HDG. DEG.	HEIGHT FT.	SIM. TIME TRACK HH:MM:SSS SLOT
14:26:486	AG450	7	00203 00	0000	1211	0219	[illegible].3980	+39.32[illegible]	218.2	194.9	21844.	14:26:486 000050
14:27:005	AG450	7	00302 00	0000	1211	0219	-8.5230	+38.[illegible]	220.0	192.9	21844.	14:27:005 000050
14:27:124	AG450	7	00203 00	0000	1211	0219	-8.7230	+37.[illegible]	220.0	192.9	21844.	14:27:124 000050
14:27:242	AG450	7	00103 00	0000	1211	0219	-8.9610	+37.090	220.8	193.8	21844.	14:27:242 000050
14:27:362	AG450	7	00302 00	0000	1211	0219	-9.1880	+36.3[illegible]	220.8	193.8	21844.	14:27:362 000050
14:27:480	AG450	7	00203 00	0000	1211	0219	-9.4960	+35.47[illegible]	225.9	195.3	21844.	14:27:480 000050
14:27:599	AG450	7	00302 00	0000	1211	0219	-9.6950	+34.75[illegible]	225.0	194.4	21844.	14:27:599 000050
14:28:119	AG450	7	00203 00	0000	1211	0219	-9.9180	+33.97[illegible]	225.0	194.4	21844.	14:28:119 000050
14:28:238	AG450	7	00302 00	0000	1211	0219	-10.246	+33.227	226.8	196.1	21844.	14:28:238 000050
14:28:357	AG450	7	00203 00	0000	1211	0219	-10.457	+32.[illegible]	225.9	195.3	21844.	14:28:357 000050
14:28:475	AG450	7	00302 00	0000	1211	0219	-10.727	+31.[illegible]	223.5	196.4	21844.	14:28:475 000050
14:28:595	AG450	7	00203 00	0000	1211	0219	-11.031	+30.[illegible]	224.5	197.2	21844.	14:28:595 000050
14:29:113	AG450	7	00103 00	0000	1211	0219	-11.305	+30.242	224.5	197.2	21844.	14:29:113 000050
14:29:232	AG450	7	00302 00	0000	1211	0219	-11.465	+29.496	222.5	195.5	21844.	14:29:232 000050
14:29:351	AG450	7	00203 00	0000	1211	0216	-11.789	+28.727	224.5	197.2	21844.	14:29:351 000050
14:29:470	AG450	7	00102 00	0000	1211	0216	-12.012	+28.035	220.1	196.6	21844.	14:29:470 000050
14:29:588	AG450	7	00003 00	0000	1211	0219	-12.355	+27.313	222.2	198.4	21844.	14:29:588 000050
14:30:107	AG450	7	00302 00	0000	1211	0219	-12.609	+26.535	222.2	198.4	21844.	14:30:107 000050
14:30:226	AG450	7	00203 00	0000	1211	0219	-12.789	+25.63[illegible]	221.1	197.5	21844.	14:30:226 000050
14:30:345	AG450	7	00302 00	0000	1211	0219	-12.918	+25.[illegible]	215.8	196.0	21844.	14:30:345 000050
14:30:464	AG450	7	00301 00	0000	1211	0219	-13.219	+24.[illegible]	216.8	196.9	21844.	14:30:464 000050
14:30:582	AG450	7	00203 00	0000	1211	0218	-13.418	+23.[illegible]	215.8	196.0	21844.	14:30:582 000050
14:31:101	AG450	7	00302 00	0000	1211	0218	-13.664	+2[illegible]	219.1	195.6	21844.	14:31:101 000050

Partnair, Skagen

Start Time of the Mågerø Printout

The Mågerø dataset has clearly been produced to show the time of passing. The printout starts at exactly 14:28:00.0, and for both the F-16 and the Braathens aircraft, there are 0 values where the transponder data should have been in the first lines. In addition, speed and heading are completely static, while position changes.

MÅKERØY RADAR
BLÅTT

18 CCCCCCCCC 14:27:44131

SYST TIME HH:MM:SSS	TRACK NUMBER	Q	TRACK ACT 123CC	1-	2---	3/A-	3/C-	X POS. DM	Y POS. DM	SPEED DM/HR	HDG. DEG.	HEIGHT FT.	HOT SOUTH	CLUTTER DELETED	AVOIDANCE	SIMULATED	REMOTE	SIM. TIME HH:MM:SSS	TRACK SLOT
14:28:000	HM556	7	00300	00	0000	6163	0000	+46.891	-90.730	24.56	180.0	3000.0	0	00	1	0	1	0	56	0	14:28:000	000060
14:28:080	AG450	7	00000	00	0000	0000	0000	-4.9492	-52.535	200.3	195.2	21750.	7	00	1	0	1	0	46	0	14:28:080	000041
14:28:122	AG151	7	00000	00	0000	0000	0000	-11.203	-67.363	509.1	9.125	18750.	7	00	1	0	1	0	46	0	14:28:122	000110

The Mågerø printout starts at 14:28:00.0.

SYST TIME HH:MM:SSS	TRACK NUMBER	Q	TRACK ACT 123CC	1-	2---	3/A-	3/C-	X POS. DM	Y POS. DM	SPEED DM/HR	HDG. DEG.	HEIGHT FT.	HOT SOUTH	CLUTTER DELETED	AVOIDANCE	SIMULATED	REMOTE	SIM. TIME HH:MM:SSS	TRACK SLOT
14:28:122	AG151	7	00000	00	0000	0000	0000	-11.203	-67.363	509.1	9.125	18750.	7	00	1	0	1	0	46	0	14:28:122	000110
14:28:202	AG151	7	00000	00	0000	0000	0000	-10.766	-66.262	509.1	9.125	18750.	7	00	1	0	1	0	46	0	14:28:202	000110
14:28:303	AG151	7	32303	22	0370	0265	0241	-9.8480	-65.168	634.7	18.71	24937.	0	00	1	0	0	0	46	0	14:28:303	000110
14:28:423	AG151	7	23303	22	0370	0265	0241	-9.3320	-63.465	611.4	18.40	24937.	0	00	1	0	0	0	46	0	14:28:423	000110
14:28:545	AG151	7	32303	22	0370	0265	0241	-8.7420	-61.406	616.9	17.90	25031.	0	00	1	0	0	0	46	0	14:28:545	000110

F-16, Mågerø: Static data in the first 2 lines.

Plot	System time	Interval	Track Number	Track Q	SIF ACT	1-	2---	3/A-	3/C-	X Pos.	Y. Pos	Speed	Heading	Height	HT Stale
5	14:28:13.7		AG571	7	00000	0	0	0	0	-1.844	-35.961	277.6	180.0	0	7
11	14:28:21.4	7.7	AG571	7	00000	0	0	0	0	-1.844	-36.582	277.6	180.0	0	7
17	14:28:30.3	8.9	AG571	7	00300	0	0	1261	0	-2.844	-38.063	277.6	180.0	0	7
23	14:28:41.0	10.7	AG571	7	00300	0	0	1261	0	-3.219	-38.836	277.6	180.0	0	7
32	14:28:54.5	13.5	AG571	7	00303	0	0	1261	290	-3.465	-40.727	359.6	184.4	29906	0
39	14:29:06.6	12.1	AG571	7	00303	0	0	1261	290	-3.566	-41.887	356.1	184.5	29906	1
46	14:29:18.5	11.9	AG571	6	00303	0	0	1261	290	-3.656	-43.066	356.1	184.5	29906	1

Braathens, Mågerø: Static data in the first 4 lines.

The most plausible scenario is that data was played back from tape into the radar system. Where the tracker has not received updated data, 0 values or a previous value remain until new radar data arrives from the tape. The only thing that changes in the first lines is the position, which suggests it does not come from tape. It is difficult to establish whether these positions were produced by the simulation function in the radar system, whether they were entered manually, or whether they come from another unknown source.

The main point is: the printout from Mågerø is not a normal export of radar data, as one would expect in connection with the investigation of an aircraft accident, but a printout based on radar data produced less than five days after the accident to show the pass between the F-16 and the Partnair aircraft. The data printout shows that immediately after the accident, the focus was on the pass, and that radar data has been produced that bears the hallmarks of manual adjustment.

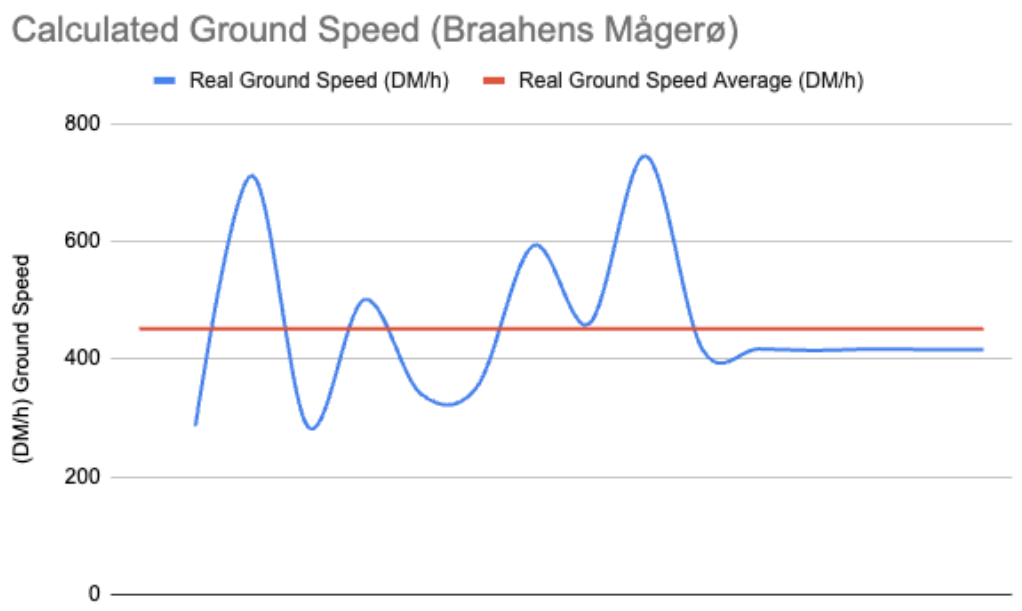
Braathens

The main focus is naturally on radar data for the F-16 and the Partnair aircraft, but the dataset also includes information about the Braathens aircraft (track number AG571). As mentioned above, the Braathens data starts with some static lines, but there are also other anomalies that are difficult to find a natural explanation for.

The radar's varying rotation speed cannot be explained by switching between Mågerø and Skagen, since the intervals should have been either approximately 10 or approximately 12 seconds. The Remote/Local column indicates a change of source, but the changes in

rotation speed occur with both "remote" and "local" data. The actual speed of the Braathens aircraft was near the speed of sound, but of course not above or far below it.

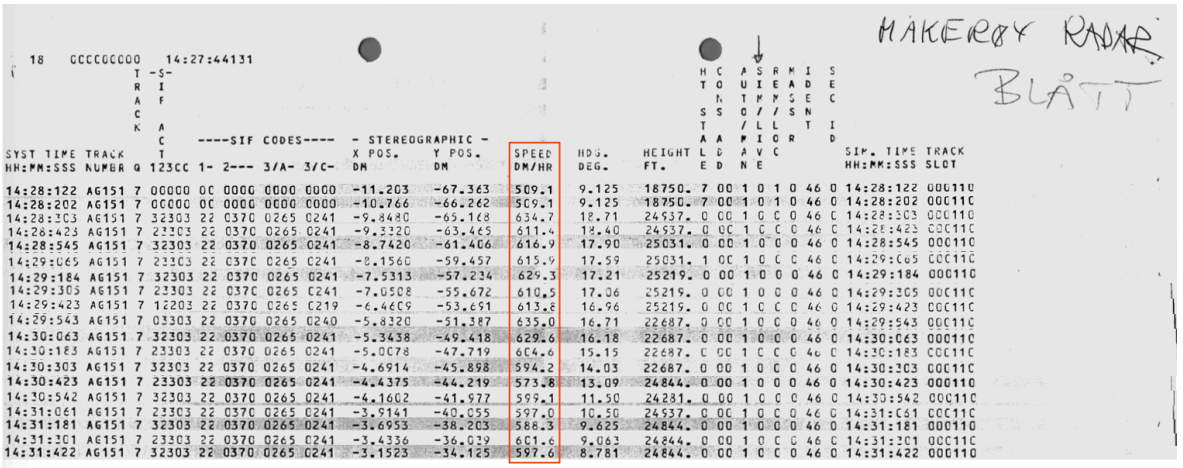
System time	Interval	Track Number	3/C Flight Level	Speed	Speed Calculated	Heading Calculated	Rem/Loc
14:28:13.7		AG571	0	277.6			1
14:28:21.4	7.7	AG571	0	277.6	286.2	179.95	1
14:28:30.3	8.9	AG571	0	277.6	712.1	213.93	1
14:28:41.0	10.7	AG571	0	277.6	284.9	205.76	1
14:28:54.5	13.5	AG571	290	359.6	501.3	187.31	0
14:29:06.6	12.1	AG571	290	356.1	341.5	184.90	0
14:29:18.5	11.9	AG571	290	356.1	352.6	184.26	0
14:29:30.6	12.1	AG571	290	402.3	593.1	185.66	0
14:29:39.1	8.5	AG571	290	423.2	460.5	185.37	0
14:29:42.4	3.3	AG571	290	423.2	745.4	184.41	0
14:29:54.4	12.0	AG571	290	423.2	417.2	184.65	0
14:30:06.4	12.0	AG571	290	423.2	417.4	184.49	0
14:30:18.4	12.0	AG571	290	423.2	414.7	184.35	0
14:30:30.4	12.0	AG571	290	432.2	417.2	184.64	0
14:30:42.4	12.0	AG571	290	423.2	416.3	184.49	0
14:30:54.3	11.9	AG571	290	423.2	415.8	184.37	0



Errors in the time interval produce large deviations in the calculated speed.

Speed Differences for the F-16

The most striking feature of the Mågerø radar data for the F-16 is that it shows supersonic speeds both before and in connection with the pass of the Partnair aircraft.



MÅKERØY RADAR
BLÅTT

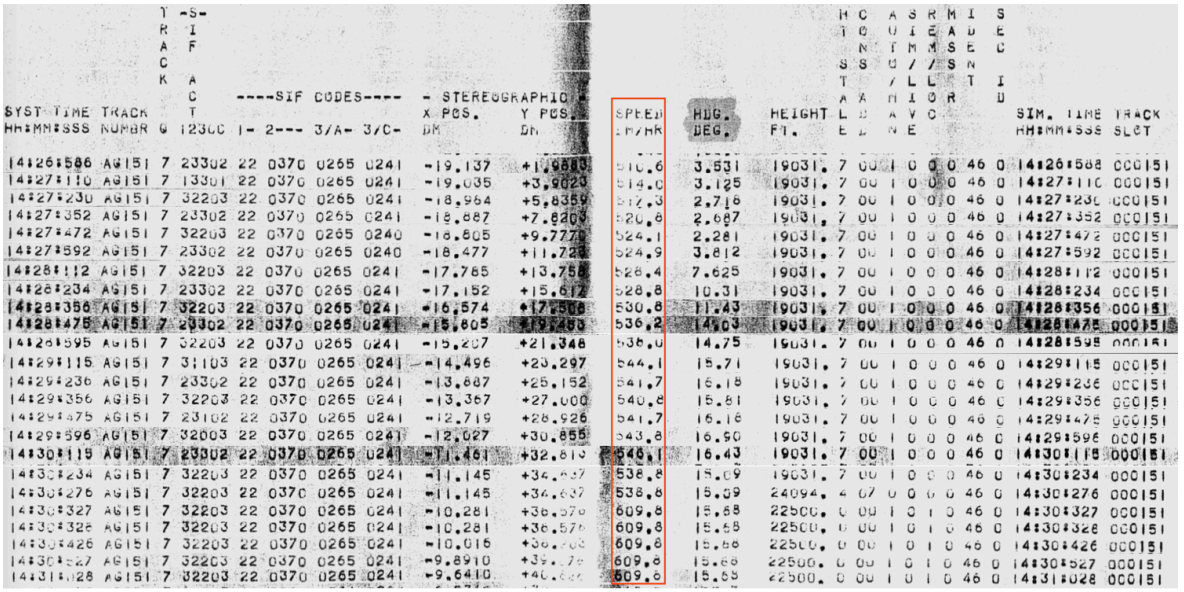
18 CCCCCCCCC 14:27:44131

SYST TIME HH:MM:SSS	TRACK NUMBR	T-SIFAC K	Q	A C T 123CC	----SIF CODES---- 1- 2---	3/A- 3/C-	- STEREOGRAPHIC - X POS. DM	Y POS. DM	SPEED DM/HR	HDG. DEG.	HEIGHT FT.	HCTOMSSTAAED	CUTMMPIAVNE	ASIEOMCE	RMAIOR	MADSCT	ISECID	SIM. TIME HH:MM:SSS	TRACK SLOT
14:28:122	AG151	7	0	00000	0000	0000	-11.203	-67.363	509.1	9.125	18750.	7	00	1	0	1	0	46	0	14:28:122	000110
14:28:202	AG151	7	0	00000	0000	0000	-10.766	-66.262	509.1	9.125	18750.	7	00	1	0	1	0	46	0	14:28:202	000110
14:28:303	AG151	7	3	2303	22	0370	0265	0241	-9.8480	-65.168	634.7	12.71	24937.	0	00	1	0	0	0	46	0	14:28:303	000110
14:28:423	AG151	7	3	2303	22	0370	0265	0241	-9.3320	-63.465	611.4	19.40	24937.	0	00	1	0	0	0	46	0	14:28:423	000110
14:28:545	AG151	7	3	2303	22	0370	0265	0241	-8.7420	-61.406	616.9	17.90	25031.	0	00	1	0	0	0	46	0	14:28:545	000110
14:29:065	AG151	7	3	2303	22	0370	0265	0241	-8.1560	-59.457	615.9	17.59	25031.	1	00	1	0	0	0	46	0	14:29:065	000110
14:29:184	AG151	7	3	2303	22	0370	0265	0241	-7.5313	-57.234	629.3	17.21	25219.	0	00	1	0	0	0	46	0	14:29:184	000110
14:29:305	AG151	7	3	2303	22	0370	0265	0241	-7.0508	-55.672	610.5	17.06	25219.	0	00	1	0	0	0	46	0	14:29:305	000110
14:29:423	AG151	7	1	2203	22	0370	0265	0219	-6.4609	-53.691	613.8	16.96	25219.	0	00	1	0	0	0	46	0	14:29:423	000110
14:29:543	AG151	7	0	3303	22	0370	0265	0240	-5.8320	-51.387	635.0	16.71	22687.	0	00	1	0	0	0	46	0	14:29:543	000110
14:30:063	AG151	7	3	2303	22	0370	0265	0241	-5.3438	-49.418	629.6	16.18	22687.	0	00	1	0	0	0	46	0	14:30:063	000110
14:30:183	AG151	7	3	2303	22	0370	0265	0241	-5.0078	-47.719	604.6	15.15	22687.	0	00	1	0	0	0	46	0	14:30:183	000110
14:30:303	AG151	7	3	2303	22	0370	0265	0241	-4.6914	-45.898	594.2	14.03	22687.	0	00	1	0	0	0	46	0	14:30:303	000110
14:30:423	AG151	7	3	2303	22	0370	0265	0241	-4.4375	-44.219	573.8	13.09	24844.	0	00	1	0	0	0	46	0	14:30:423	000110
14:30:542	AG151	7	3	2303	22	0370	0265	0241	-4.1602	-41.977	599.1	11.50	24281.	0	00	1	0	0	0	46	0	14:30:542	000110
14:31:061	AG151	7	3	2303	22	0370	0265	0241	-3.9141	-40.055	597.0	10.50	24537.	0	00	1	0	0	0	46	0	14:31:061	000110
14:31:181	AG151	7	3	2303	22	0370	0265	0241	-3.6953	-38.203	588.3	9.625	24844.	0	00	1	0	0	0	46	0	14:31:181	000110
14:31:301	AG151	7	3	2303	22	0370	0265	0241	-3.4336	-36.039	601.6	9.063	24844.	0	00	1	0	0	0	46	0	14:31:301	000110
14:31:422	AG151	7	3	2303	22	0370	0265	0241	-3.1523	-34.125	597.6	8.781	24844.	0	00	1	0	0	0	46	0	14:31:422	000110

F-16, Mågerø

According to information from the Armed Forces, and the 12-second interval between each registration, the registrations should have been made by Skagen radar. The registrations in the printout from Skagen should therefore be identical—which they are not.

Given that the F-16 aircraft's speed is of particular interest in this case, it is worth noting that the Mågerø printout shows supersonic speeds, while Skagen shows speeds that are significantly lower. Two radar stations measuring the same aircraft may obtain different individual values for calculated speed, but over several minutes the average speed must be identical.



SYST TIME HH:MM:SSS	TRACK NUMBR	T-SIFAC K	Q	A C T 123CC	----SIF CODES---- 1- 2---	3/A- 3/C-	- STEREOGRAPHIC - X POS. DM	Y POS. DM	SPEED DM/HR	HDG. DEG.	HEIGHT FT.	HCTOMSSTAAED	CUTMMPIAVNE	ASIEOMCE	RMAIOR	MADSCT	ISECID	SIM. TIME HH:MM:SSS	TRACK SLOT
14:26:586	AG151	7	2	3302	22	0370	0265	0241	-19.137	+1.9883	510.6	3.531	19031.	7	00	1	0	0	0	46	0	14:26:588	000151
14:27:110	AG151	7	1	3301	22	0370	0265	0241	-19.035	+3.9020	514.0	3.125	19031.	7	00	1	0	0	0	46	0	14:27:110	000151
14:27:230	AG151	7	3	2203	22	0370	0265	0241	-18.964	+5.8359	512.3	2.718	19031.	7	00	1	0	0	0	46	0	14:27:230	000151
14:27:352	AG151	7	3	2302	22	0370	0265	0241	-18.887	+7.8203	520.8	2.687	19031.	7	00	1	0	0	0	46	0	14:27:352	000151
14:27:472	AG151	7	3	2203	22	0370	0265	0240	-18.805	+9.7770	524.1	2.281	19031.	7	00	1	0	0	0	46	0	14:27:472	000151
14:27:592	AG151	7	3	2302	22	0370	0265	0240	-18.477	+11.723	524.9	3.812	19031.	7	00	1	0	0	0	46	0	14:27:592	000151
14:28:112	AG151	7	3	2203	22	0370	0265	0241	-17.785	+13.758	528.4	7.625	19031.	7	00	1	0	0	0	46	0	14:28:112	000151
14:28:234	AG151	7	3	2302	22	0370	0265	0241	-17.152	+15.612	528.8	10.31	19031.	7	00	1	0	0	0	46	0	14:28:234	000151
14:28:356	AG151	7	3	2203	22	0370	0265	0241	-16.574	+17.508	530.8	11.43	19031.	7	00	1	0	0	0	46	0	14:28:356	000151
14:28:475	AG151	7	3	2302	22	0370	0265	0241	-15.805	+19.450	536.2	14.03	19031.	7	00	1	0	0	0	46	0	14:28:475	000151
14:28:595	AG151	7	3	2203	22	0370	0265	0241	-15.207	+21.348	538.0	14.75	19031.	7	00	1	0	0	0	46	0	14:28:595	000151
14:29:115	AG151	7	3	3103	22	0370	0265	0241	-14.496	+23.297	544.1	15.71	19031.	7	00	1	0	0	0	46	0	14:29:115	000151
14:29:236	AG151	7	3	2302	22	0370	0265	0241	-13.687	+25.152	541.7	16.18	19031.	7	00	1	0	0	0	46	0	14:29:236	000151
14:29:356	AG151	7	3	2203	22	0370	0265	0241	-13.367	+27.000	540.8	15.81	19031.	7	00	1	0	0	0	46	0	14:29:356	000151
14:29:475	AG151	7	3	2302	22	0370	0265	0241	-12.719	+28.926	541.7	16.16	19031.	7	00	1	0	0	0	46	0	14:29:475	000151
14:29:596	AG151	7	3	2203	22	0370	0265	0241	-12.027	+30.855	543.8	16.50	19031.	7	00	1	0	0	0	46	0	14:29:596	000151
14:30:115	AG151	7	3	2302	22	0370	0265	0241	-11.461	+32.810	546.1	16.43	19031.	7	00	1	0	0	0	46	0	14:30:115	000151
14:30:234	AG151	7	3	2203	22	0370	0265	0241	-11.145	+34.687	538.8	15.09	19031.	7	00	1	0	0	0	46	0	14:30:234	000151
14:30:276	AG151	7	3	2203	22	0370	0265	0241	-11.145	+34.687	538.8	15.09	24094.	4	07	0	0	0	0	46	0	14:30:276	000151
14:30:327	AG151	7	3	2203	22	0370	0265	0241	-10.281	+36.570	609.8	15.68	22500.	0	00	1	0	1	0	46	0	14:30:327	000151
14:30:328	AG151	7	3	2203	22	0370	0265	0241	-10.281	+36.570	609.8	15.68	22500.	0	00	1	0	1	0	46	0	14:30:328	000151
14:30:426	AG151	7	3	2203	22	0370	0265	0241	-10.016	+38.[illegible]	609.8	15.68	22500.	0	00	1	0	1	0	46	0	14:30:426	000151
14:30:527	AG151	7	3	2203	22	0370	0265	0241	-9.8910	+39.[illegible]	609.8	15.68	22500.	0	00	1	0	1	0	46	0	14:30:527	000151
14:31:028	AG151	7	3	2203	22	0370	0265	0241	-9.6410	+40.[illegible]	609.8	15.68	22500.	0	00	1	0	1	0	46	0	14:31:028	000151

F-16, Skagen

Rather than having speed values that change with every measurement, techniques for "smoothing" are employed in the radar system's tracker—in practice, average values from a given number of measurements. Smoothing cannot explain large speed differences over several minutes, as the datasets show between Skagen and Mågerø. Post-calculated values based on change in position over time also provide a clear indication that the speed values in the Skagen data are lower than what the F-16 aircraft actually had.

Skagen Tidspunkt	Skagen Speed	Skagen Calculated	F-16	Mågerø Tidspunkt	Mågerø Speed	Mågerø Calculated
14:28:47.5	536.2	631.5		14:28:30.3	634.7	507.8
14:28:59.5	538.0	595.0		14:28:42.3	611.4	532.9
14:29:11.5	544.1	621.2		14:28:54.5	616.9	630.9
14:29:23.6	541.7	579.8		14:29:06.5	615.9	609.4
14:29:35.6	540.8	574.9		14:29:18.4	629.3	697.3
14:29:47.5	541.7	613.6	Passing	14:29:30.5	610.5	485.3
14:29:59.6	543.8	608.6		14:29:42.3	613.8	629.4
14:30:11.5	546.1	617.2		14:29:54.3	635.0	715.2
14:30:23.4	538.8	557.2		14:30:06.3	629.6	607.5
14:30:27.6	538.8	0		14:30:18.3	604.6	518.7
14:30:32.7	609.8	1495.4		14:30:30.3	594.2	553.5
14:30:32.8	609.8	0		14:30:42.3	573.8	508.5
14:30:42.6	609.8	824.6		14:30:54.2	599.1	682.2
14:30:52.7	609.8	311.6		14:31:06.1	597.0	585.2
14:31:02.8	609.8	419.4		14:31:18.1	588.3	558.5

Time Differences for the F-16

The timestamps in radar data have been a recurring theme in the lawsuits following the Partnair accident. The Armed Forces have established that the Mågerø timestamps are correct, while Skagen and AWACS have incorrect time indications:

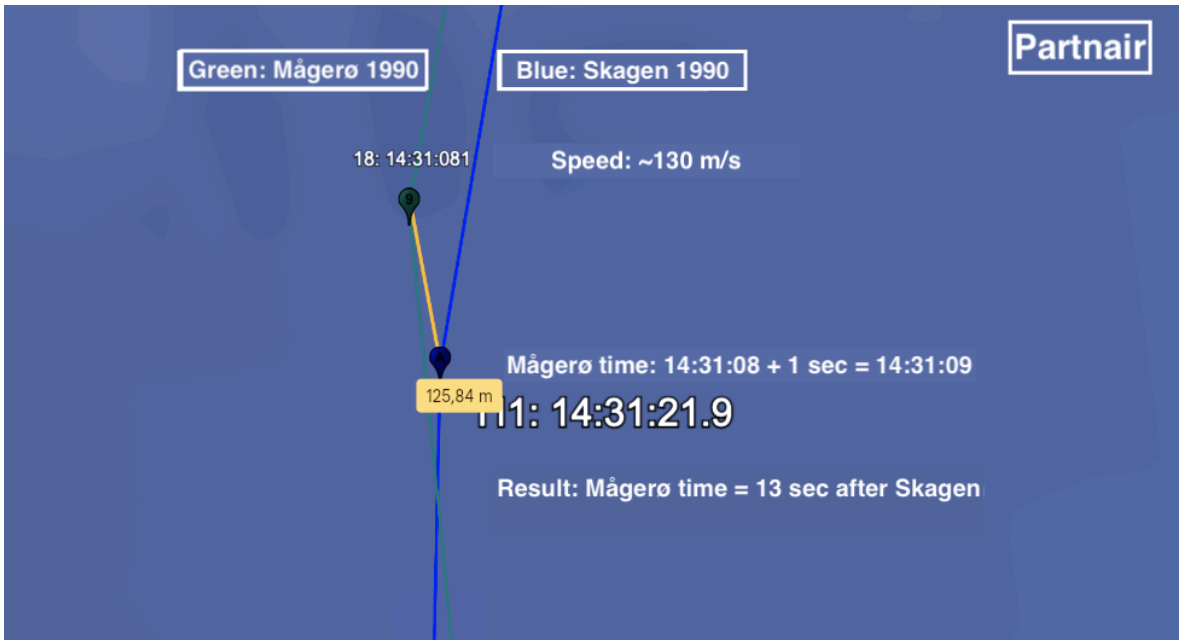
«Skagen radar: the clock is 15 sec fast. Måkerøy radar: the clock is approximately correct. AWACS radar: the clock is 15 sec slow.» (Barvik, 1990, p. 2)

In practice, this means that all radar data showing one aircraft at the same position in the Skagen and Mågerø datasets should have approximately 15 seconds' difference in the

timestamp. Since the printouts from Mågerø and Skagen have separate data sources, none of the points are identical. To calculate the time difference, one must:

1. Find a point that is close in both datasets
2. Calculate the distance between the two points
3. Adjust the timestamp to compensate for the time it takes the aircraft to fly the distance

For all aircraft in the two datasets, this exercise should always yield the same time difference. This is not the case. If one compares the timestamps for the Partnair aircraft, it is consistent with approximately 15 seconds' time difference. For the F-16, the time difference is approximately double.

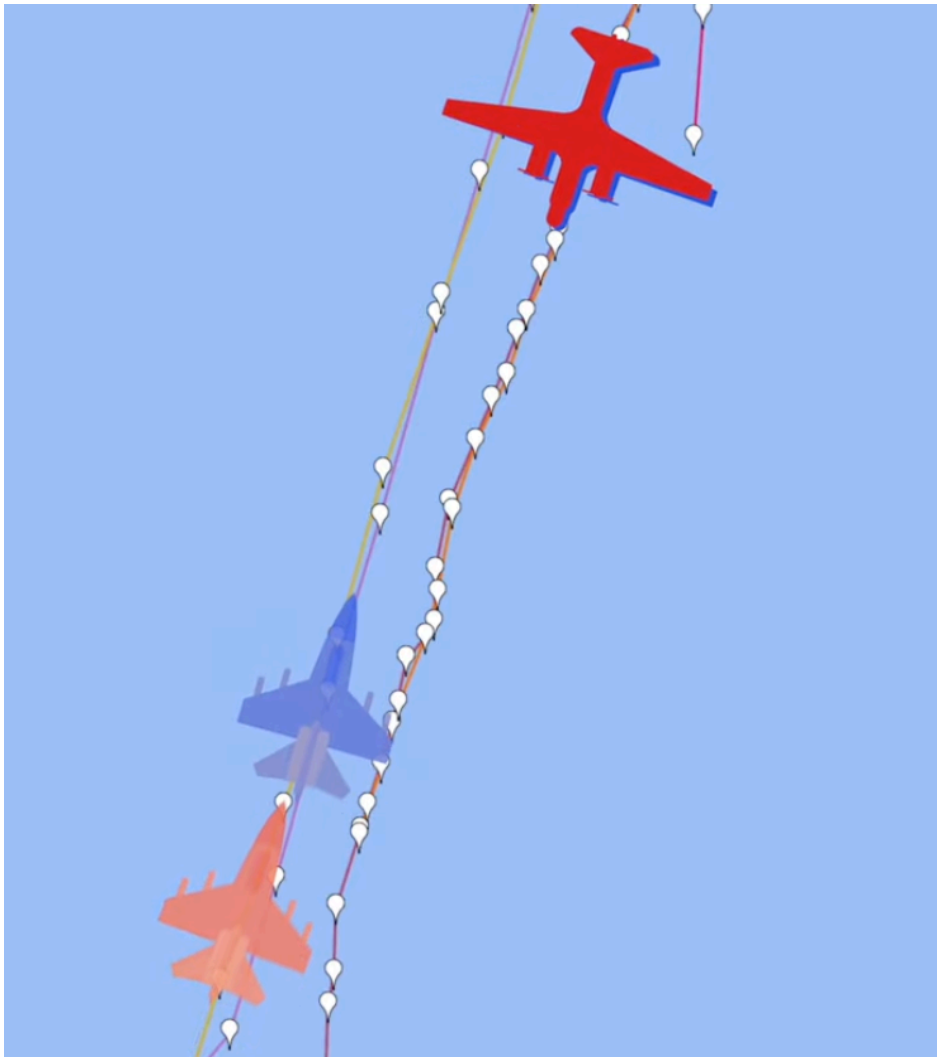


The Partnair aircraft's position yields a time difference of approximately 13 seconds between Mågerø and Skagen.

The F-16 aircraft's position yields a time difference of approximately 28 seconds between Mågerø and Skagen.

This reveals a physically impossible situation where Skagen and Mågerø register the F-16 at a given time as being in two different locations several kilometres apart. It is difficult to visualise this impossibility by studying numerical data, but when the radar data is animated, it becomes obvious.

In the animation, the timestamps are synchronised so that they correspond between Skagen and Mågerø for the Partnair aircraft. If the radar data were real, the red and blue F-16 aircraft would be as closely aligned as the Partnair aircraft. It is not possible to explain this large time discrepancy by low precision in the radar systems. The difference between Skagen and Mågerø constitutes a period longer than the rotation period of the radar heads at both stations.

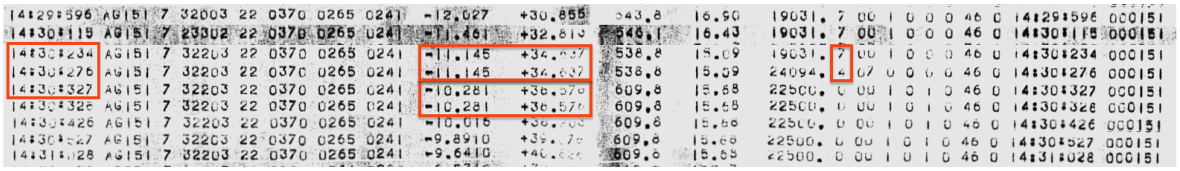


Radar data showing physically impossible observations of the F-16.
https://www.youtube.com/watch?v=7brfTxEplAQ

Impossible Situations in the Skagen Data

According to the radar data from Skagen, abnormal situations arise in connection with the pass of the Partnair aircraft: the radar changes rotation speed, and the F-16 is registered at exactly the same position despite several seconds elapsing between measurements.

Another impossibility is the "HT Stale" column to the right of the altitude measurement. This value can increase or return to 0, but it cannot go from a high value to a lower value without having gone via 0 first. In the Skagen dataset for the F-16, there is an instance of the value changing from 7 to 4—something that would not occur in a real dataset.



F-16, Skagen

Plot	System time	Interval	Track Number	Track Q	SIF ACT	1-	2---	3/A-	3/C-	X Pos.	Y. Pos	Speed	Heading	Height	HT Stale
4	14:26:58.6		AG151	7	23302	22	370	265	241	-19.137	1.988	510.6	3.531	19031	7
8	14:27:11.0	12.4	AG151	7	13301	22	370	265	241	-19.035	3.902	514.0	3.125	19031	7
11	14:27:23.0	12.0	AG151	7	32203	22	370	265	241	-18.984	5.836	517.3	2.718	19031	7
15	14:27:35.2	12.2	AG151	7	23302	22	370	265	241	-18.887	7.820	520.8	2.687	19031	7
17	14:27:47.2	12.0	AG151	7	32203	22	370	265	240	-18.805	9.777	524.1	2.281	19031	7
20	14:27:59.2	12.0	AG151	7	23302	22	370	265	240	-18.477	11.723	524.9	3.812	19031	7
22	14:28:11.2	12.0	AG151	7	32203	22	370	265	241	-17.785	13.758	528.4	7.625	19031	7
28	14:28:23.4	12.2	AG151	7	23302	22	370	265	241	-17.152	15.617	528.8	10.31	19031	7
45	14:28:35.6	12.2	AG151	7	32203	22	370	265	241	-16.574	17.508	530.8	11.43	19031	7
51	14:28:47.5	11.9	AG151	7	23302	22	370	265	241	-15.805	19.453	536.2	14.03	19031	7
57	14:28:59.5	12.0	AG151	7	32203	22	370	265	241	-15.207	21.348	538.0	14.75	19031	7
65	14:29:11.5	12.0	AG151	7	31103	22	370	265	241	-14.496	23.297	544.1	15.71	19031	7
77	14:29:23.6	12.1	AG151	7	23302	22	370	265	241	-13.887	25.152	541.7	16.18	19031	7
85	14:29:35.6	12.0	AG151	7	32203	22	370	265	241	-13.367	27.000	540.8	15.81	19031	7
93	14:29:47.5	11.9	AG151	7	23102	22	370	265	241	-12.719	28.926	541.7	16.18	19031	7
103	14:29:59.6	12.1	AG151	7	32003	22	370	265	241	-12.027	30.855	543.8	16.9	19031	7
111	14:30:11.5	11.9	AG151	7	23302	22	379	265	241	-11.461	32.813	546.1	16.43	19031	7
124	14:30:23.4	11.9	AG151	7	32203	22	370	265	241	-11.145	34.637	538.8	15.09	19031	7
127	14:30:27.6	4.2	AG151	7	32203	22	370	265	241	-11.145	34.637	538.8	15.09	24094	4
129	14:30:32.7	5.1	AG151	7	32203	22	370	265	241	-10.281	36.576	609.8	15.68	22500	0
130	14:30:32.8	0.1	AG151	7	32203	22	370	265	241	-10.281	36.576	609.8	15.68	22500	0
138	14:30:42.6	9.8	AG151	7	32203	22	370	265	241	-10.016	38.809	609.8	15.68	22500	0
146	14:30:52.7	10.1	AG151	7	32203	22	370	265	241	-9.891	39.676	609.8	15.68	22500	0
154	14:31:02.8	10.1	AG151	7	32203	22	370	265	241	-9.641	40.828	609.8	15.68	22500	0

F-16, Skagen

The Skagen Versions

Version 1990

In the post-processed radar data, which the Armed Forces delivered to the accident investigation board several months after the aircraft accident, data for the different aircraft has been split into separate documents. The most obvious errors—the change in the radar's rotation interval and identical registrations at two different timestamps—are still present in this printout.

Despite the fact that both Skagen and Mågerø were part of the NATINADS network and both received data from each other in real time, a line has been inserted stating "track reporting transferred to Måkerøy radar." The printout from Skagen was produced by the tracker at Skagen, and both the F-16 and Partnair were well within range. The line marks a division where radar data from different sources has been stitched together. Regardless of whether one chooses to accept this explanation, and why it only applied to the F-16 aircraft, it does not explain the physical impossibilities shortly beforehand.

TRACK DATA PRINTOUT OF TRACK AG151. F-16 to Rygge

DATE 08 SEP 89, SKAGEN RADAR

SYST TIME HH:MM:SEC	TRACK NUMBR	T Q	ACTIV 123CC	SIF/IFF M1 MOD2	3/A	3/C	X.POS DATA M	Y.POS DATA M	SPEED DM/HR	HDGNG DEGRE	HIGHT FEET	OK
14:27:11.0	AG151	7	13301	.. ....	0265	----	-19,035	+3,9023	514,0	3,125	24100	3/C
14:27:23.0	AG151	7	32203	.. ....	0265	0241	-18,984	+5,8359	517,3	2,718	24100	3/C
14:27:35.2	AG151	7	23302	.. ....	0265	0241	-18,887	+7,8203	520,8	2,687	N/M	
14:27:47.2	AG151	7	32203	.. ....	0265	0240	-18,805	+9,7770	524,1	2,281	24000	3/C
14:27:59.2	AG151	7	23302	.. ....	0265	0240	-18,477	+11,723	524,9	3,812	N/M	
14:28:11.2	AG151	7	32203	.. ....	0265	0241	-17,785	+13,758	528,4	7,625	24100	3/C
14:28:23.4	AG151	7	23302	.. ....	0265	0241	-17,152	+15,617	528,8	10,31	N/M	
14:28:35.6	AG151	7	32203	.. ....	0265	0241	-16,574	+17,508	530,8	11,43	24100	3/C
14:28:47.5	AG151	7	23302	.. ....	0265	0241	-15,805	+19,453	536,2	14,03	N/M	
14:28:59.5	AG151	7	32203	.. ....	0265	0241	-15,207	+21,348	538,0	14,75	24100	3/C
14:29:11.5	AG151	7	31103	.. ....	0265	0241	-14,496	+23,297	544,1	15,71	24100	3/C
14:29:23.6	AG151	7	23302	.. ....	0265	0241	-13,887	+25,152	541,7	16,18	N/M	
14:29:35.6	AG151	7	32203	.. ....	0265	0241	-13,367	+27,000	540,8	15,81	24100	3/C
14:29:47.5	AG151	7	23102	.. ....	0265	0241	-12,719	+28,926	541,7	16,18	N/M	
14:29:59.6	AG151	7	32003	.. ....	0265	0241	-12,027	+30,855	543,8	16,90	24100	3/C
14:30:11.5	AG151	7	23302	.. ....	0265	0241	-11,461	+32,813	546,1	16,43	N/M	
14:30:23.4	AG151	7	32203	.. ....	0265	0241	-11,145	+34,637	538,8	15,09	24100	3/C
14:30:27.6	AG151	7	32203	.. ....	0265	0241	-11,145	+34,637	538,8	15,09	24094	MC
14:30:32.7	AG151	7	32203	.. ....	0265	0241	-10,281	+36,576	604,6	15,15	22687	H/F
TRACK RAPPORTERING OVER TIL MAKERØY RADAR												
14:30:42.6	AG151	7	32303	.. ....	0265	0241	-10,016	+38,203	594,2	14,03	24844	H/F
14:30:52.7	AG151	7	23303	.. ....	0265	0241	-09,891	+39,078	573,8	13,09	24844	H/F
14:31:02.8	AG151	7	32303	.. ....	0265	0241	-09,641	+40,828	599,1	11,50	24281	H/F
14:31:22.8	AG151	7	23303	.. ....	0265	0241	-09,141	+43,953	597,0	10,50	24937	H/F
14:31:32.7	AG151	7	32303	.. ....	0265	0241	-08,875	+45,828	588,3	9,625	24844	H/F
14:31:42.9	AG151	7	23303	.. ....	0265	0241	-08,625	+47,703	601,6	9,063	24844	H/F
14:31:53.0	AG151	7	32303	.. ....	0265	0241	-08,625	+48,953	597,6	8,781	24844	H/F
14:32:02.8	AG151	7	23303	.. ....	0265	0241	-08,250	+50,703	601,1	8,719	24844	H/F
14:32:12.9	AG151	7	32303	.. ....	0265	0241	-07,984	+52,703	622,4	8,750	24094	H/F
14:32:23.1	AG151	7	32303	.. ....	0265	0241	-07,859	+53,703	622,4	7,750	24100	3/C
14:32:33.3	AG151	7	23303	.. ....	0265	0241	-07,484	+56,078	633,4	8,938	24094	H/F
14:32:43.2	AG151	7	32303	.. ....	0265	0241	-07,109	+58,203	636,8	8,875	23437	H/F
14:32:53.4	AG151	7	23303	.. ....	0265	0241	-06,718	+60,328	647,8	9,031	22687	H/F
14:33:03.5	AG151	7	32303	.. ....	0265	0236	-06,593	+61,578	651,8	9,281	22687	H/F
14:33:14.3	AG151	7	23303	.. ....	0265	0214	-06,218	+63,828	631,6	9,906	21400	3/C
14:33:33.5	AG151	7	32303	.. ....	0265	0177	-05,578	+66,578	628,2	9,969	17700	3/C
14:33:43.8	AG151	7	23303	.. ....	0265	0145	-05,203	+68,703	642,6	10,06	16125	H/F

Passing

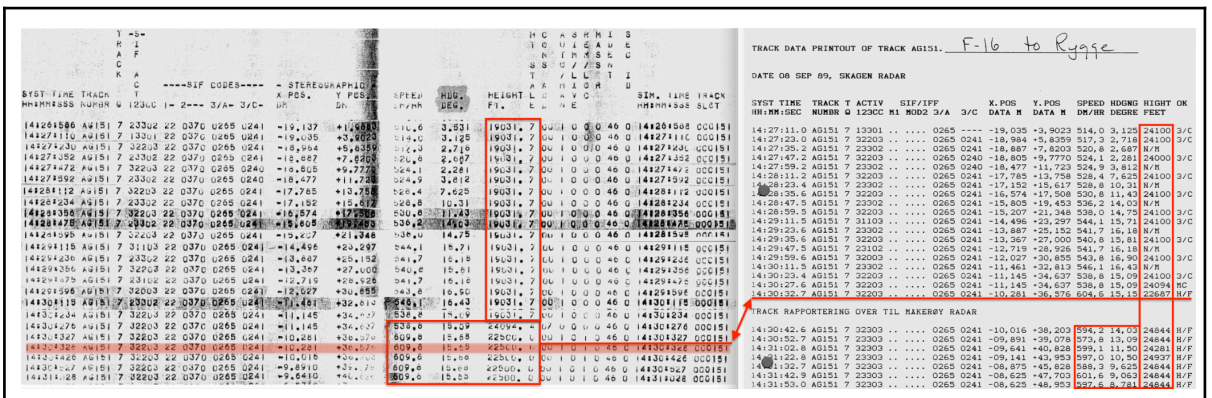
Wrong Interval

Aircraft stops mid-air

F16, Skagen, 1990

If one compares the printout from 1989 with the 1990 version, one can see that one line has been removed. In addition, the column with altitude data has been changed. The static speed and altitude measurements at the end of the dataset, showing supersonic speed and an altitude for the F-16 of 22,500 feet, have been altered. The HT-Stale column, which shows 0 values at the end of the dataset indicating completely fresh altitude measurements, has not been carried over to the 1990 version.

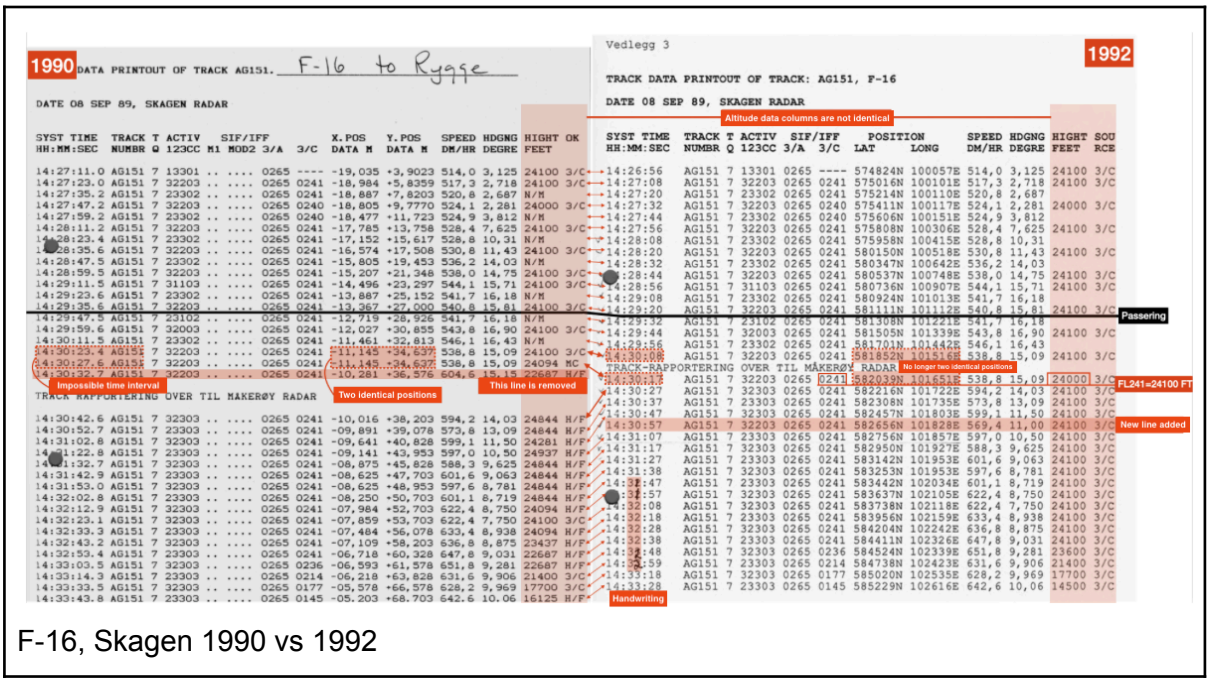
Overall, it appears that attempts have been made to correct some of the data, as well as to make the altitude data somewhat more consistent.



F-16, Skagen, 1989 vs 1990

Version 1992

In August 1992, the Armed Forces delivered yet another version of the radar data. The most obvious change was that all timestamps had been adjusted by −15 seconds. The changes were made by hand, as several errors have crept in that have been corrected with pen. Given that the new version was delivered under the pretext that the timestamps needed to be changed, this should also have been the only change. However, several other corrections have been made.



F-16, Skagen 1990 vs 1992

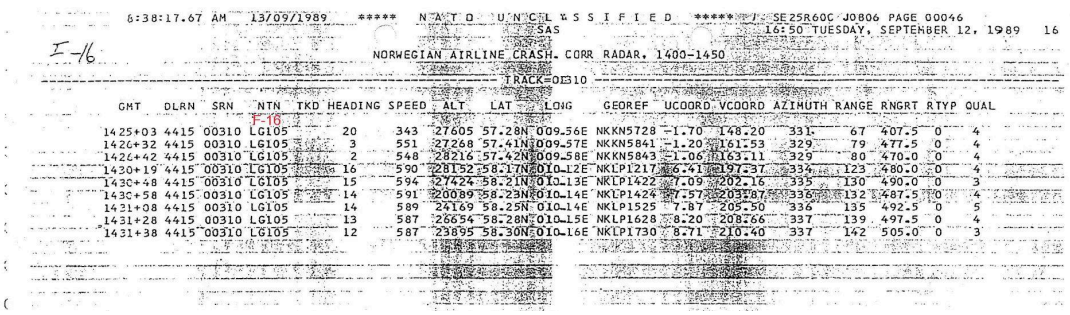
This is clear evidence that someone has manually made corrections where the dataset shows physical impossibilities. The registrations showing that the F-16 was stationary in the air for 4.2 seconds have been removed. A new registration has been inserted a few rows further down so that the total number of lines remains the same.

Another important observation is that the altitude data has been manually adjusted. In the altitude column of the 1990 version, one can clearly see that two different datasets have been spliced together, where the latter part has few Mode C registrations. It is evident that someone has wished to remove any doubt about the F-16's altitude, and has therefore manually written in the number of feet in the altitude column of the 1992 dataset. That this was done manually is confirmed by the fact that one of the lines contains an arithmetic error: Flight level 241, registered in the 3/C column, becomes 24,100 feet when multiplied by 100—not 24,000 feet as stated.

AWACS

Printouts

The printouts from the AWACS registrations have built-in noise and discrepancies between what was registered by primary and secondary radar respectively. The main problem is that most of the registrations of the F-16 are classified. Only 9 points have been released as "NATO Unclassified."



6:38:17.67 AM 13/09/1989 ***** N A T O U N C L A S S I F I E D ***** / SE25R60C J0806 PAGE 00046
SAS 16:50 TUESDAY, SEPTEMBER 12, 1989 16

F-16

NORWEGIAN AIRLINE CRASH. CORR RADAR. 1400-1450

TRACK=01310

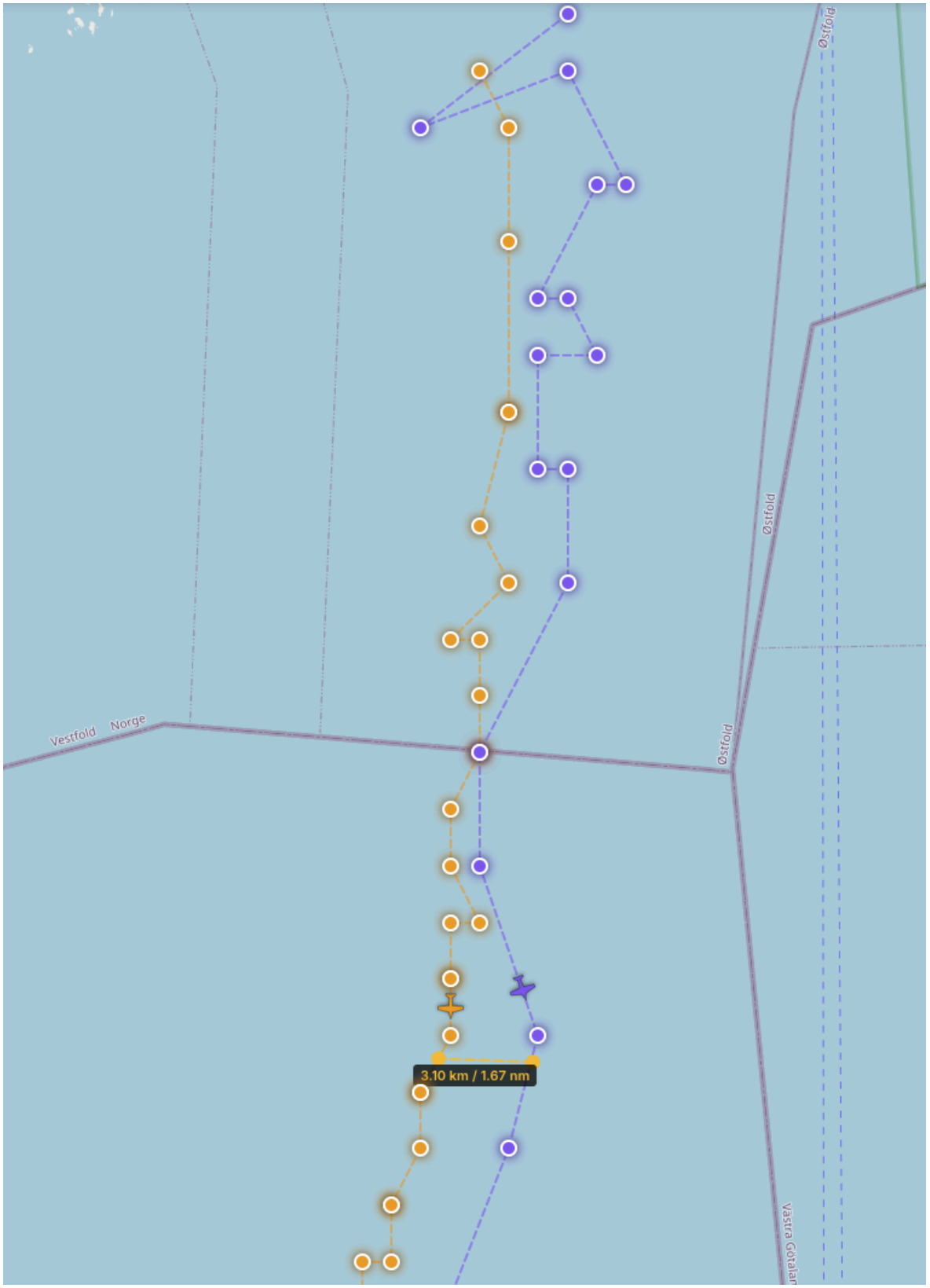
GMT	DLRN	SRN	NTN	TKD	HEADING	SPEED	ALT	LAT	LONG	GEOREF	UCOORD	VCOORD	AZIMUTH	RANGE	RNGRT	RTYP	QUAL
			F-16														
1425+03	4415	00310	LG105		20	343	27605	57.28N	009.56E	NKKN5728	-1.70	148.20	331	67	407.5	0	4
1426+32	4415	00310	LG105		3	551	27268	57.41N	009.57E	NKKN5841	-1.20	161.53	329	79	477.5	0	4
1426+42	4415	00310	LG105		2	548	28216	57.42N	009.58E	NKKN5843	-1.06	163.11	329	80	470.0	0	4
1430+19	4415	00310	LG105		16	590	28152	58.17N	010.12E	NKLP1217	6.41	197.37	334	123	480.0	0	4
1430+48	4415	00310	LG105		15	594	27424	58.21N	010.13E	NKLP1422	7.09	202.16	335	130	490.0	0	3
1430+58	4415	00310	LG105		14	591	20089	58.23N	010.14E	NKLP1424	7.57	203.87	336	132	487.5	0	4
1431+08	4415	00310	LG105		14	589	24169	58.25N	010.14E	NKLP1525	7.87	205.50	336	135	492.5	0	5
1431+28	4415	00310	LG105		13	587	26654	58.28N	010.15E	NKLP1628	8.20	208.66	337	139	497.5	0	4
1431+38	4415	00310	LG105		12	587	23895	58.30N	010.16E	NKLP1730	8.71	210.40	337	142	505.0	0	3

F-16, AWACS

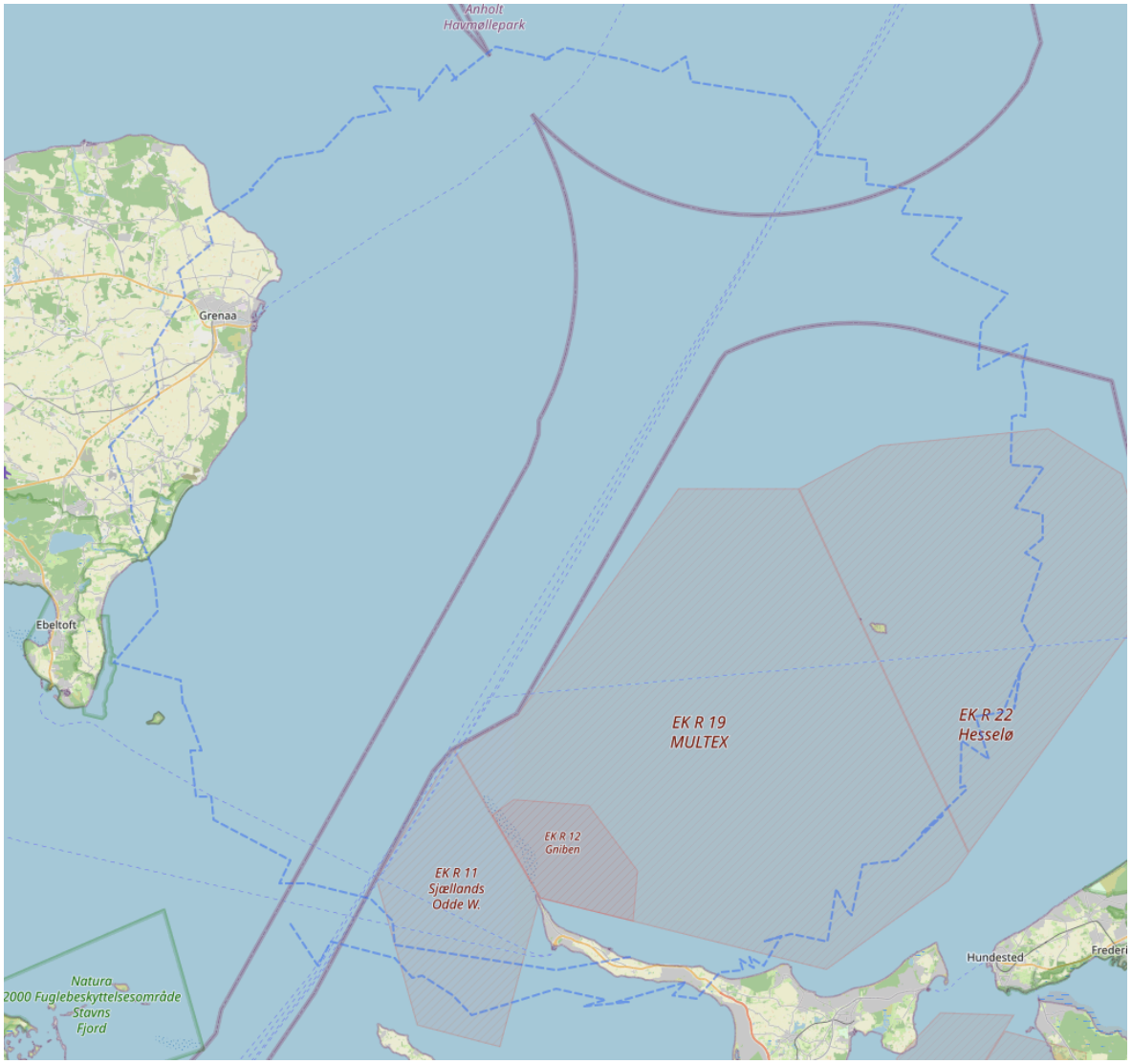
Noise

The AWACS radar printouts have obviously reduced resolution. Regardless of whether this was done to avoid revealing military secrets about the radars' precision or for another reason, it constitutes a very large amount of noise in the data. Noise has been systematically introduced with such large deviations that the data cannot be used to establish where the F-16 and Partnair were in relation to each other at the time of passing.

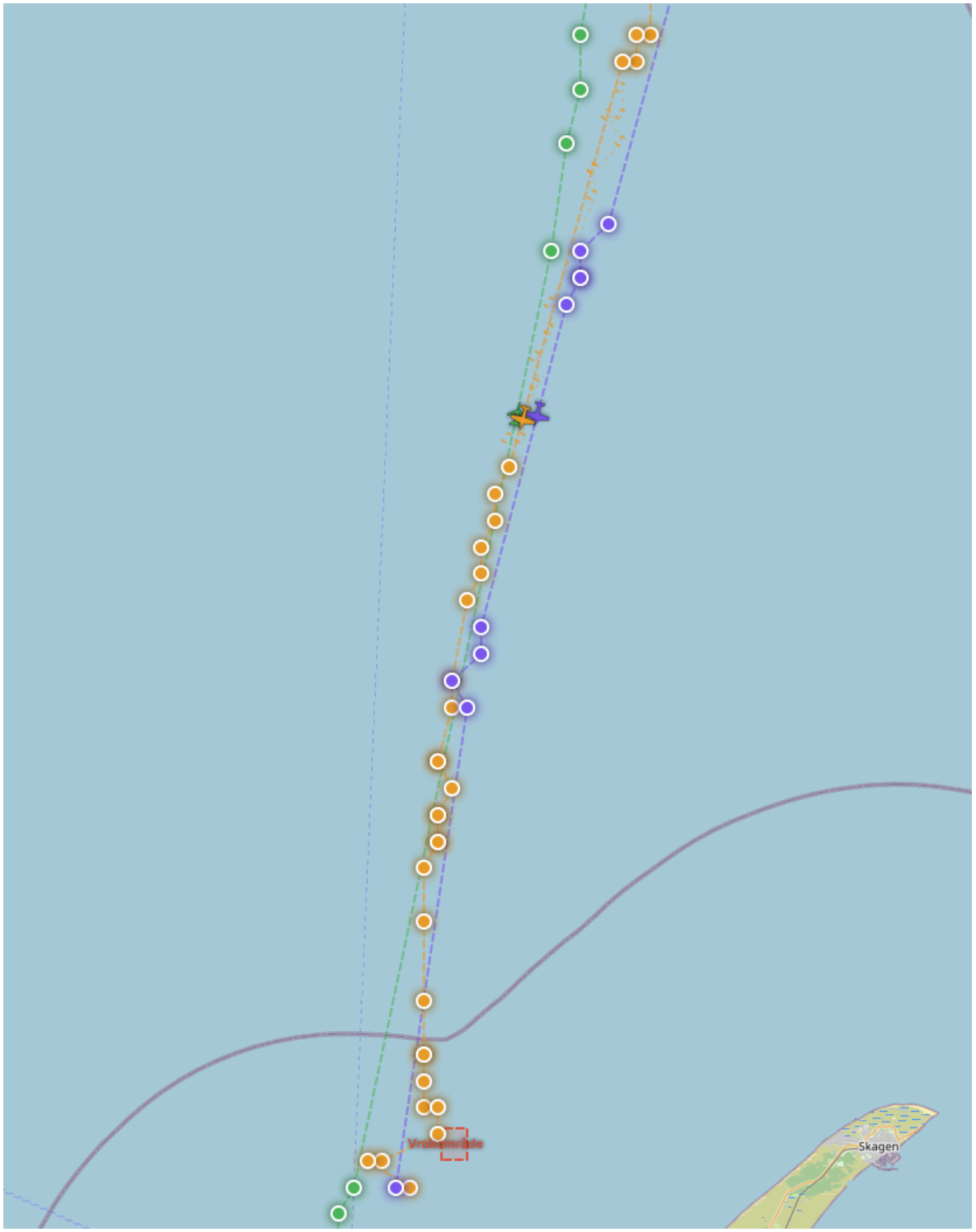
Two sets of data have been delivered for Partnair: primary radar and secondary radar (labelled IFF in the dataset). These tracks should in theory have been approximately identical, but there is at times several kilometres' distance between them.



Partnair, primary and secondary radar (IFF) track, with reduced resolution.



AWACS aircraft track with reduced resolution, jagged track instead of a smooth circle.



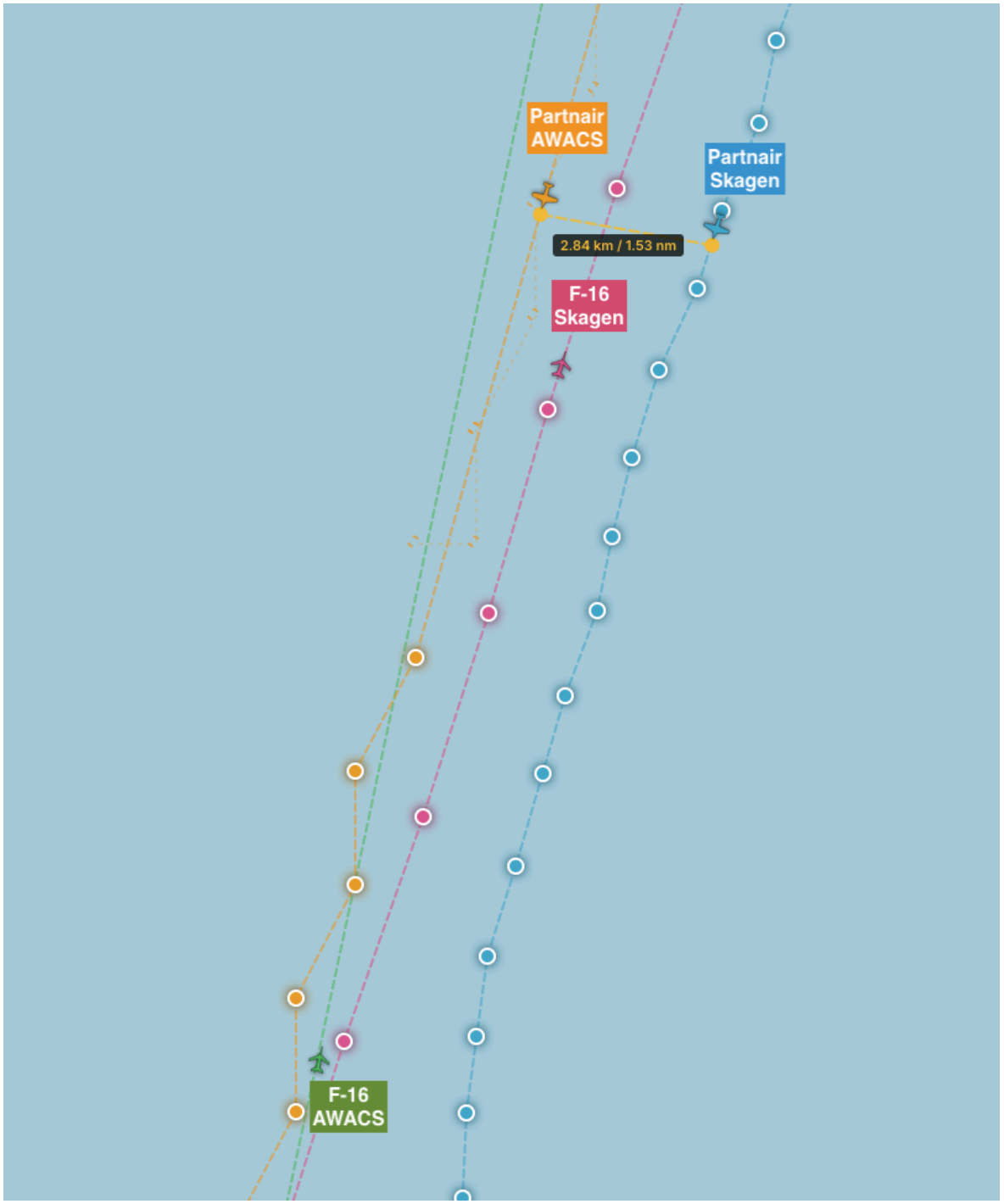
AWACS, F-16, Partnair (Primary + Secondary/IFF).

AWACS versus Skagen

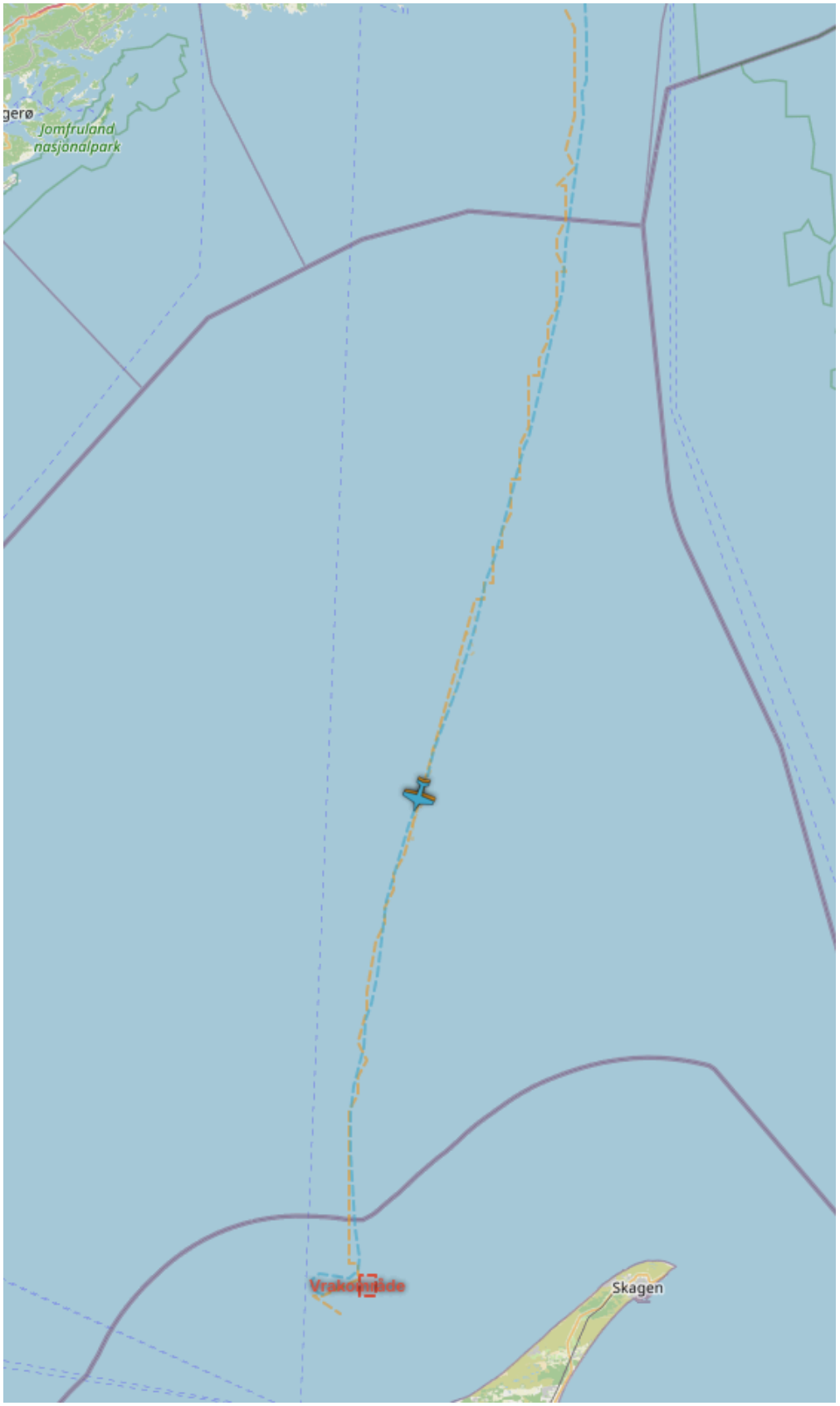
Both Skagen and AWACS were relatively close to the F-16 and Partnair aircraft and should have relatively high precision. A systematic deviation of several kilometres is difficult to understand.

If one compares the Partnair aircraft track between Skagen and AWACS, it looks fairly coincident, but the tracks appear to have a systematic measurement error of 3 kilometres in the east/west direction.

AWACS, Skagen, F-16, Partnair, overview.



AWACS, Skagen, F-16, Partnair, near the meeting point.



Partnair AWACS track, with the entire Skagen track shifted 3 km westward.

AWACS-video

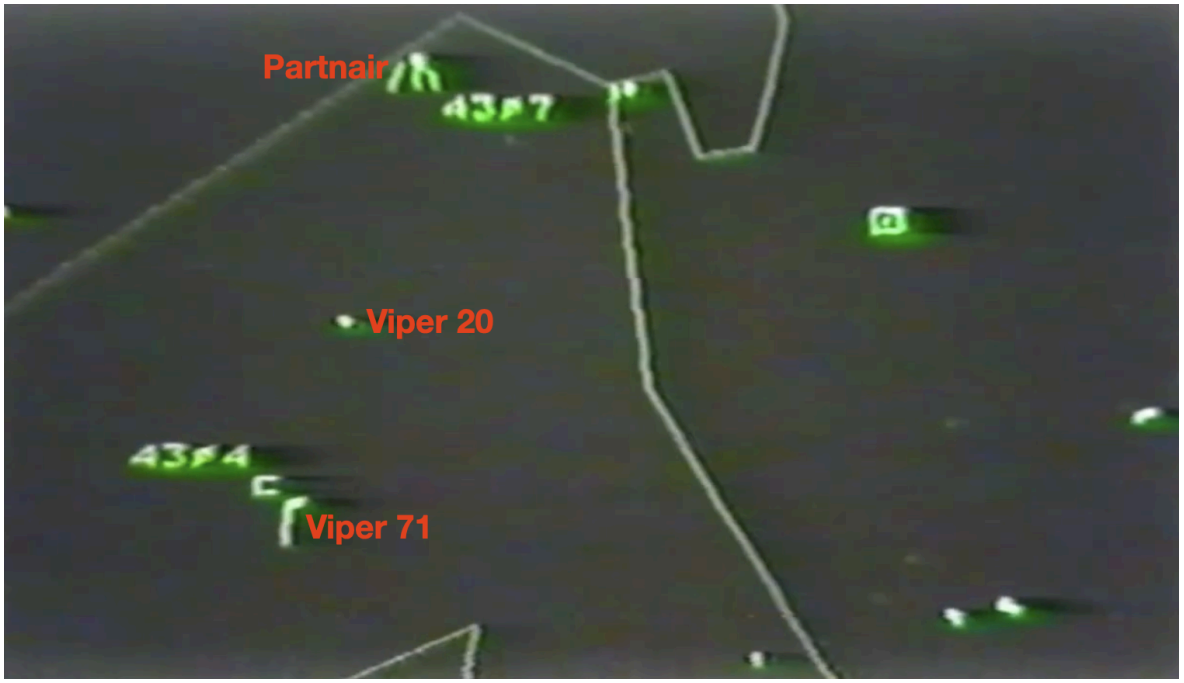
Data from AWACS has been video-recorded by hand and shows Partnair (track 4307), the Norwegian F-16 (track 4310), and the Braathens aircraft (track 4311). This is a post-hoc simulation, where recordings of radar data from the accident have apparently been used.

In addition, track 4304 is visible on the radar screen. Track 4304 is flying in the direction of Aalborg at relatively high speed and is located over Denmark when Norwegian 5007 takes off and flies northward. The radar images show that 4304 reduces speed and apparently makes an approach towards Aalborg.

The AWACS radar data shows a number of other aircraft in the area, which suggests that the Mågerø data should have included far more aircraft. Viper 20 and 71 are aircraft that naturally should have been included in the dataset, as they were two military aircraft operating in the same area shortly before the accident.

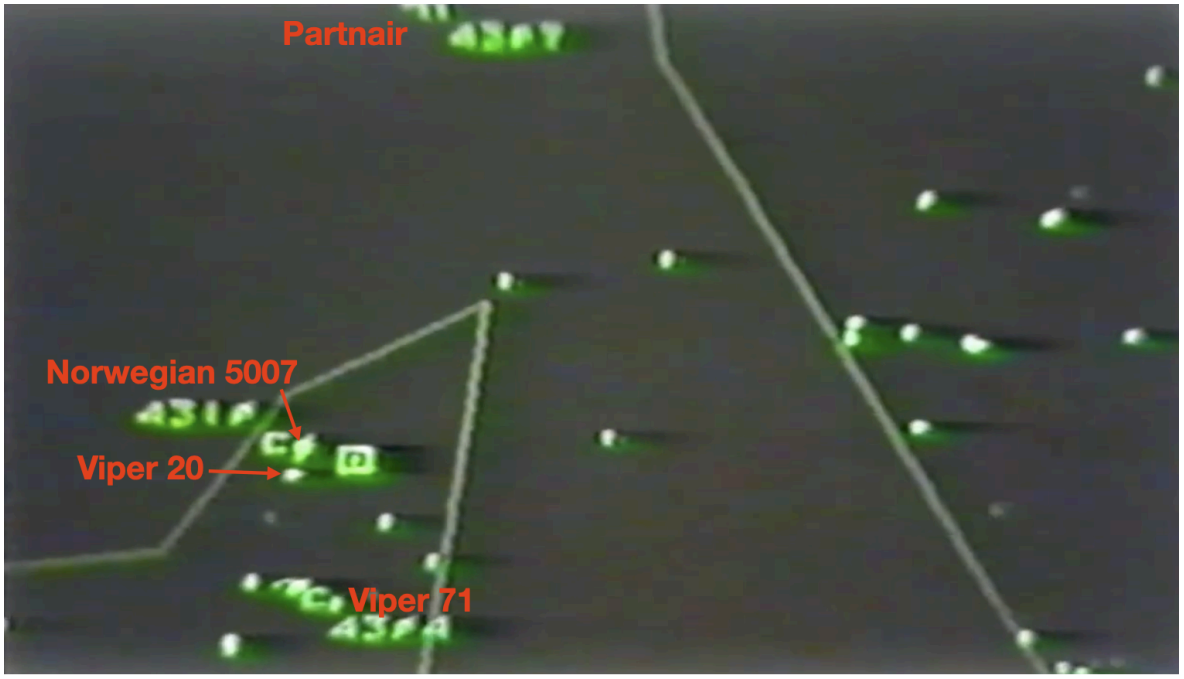
Viper 71 and 20

Ahead of Partnair, first Viper 71 flew, followed by Viper 20. Viper 71 is registered as track 4304 by AWACS.



Viper 71 and 20 on AWACS radar.

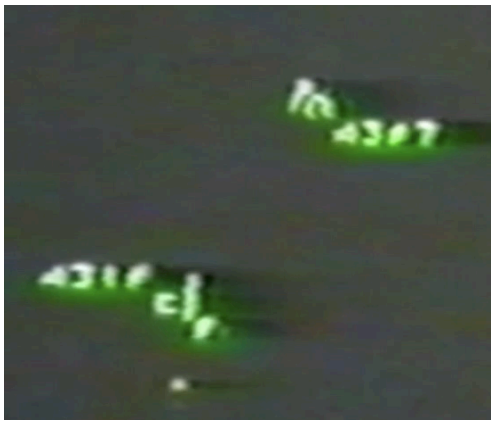
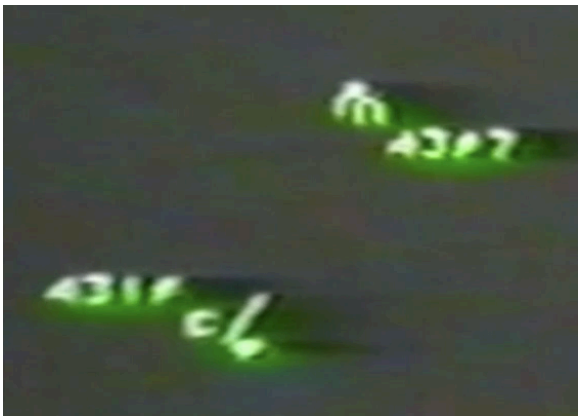
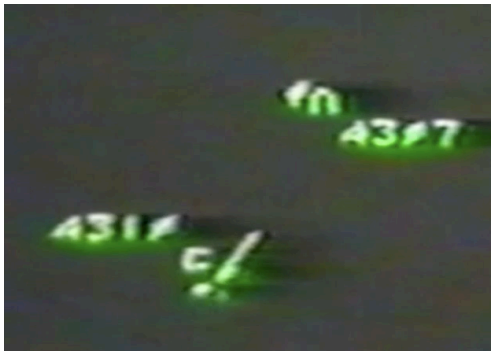
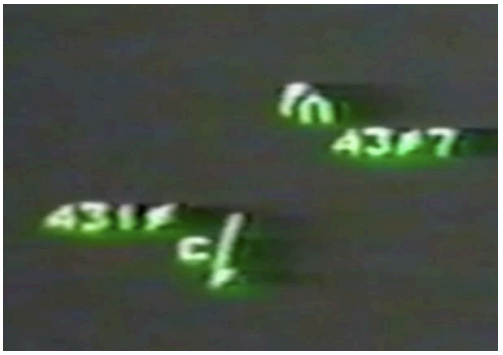
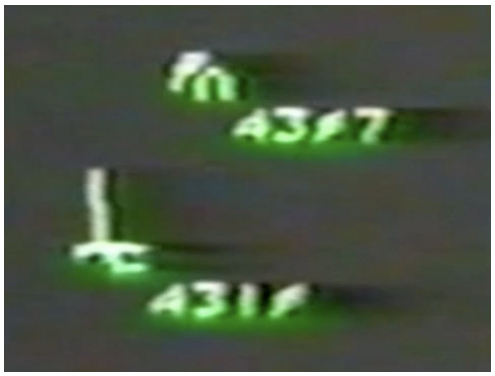
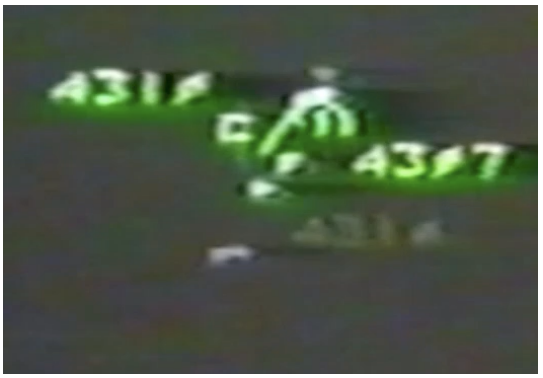
Directly over Hirtshals, the AWACS radar shows Viper 20 and Norwegian 5007 meeting. It may be that the F-16 crew assumed this was the first of the two fighter jets, while in reality it was the last. This assumption may have been reinforced by the F-16's own radar detecting the Partnair aircraft, which at that point was over the Skagerrak heading towards Rygge.



The encounter between Viper 20 and Norwegian 5007.

F-16 Heading Changes

Prior to the encounter with Partnair, the F-16 makes several heading corrections and appears to pass the Partnair aircraft very closely.

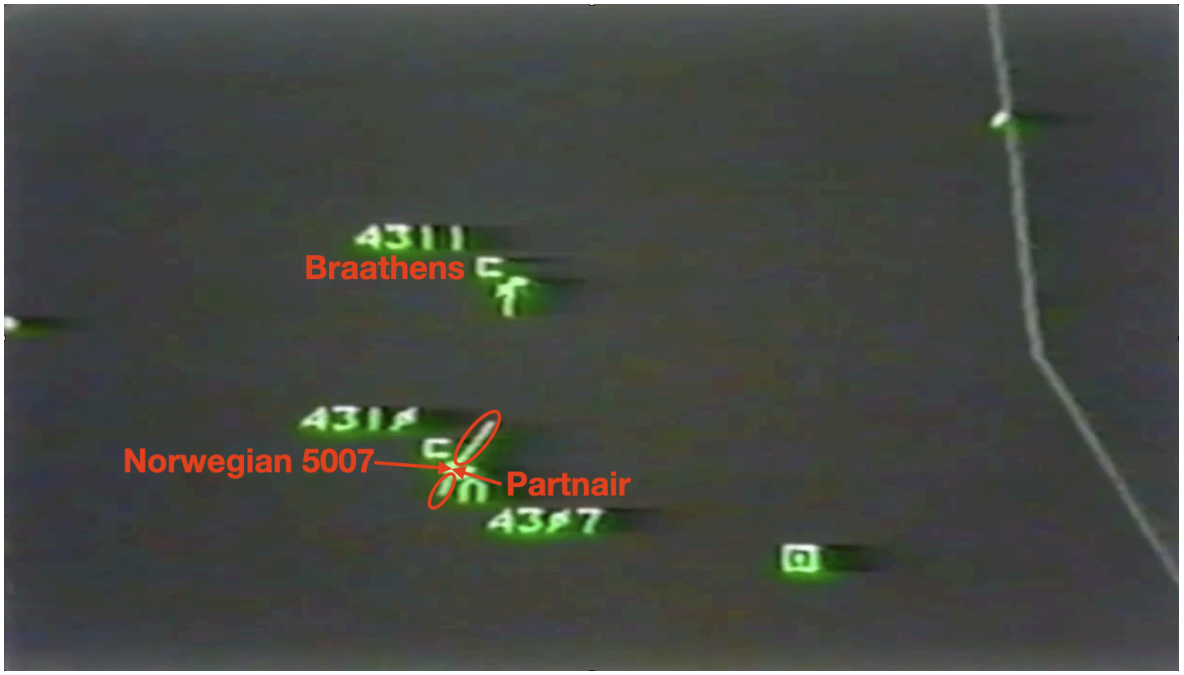
1) F-16 just before turn to the right	2) Turn to the right
	
3) Speed increases (the length of the heading line indicates speed)	4) F-16 turns northward
	
5) Continues straight northward, increases speed	6) Turns right towards the Partnair aircraft
	

The Pass in the AWACS Video

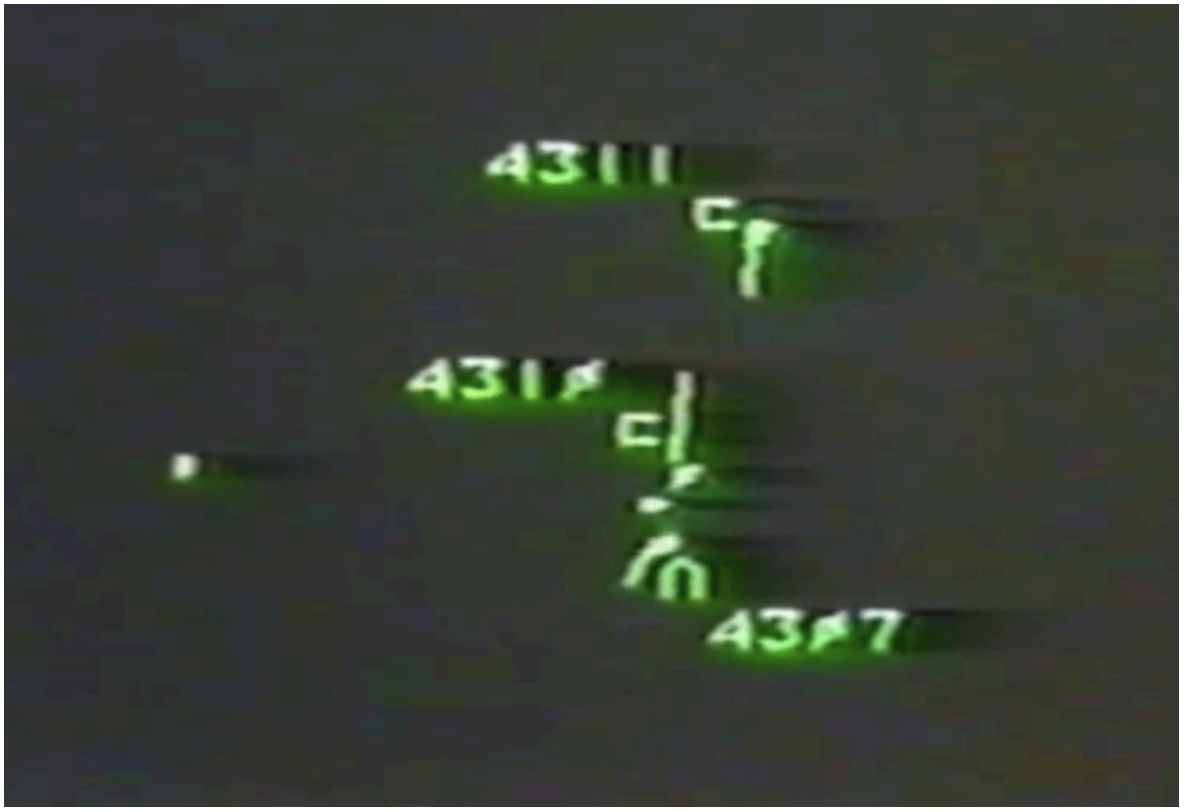
Just before the pass, the operator clicks with the cursor on the radar plot for the Partnair aircraft and the F-16 aircraft, probably to obtain information from the radar system:

«The subject track has track 4310 off its nose, bearing 211 for two miles. The altitude separation appears to be 2,000 feet, there is a difference of altitude of 21,800 feet and 24,100 feet. The subject aircraft is flying underneath the northbound track.» (19:21 in the video)

The pass occurs before the operator has finished reading out the quote. "Two miles" is two nautical miles, and at a relative speed of 450–500 m/s, this distance is covered in 7–8 seconds. Based on radar data from Skagen, the F-16 should not have come closer than one nautical mile, but the AWACS video shows the aircraft continuing to approach each other until the radar plots merge. After the encounter, the F-16 turns to the left.



The radar plots merge at the time of passing; the F-16 maintains high speed.



After the pass, the AWACS video shows the F-16 turning to the left.

Swedish Radar

Just before the pass, the operator clicks with the cursor on the radar plot for the Partnair aircraft and the F-16 aircraft, probably to obtain information from the radar system:

«The subject track has track 4310 off its nose, bearing 211 for two miles. The altitude separation appears to be 2,000 feet, there is a difference of altitude of 21,800 feet and 24,100 feet. The subject aircraft is flying underneath the northbound track.» (19:21 in the video)

The pass occurs before the operator has finished reading out the quote. "Two miles" is two nautical miles, and at a relative speed of 450–500 m/s, this distance is covered in 7–8 seconds. Based on radar data from Skagen, the F-16 should not have come closer than one nautical mile, but the AWACS video shows the aircraft continuing to approach each other until the radar plots merge. After the encounter, the F-16 turns to the left.

The radar plots merge at the time of passing; the F-16 maintains high speed.

After the pass, the AWACS video shows the F-16 turning to the left.

Swedish Radar

The Swedish radar stations were of an older, analogue type. Recordings were made by photographing the radar screen every 40 seconds. In practice, the F-16 moved 12 kilometres

between each image. This is not sufficient precision to see whether the F-16 made heading corrections. When the F-16 additionally passed so close to the Partnair aircraft that the image points merged and became invisible, at the time of passing there were only two points for the F-16 with 80 seconds between them—a straight line in the sketch corresponding to 24 kilometres.

The speed calculation shows that the F-16 was flying just below Mach 1 over this distance. Any turn away from the straight line increases the distance, and thus in practice indicates supersonic speed. It is also worth mentioning that despite a very straight track—due to few registrations—the pass is registered with a separation of 0.5 nautical miles, which is half the separation shown in radar data from Skagen and Mågerø.

On 7 January 1993, Jon P. Pran wrote to Chief Radar Analyst Gunno Gunnvall:
«The report regarding the Metropolitan accident on 8 September 1989 has been out for consultation. Certain consultation bodies have noted that the radar information from the Swedish Armed Forces does not contain the position where a Norwegian F-16 fighter jet passed the Metropolitan aircraft LN-PAA. According to Norwegian radar and the pilot in question, this occurred at 1429:30 UTC when the F-16 passed approximately 1 NM west of LN-PAA. If you still have this radar information, could you send us the time and position of the pass.» (Pran, 1993, p. 1)

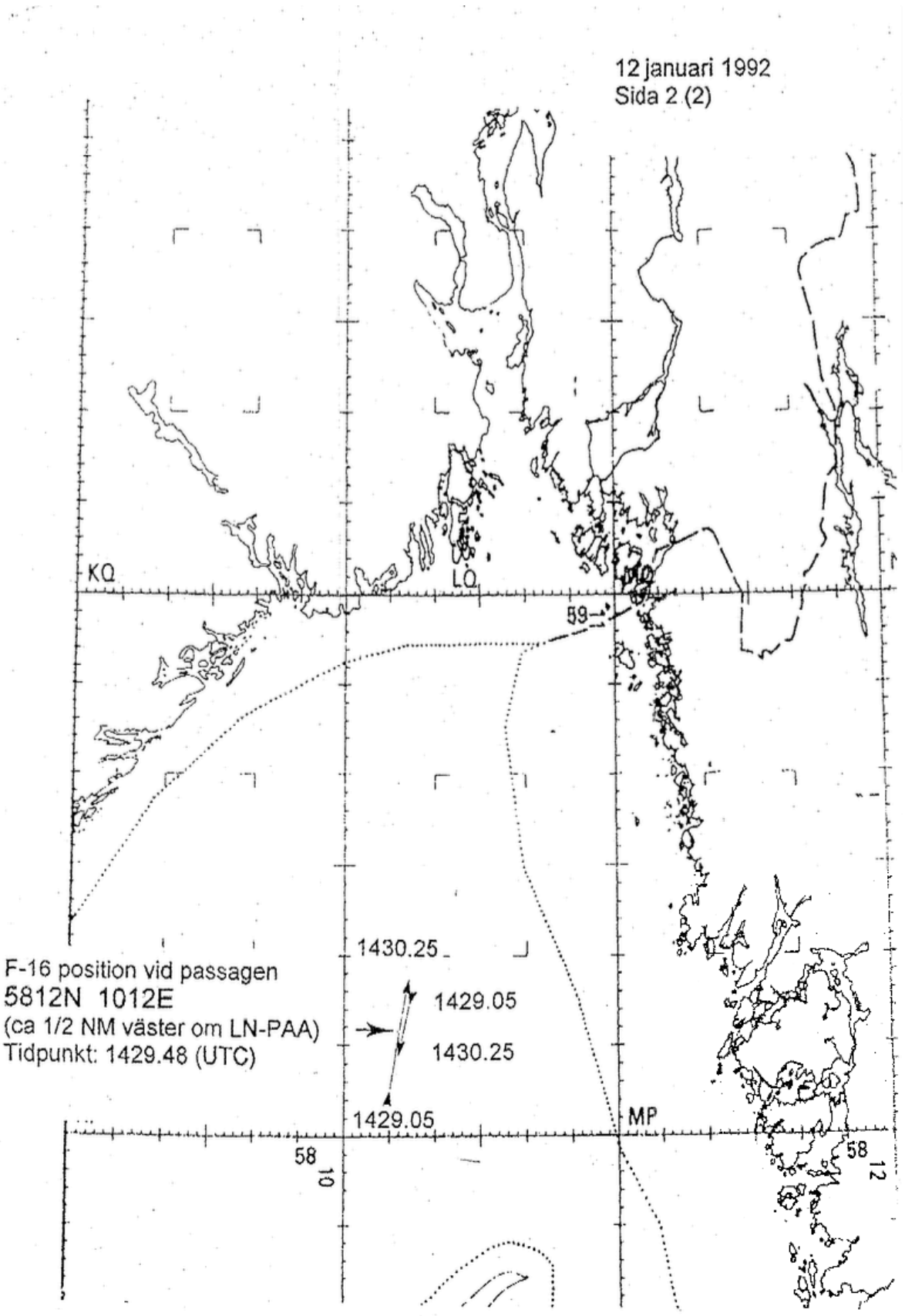
Radar analyst Gunnvall replied and enclosed a new sketch:
«I have made a plot of the two frames 1429.05 and 1430.25 (UTC), thus the simultaneous mutual positions of LN-PAA and the F-16.

I also have a frame at 1429.45 (You will recall that the film was taken with one image every 40 seconds) but on that frame the two aircraft were so close to each other that both echoes merged (the light spreads in the picture tube glass and blackens the film). That frame was therefore not usable.

By calculating the aircraft ground speed for these 80 seconds, I obtained 300 metres/second for the F-16 and 131 metres/second for LN-PAA. The two distances were 24 and 10.5 kilometres respectively. From this, I have interpolated the position and time of the pass according to the sketch on the next page.

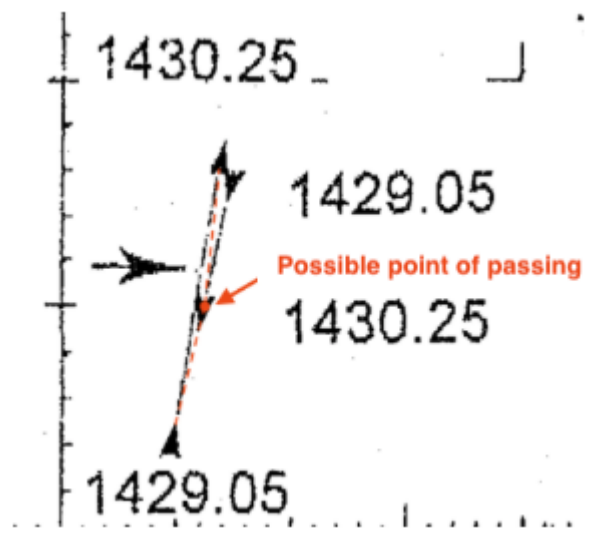
The result was that the F-16 passed approximately ½ (one half) nautical mile west of LN-PAA. The F-16's position was then 5812N 1012E and the time was 1429.48.

I have no concrete altitude information but have an impression that the F-16 was then (at the pass) flying lower than LN-PAA. Am not certain of this, however. (I have assessed that the F-16 departed from Aalborg at approximately 1421 and initially climbed over Jutland but decreased altitude before the encounter with LN-PAA. Is this correct?)» (Gunnvall, 1992, p. 1)



(Gunnvall, 1992) Sketch showing the pass between the F-16 and Partnair.

Gunnvall described that the F-16 and LN-PAA flew so close to each other that the radar points merged and became invisible on the image. Any heading corrections within the 80 seconds are not included in the calculations. The speed calculations will be incorrect because the straight-line distance between the endpoints is shorter than the distance the F-16 likely flew. An average speed over 80 seconds also cannot capture whether the F-16 was supersonic during parts of the time interval.



Swedish radar, pass between the F-16 and Partnair.

As described in the chapter on supersonic speed, the speed of sound at 25,000 feet altitude will be just above 601 knots, which corresponds to 309 m/s. The average speed of 300 m/s that Gunnvall calculated is only 30 km/h below the speed of sound. Given the uncertainty regarding atmospheric conditions and averaging over a large time interval, there is a high probability that the F-16 was flying at supersonic speed at the time of passing.

Speed Calculations

With obvious logical errors in both datasets, it is natural to verify the speed calculations. The radar system calculates the ground speed of the aircraft based on the distance between two registrations and the time interval between them. The radar operates with distances in "data miles" and speed in "data miles per hour" (1 data mile = 1.8288 km).

F-16 Speed Discrepancies

Speed between two points is calculated by finding the distance between the coordinates and then calculating speed based on the 12-second time interval.

1992 Dataset

```
11 14:28:56   AG151 7 31103 0265 0241 580736N 100907E 544,1 15,71 24100 3/C
12 14:29:08   AG151 7 23302 0265 0241 580924N 101013E 541,7 16,18
13 14:29:20   AG151 7 32203 0265 0241 581111N 101112E 540,8 15,81 24100 3/C
14 14:29:32   AG151 7 23102 0265 0241 581308N 101221E 541,7 16,18
```

Skagen 1992, F-16, sample data.

Example (lines 11 and 12): The distance between (580736N, 100907E) and (580924N, 101013E) is 3.51 km. This gives 292.5 m/s (1,053 km/h), which corresponds to 575.8 DM/H. The speed logged is only 544.1 DM/H (995 km/h).

1990 Dataset

In the 1990 dataset, the position is given in X and Y position. This is the distance from the radar station to the aircraft. By using stereographic projection, with the radar station's position as the origin, the X and Y values can be converted to map coordinates. This conversion must be done to be able to plot the points on a map and calculate the distance between two points.

```
11 14:29:11.5 AG151 7 31103 .. .... 0265 0241 -14,496 +23,297 544,1 15,71 24100 3/C
12 14:29:23.6 AG151 7 23302 .. .... 0265 0241 -13,887 +25,152 541,7 16,18 N/M
13 14:29:35.6 AG151 7 32203 .. .... 0265 0241 -13,367 +27,000 540,8 15,81 24100 3/C
14 14:29:47.5 AG151 7 23102 .. .... 0265 0241 -12,719 +28,926 541,7 16,18 N/M
```

Skagen 1990, F-16, sample data.

The decimal coordinates for line 11 are (58.1248762, 10.15325583) and (58.15539755, 10.17178854) for line 12. The distance between these points is 3.563 km. There are 12.1 seconds between the two measurements, and the speed is therefore 579.7 DM/H (294.5 m/s).

If one performs the corresponding calculation for lines 12 and 13, the speeds are 574.9 DM/H (292.0 m/s) and 613.6 DM/H (311.7 m/s).

For the F-16 aircraft, there is a significant discrepancy between the speeds in the dataset and the results obtained by calculating speed based on change of position over time. The deviation was between 6% and 13% for the lines in the example. For the entire dataset, the deviation varies between 1% and 53%.

Partnair Speed Discrepancies

If the radar system uses a different method for calculating speed that would produce such differences, this should also apply to data from the Partnair aircraft.

```
14:22:26.8 AG450 7 00103 00 0000 ---- 0218 -04.226 +54.836 189.5 190.6 21800 3/C
14:22:38.7 AG450 7 00302 00 0000 1211 0218 -04.394 +54.215 189.5 190.6 N/M
```

Skagen 1990, Partnair, sample 1.

Converted to map coordinates, these points are (58.64339654094567, 10.470050392698258) and (58.63319645187729, 10.464800063415908) respectively. The distance between these points is 1.18 km. With a time difference of 12.1 seconds, the speed between the points was 97.5 m/s (351 km/h). This corresponds to a speed of 191.7 DM/H.

```
14:24:02.0 AG450 7 00301 00 0000 1211 ---- -05.433 +49.439 194.4 192.5 N/M
14:24:13.9 AG450 7 00203 00 0000 1211 0220 -05.632 +48.867 194.4 192.5 22000 3/C
```

Skagen 1990, Partnair, sample 2.

The corresponding speed calculation yields a speed of 198.5 DM/H.

The discrepancy in the speed data for the Partnair aircraft appears to be around 1–2%, based on these two samples. This indicates that the speed calculations are consistent for Partnair, but not for the F-16.

Supersonic Speed for the F-16

«The speed of sound (Mach 1) varies with altitude and temperature. If an aircraft is travelling at the speed of sound at sea-level then its speed will be 661 knots (760 miles per hour) or if it is travelling at the speed of sound at 30,000 feet then its speed will be 589 knots (677 miles per hour).

Aircraft speed is usually measured in knots which is a unit of speed equal to one nautical mile per hour. Fast military jets have their top speed listed as a Mach number with Mach 1 being the speed of sound, and Mach 2 is twice the speed of sound.

An aircraft that is travelling at supersonic speed is exceeding the speed of sound (Mach 1). Speeds greater than five times the speed of sound (Mach 5) are often referred to as hypersonic.» (The Speed Of Sound – Mach 1 – Supersonic, n.d.)

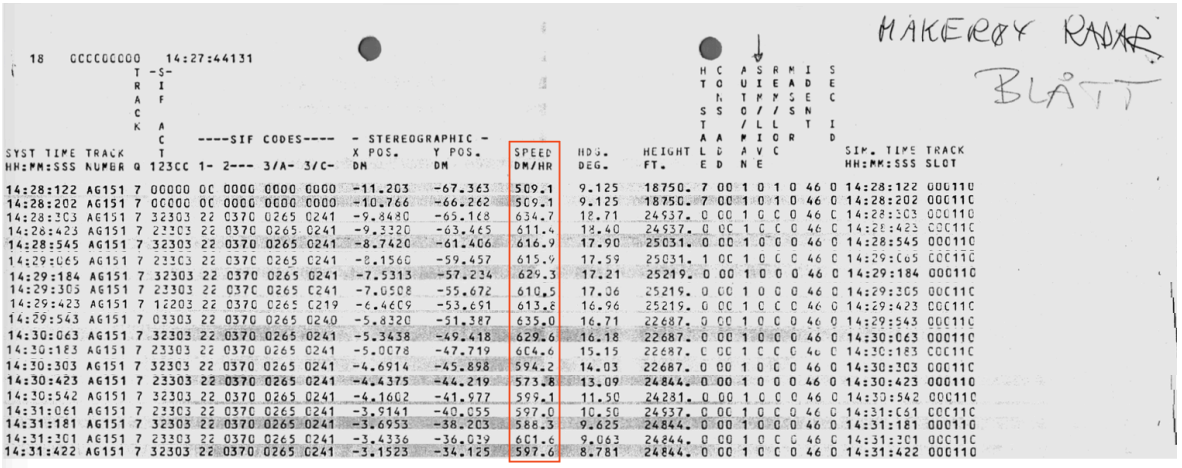
Based on the table on the aforementioned page, Mach 1 would be approximately 601 knots at 25,000 feet.

Altitude	Temperature		Speed	
Feet	Centigrade	Farenheit	Knots	MPH
0 (Sea Level)	15	59	661	760
5,000	5.094	41.200	649	747
10,000	-4.812	23.300	638	733
15,000	-14.718	5.500	626	720
20,000	-24.624	-12.300	614	707
25,000	-34.530	-30.200	601	692
30,000	-44.436	-48.000	589	677
35,000	-54.342	-65.800	576	663
40,000	-56.500	-69.700	573	659
45,000	-56.500	-69.700	573	659
50,000	-56.500	-69.700	573	659
55,000	-56.500	-69.700	573	659
60,000	-56.500	-69.700	573	659

Table with Mach speeds at different altitudes.

Using this speed, it is possible to calculate the F-16 aircraft's Mach number in connection with the pass of the Partnair aircraft. To find true airspeed, tailwind must be added to the ground speed. Before the pass, the F-16 was on a heading of approximately 015°. With 70 knots of wind from 260°, this would have given the F-16 a tailwind of 24 knots. Mach 1 then means a ground speed of 625 knots.

According to the dataset, the F-16 broke the sound barrier for the first time at 14:28:30 (634 knots, line 3 in the dataset), when it was located approximately 40 kilometres northwest of Skagen.



MÅKERØY RADAR
BLÅTT

18 0000000000 14:27:44131

SYST TIME HH:MM:SSS	TRACK NUMBER	T R A C K	Q	T C 123CC	1-	2---	3/A-	3/C-	X POS. DM	Y POS. DM	SPEED DM/HR	HDG. DEG.	HEIGHT FT.	HOSTS	CONTROL	ASSUMED	TIME	MISSED	RADAR	SECT	SIM. TIME HH:MM:SSS	TRACK SLOT
14:28:122	AG151	7		00000	00	0000	0000	0000	-11.203	-67.363	509.1	9.125	18750.	7	00	1	0	1	0	46	0	14:28:122	000110
14:28:202	AG151	7		00000	00	0000	0000	0000	-10.766	-66.262	509.1	9.125	18750.	7	00	1	0	1	0	46	0	14:28:202	000110
14:28:303	AG151	7		32303	22	0370	0265	0241	-9.8480	-65.168	634.7	18.71	24937.	0	00	1	0	0	0	46	0	14:28:303	000110
14:28:423	AG151	7		23303	22	0370	0265	0241	-9.3320	-63.465	611.4	18.40	24937.	0	00	1	0	0	0	46	0	14:28:423	000110
14:28:545	AG151	7		32303	22	0370	0265	0241	-8.7420	-61.406	616.9	17.90	25031.	0	00	1	0	0	0	46	0	14:28:545	000110
14:29:065	AG151	7		23303	22	0370	0265	0241	-8.1560	-59.457	615.9	17.59	25031.	1	00	1	0	0	0	46	0	14:29:065	000110
14:29:184	AG151	7		32303	22	0370	0265	0241	-7.5313	-57.234	629.3	17.21	25219.	0	00	1	0	0	0	46	0	14:29:184	000110
14:29:305	AG151	7		23303	22	0370	0265	0241	-7.0508	-55.672	610.5	17.06	25219.	0	00	1	0	0	0	46	0	14:29:305	000110
14:29:423	AG151	7		12203	22	0370	0265	0219	-6.4609	-53.691	613.8	16.96	25219.	0	00	1	0	0	0	46	0	14:29:423	000110
14:29:543	AG151	7		03303	22	0370	0265	0240	-5.8320	-51.387	635.0	16.71	22687.	0	00	1	0	0	0	46	0	14:29:543	000110
14:30:063	AG151	7		32303	22	0370	0265	0241	-5.3438	-49.418	629.6	16.18	22687.	0	00	1	0	0	0	46	0	14:30:063	000110
14:30:183	AG151	7		23303	22	0370	0265	0241	-5.0078	-47.719	604.6	15.15	22687.	0	00	1	0	0	0	46	0	14:30:183	000110
14:30:303	AG151	7		32303	22	0370	0265	0241	-4.6914	-45.898	594.2	14.03	22687.	0	00	1	0	0	0	46	0	14:30:303	000110
14:30:423	AG151	7		23303	22	0370	0265	0241	-4.4375	-44.219	573.8	13.09	24844.	0	00	1	0	0	0	46	0	14:30:423	000110
14:30:542	AG151	7		32303	22	0370	0265	0241	-4.1602	-41.977	599.1	11.50	24281.	0	00	1	0	0	0	46	0	14:30:542	000110
14:31:061	AG151	7		23303	22	0370	0265	0241	-3.9141	-40.055	597.0	10.50	24937.	0	00	1	0	0	0	46	0	14:31:061	000110
14:31:181	AG151	7		32303	22	0370	0265	0241	-3.6953	-38.203	588.3	9.625	24844.	0	00	1	0	0	0	46	0	14:31:181	000110
14:31:301	AG151	7		23303	22	0370	0265	0241	-3.4336	-36.039	601.6	9.063	24844.	0	00	1	0	0	0	46	0	14:31:301	000110
14:31:422	AG151	7		32303	22	0370	0265	0241	-3.1523	-34.125	597.6	8.781	24844.	0	00	1	0	0	0	46	0	14:31:422	000110

F-16, Mågerø, 634 knots at 14:28:30.

F-16 Speed in the AWACS Video

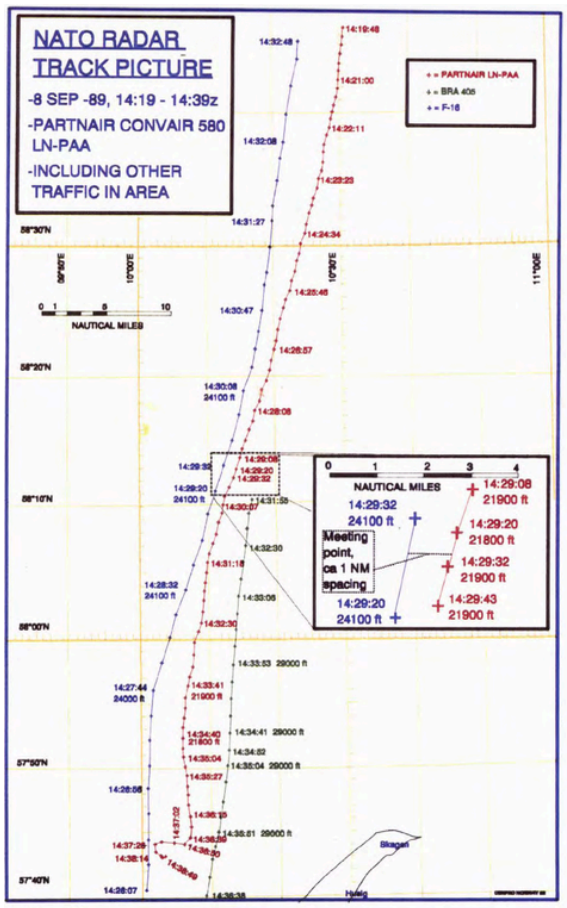
In the AWACS video, the right turn is shown approximately 77 seconds before the aircraft meet:

«The track from the south, 4310, is heading 034 altitude 24100, speed of 585 knots.» (18:45 in the video)

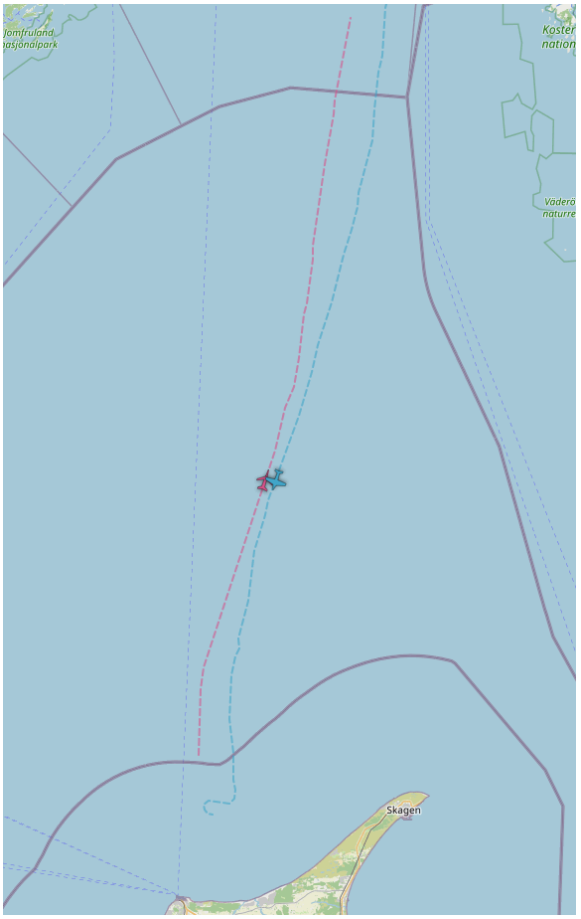
585 knots is approximately 50 knots higher than the speeds in the Skagen dataset, but corresponds more closely with what has been calculated based on position changes. In other words, there is a discrepancy between the AWACS-registered speed and the Skagen dataset.

The Accident Report's Radar Sketch

By comparing the sketch in the accident report with the various datasets, one can see that the closest dataset is the 1992 version from Skagen. Given that the new versions contain corrections where there are obvious errors, a logical explanation is that the new versions were produced because it was not possible to create a sketch without correcting the errors. Had the original data been used, the errors would have been very clearly apparent.



(The Accident Report, 1993, Figure 8)

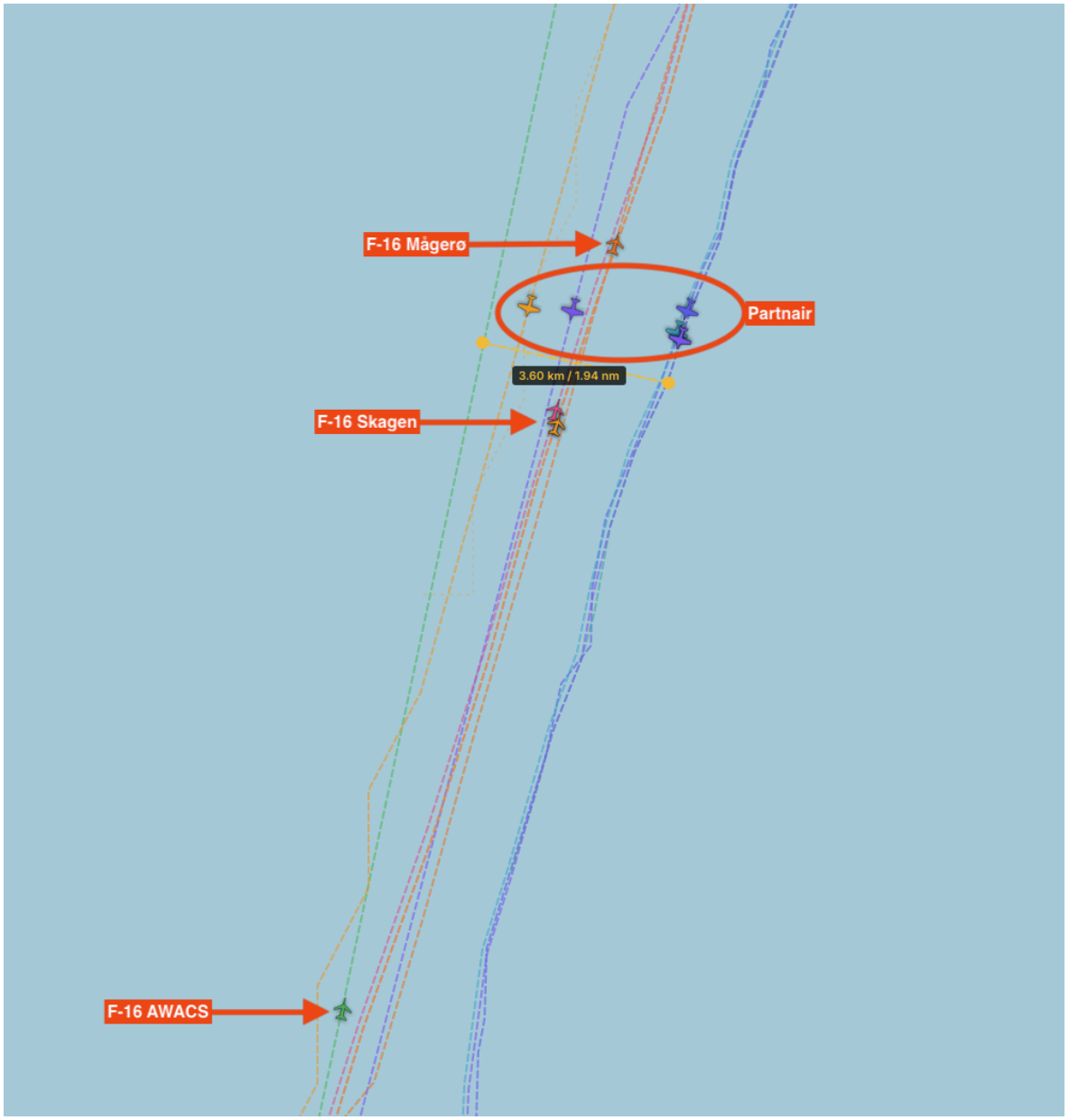


F-16 and Partnair, Skagen, 1992.

When producing a radar sketch from a few divergent datasets, one cannot make a selective selection and correct the data by hand. This is not a scientific method. If one truly wished to establish with a high degree of certainty where the aircraft were, one would have had to compare the data from all sources, remove the noise, and then be left with a radar track with relatively high precision.

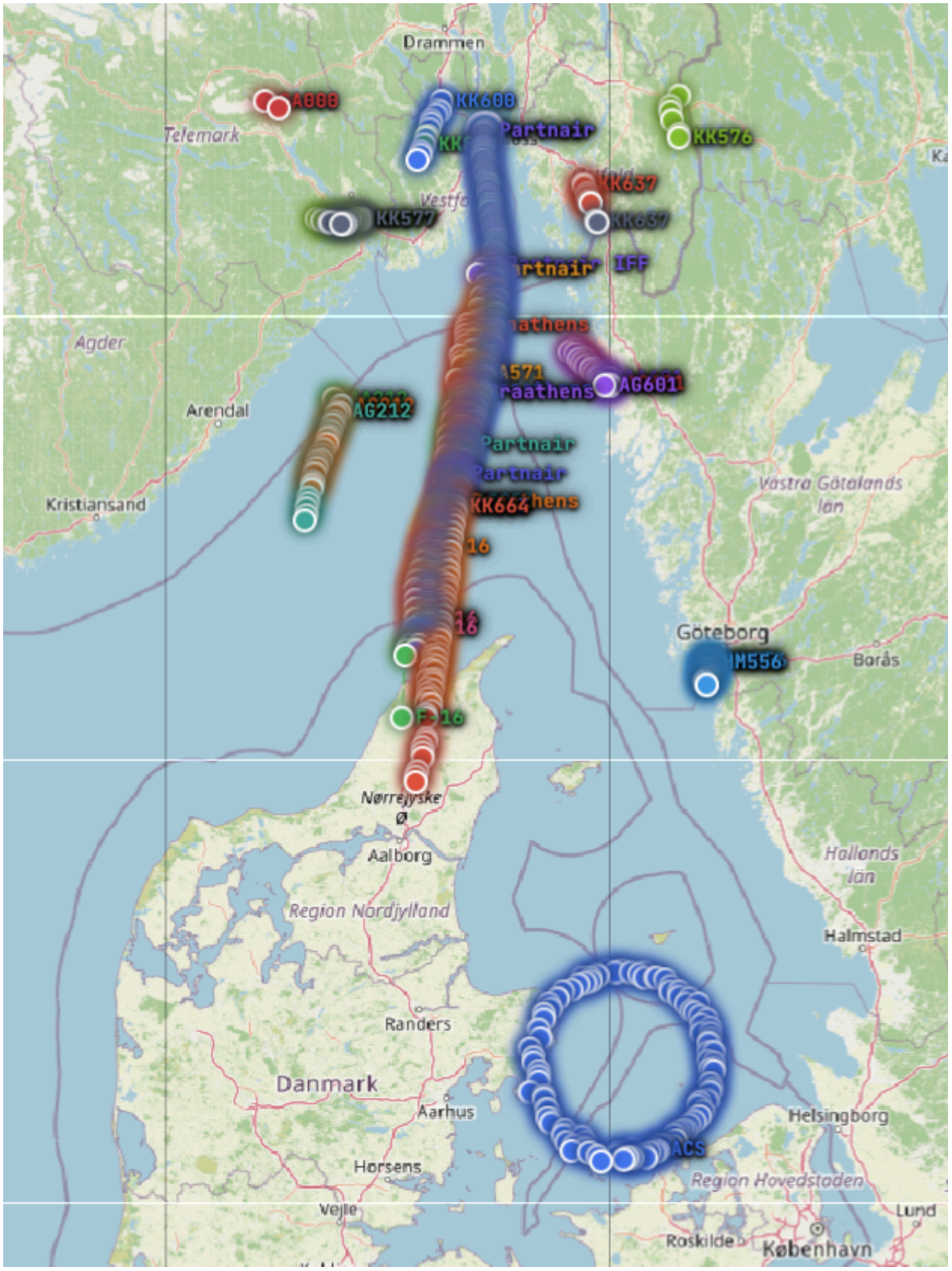
All NATO Radar Data Plotted

If one plots all the radar data that NATO delivered, the problems with the datasets become apparent. The datasets form 10 different tracks for the 2 aircraft. The AWACS tracks lie approximately 3 kilometres west of the tracks from Skagen and Mågerø. The horizontal spread is approaching 2 nautical miles.



F-16 and Partnair, Skagen, Mågerø, AWACS.

In the datasets, there is primarily data for Partnair, the F-16, and Braathens, but there are also other registrations. No position data has been presented for the AWACS aircraft, but the track can be plotted by reversing the position plotting: using the F-16 and Partnair aircraft positions as the starting point, the AWACS aircraft's position can be calculated using the distance and azimuth given in the AWACS dataset.



All NATO radar sources, with the AWACS aircraft's track (circle at bottom).

Discussion

The radar data is consistently of low quality with obvious errors and few registrations. Swedish radar has stored data at such low resolution (40–80 second intervals) and with analogue interpretation of position data from a screen that they in practice cannot be used to establish exactly where the aircraft were in relation to each other. It is nevertheless interesting that the speed calculations indicate a far higher speed than that stated in the Skagen data, and that the distance between the tracks is also markedly less than what the NATO radars show.

All the errors in the radar data appear to be the result of human involvement. The errors with time differences for the F-16 provide a clear indication that multiple simulations have been carried out and data has been stitched together. In combination with human errors, this has produced datasets with clear indications of manipulation.

The timestamps on the printouts indicate that radar data from Skagen, Mågerø, and AWACS was produced a few days after the accident. The time pressure must have been enormous if an alternative reality was to be produced, and it is likely this that one sees traces of through the many human-made errors.

When radar data has been clearly manipulated, it cannot be trusted. A selection of radar data, even if it shows a real situation, is not reliable when certain sequences have been removed—as for the F-16 in the AWACS data, where only 9 points have been released and the pass between the aircraft has been removed. Nor is it possible to trust the altitude data in any of the datasets, since there are no objective sources, and the altitude data cannot be verified from other columns.

That Partnair departed from Fornebu and crashed north of Hirtshals, and that the F-16 flew from Aalborg to Rygge, are known facts. Exactly where the aircraft were between these points cannot be established based on the radar data that has been made available. It is therefore not possible to establish, with the accuracy needed to determine whether a supersonic shock wave damaged the Partnair aircraft, where the aircraft were in relation to each other.

It is natural to ask why the radar data is full of obvious errors if someone deliberately altered it. The most plausible explanation is that the datasets were produced under intense time pressure, probably with tools that were not suited for the purpose. The datasets bear the hallmarks of having been assembled from multiple sources and simulations, and it is this that one sees traces of through the errors.

Chronology

The following is a reconstruction of the sequence of events based on available documentation, witness statements, and logical reasoning.

The Day of the Accident

Friday 8 September 1989, Osmoen and Meek are following a Norwegian F-16 that has just taken off from Aalborg and climbed to 24,000 feet. On the F-16's radar, which has a range of 65 nautical miles, the crew sees two opposing aircraft that they assume are American F-16s en route from Rygge to Aalborg. Over Hirtshals, they meet the first of the American F-16s. Thanks to the radar's display of the aircraft on the head-up display, they manage to see the oncoming F-16 passing 2,000 feet below. The Norwegian F-16 now continues out over the sea and follows the second of the two aircraft on radar. The pilots decide to greet the pilot of the other aircraft and steer towards where the radar shows it to be.

At Mågerø, Ketil Meek is following the Norwegian F-16. He notices that the aircraft is continuously changing heading, altitude, and speed. The aircraft is at supersonic speed on several occasions as it approaches the oncoming civilian aircraft. The radar system alerts that the aircraft are in conflict with each other. Together with Osmoen, they use the height-finding radar to verify that the aircraft are indeed on a collision course at the same altitude. The radar plot merges when the F-16 and the Partnair aircraft meet. To their great alarm, Osmoen and Meek see that only the radar echo from the F-16 continues northward, while the echo from Partnair disappears from the radar screen. They conclude that something catastrophic must have occurred and immediately alert their superiors about what they have witnessed. The radar echo for the Partnair aircraft reappears after a short while, when sufficient distance has developed between the aircraft. A few minutes later, the Partnair aircraft makes some abrupt manoeuvres and disappears from radar. At this point, there is complete chaos at Mågerø.

Civilian Timeline

Time	Event	Source
15:59:50	Take-off from Fornebu	ATC
~16:29:30	F-16 passes the Partnair aircraft	Swedish radar, FDR, Skagen radar, radio log
~16:35:30	The pilots must have understood that the problem was very serious	FDR
~16:36:15	Loss of control	FDR
~16:39	The aircraft hits the water	Skagen radar
16:39:56	Copenhagen Control calls Partnair several times without receiving a response	Radio log
~16:42	Copenhagen Control calls Oslo and asks whether the Partnair aircraft has been transferred to their frequency	Radio log
16:45:00	Copenhagen Control calls Aalborg and asks whether they can see the Partnair aircraft	Radio log
~16:56	Copenhagen Control calls Oslo and asks whether they can contact the Partnair airline on "company frequency"	Radio log
~16:59	Copenhagen Control calls Oslo and reports that the rescue centre at Karup has been notified. Oslo confirms that they will notify the main rescue centre.	Radio log

Vedbæk

The following is based on a witness statement from a person who was on duty at the Sector Operations Centre (SOC) in Vedbæk on the evening in question. SOC Vedbæk was the operational command of Denmark's air surveillance, responsible for the four Danish radar stations and coordination of air defence.

At 16:45 local time—a few minutes after the Partnair aircraft had disappeared from radar—the telephone rang at the Sector Controller's radar console in the operations room. It was the radar station at Skagen. They reported that they had lost radar contact with an aircraft that, according to the flight plan, was en route from Oslo to Hamburg. The radar plot had disappeared approximately 20 kilometres north of Hirtshals.

The atmosphere in the room changed immediately. Everyone went from a normal watch mood to full concentration. All positions in the operations room were quickly manned. The Sector Controller ordered the scramble of two F-16 fighter jets that were always standing ready on high alert, as part of NATO's Quick Reaction Alert (QRA) readiness.

When the scramble alarm sounded, they ran to the aircraft, started the engines, and reported ready on the radio. They were briefed on the situation and sent towards the area where the Partnair aircraft was last registered on radar.

When the Danish F-16s reached the area, they observed wreckage in the water. With the two F-16s circling over the area, Vedbæk received coordinates for the possible accident site. The Naval Operational Command in Aarhus was contacted. They could report that warships were in the area in connection with a NATO naval exercise, and that these could quickly be dispatched to the accident site.

The First Days

The crew of the Norwegian F-16 is taken in for debriefing immediately after landing at Rygge. Since a NATO exercise is underway in the area, the Danish Air Force High Command in Vedbæk is notified. At both Mågerø in Norway and Vedbæk in Denmark, there are Control and Reporting Centres (CRC) in NATO's radar network (NATINADS). Both stations receive data from each other's and NATO members' radar stations, and store them on tape. At both locations, there is personnel with high radar expertise.

The work of extracting radar data and replaying it in the radar system to analyse the incident is done both at Mågerø and on the Danish side by those on duty. Over the weekend, additional resources are brought in to work with the radar data. Sigve Barvik is one of the resources at Mågerø and realises already on Friday evening that his assistance will probably be needed. On Sunday 10 September (day 2), Jon Pran calls Sigve Barvik for help interpreting radar data so that the search area can be narrowed. This marks the beginning of Barvik's assistance to the accident investigation board.

Both Mågerø and the Danish Air Force have large quantities of radar data from a number of radar stations in the NATO network. For personnel with radar expertise analysing this data, it would be difficult to reach any conclusion other than that the accident is connected to the

supersonic close pass. After several decades of testing supersonic flight, and a long series of incidents, NATO possesses significant knowledge about the damage a supersonic shock wave can inflict on aircraft not designed to withstand such forces.

Given that the Air Force in both Norway and Denmark would in all probability be asked by the accident investigation board to deliver radar data, the subsequent course of events suggests that an effort was initiated to construct radar data. The sequence of events is also consistent with standard military procedure in connection with incidents: Deny all blame. Admit nothing other than what is publicly known. Keep as much information as possible classified.

Week 1: Radar Data is Prepared

Monday 11 September (day 3) at 10:10 UTC, the operations division at Vedbæk CRC sends a request to the E-3A Component (AWACS) in Geilenkirchen to deliver data that can be shared with the accident investigation board. Work on the AWACS data begins immediately, and less than 24 hours later, resources at the E-3A Component have filtered out classified information from the AWACS radar data and printed what can be released: a total of 85 points for Partnair, 66 points for Braathens, and 9 points for the F-16. The reason for only 9 points for the Norwegian F-16 is that its movements near the Partnair aircraft are classified.

Simultaneously, on the Danish side, radar data is prepared that Mågerø can later deliver. The data basis is produced based on real radar data, which is then adjusted in a simulation tool and subsequently exported to a written format. Three declassified (NATO Unclassified) datasets are prepared that can be delivered as needed—one for each of the three aircraft (Braathens, Partnair, and F-16). In connection with the pass, several data points are removed, so that there is only every other data point for the F-16 and every third point for the Partnair aircraft. This reduction is done to reduce the precision and value of the data.

The Civil Aviation Authority secures evidence and writes its report immediately. On Monday 11 September, they send reports and audio log transcripts to the accident investigation board. The accident investigation board now knows with certainty that there was military flying activity in the area over the Skagerrak at the same time as the Partnair aircraft's journey over the sea.

Weeks 2–3: Minimal Data is Delivered

Wednesday 13 September (day 5), Bjørn Neråsen writes a letter to the accident investigation board stating that Mågerø hereby delivers all data that they can contribute. He encloses the minimal dataset concerning the Partnair aircraft's movements. Mågerø has access to far more data than what is delivered. In the letter, Neråsen describes the data as coming from Denmark, and that the radar positions have been converted to geographic positions. It is, however, unclear whether Neråsen is aware that the data for the Partnair aircraft actually originates from the radar at Mågerø, not Skagen, or that the converted geographic positions are anomalous at the accident site—which indicates that someone has made manual adjustments to the final radar registrations.

The accident investigation board is at this point aware that there have been other aircraft in the area. On 19 September (day 11), Neråsen refers to an agreement between Rygnestad and Lieutenant Colonel Johannessen and sends a new appendix with "NATO Unclassified" radar data. He specifies that only one aircraft movement (Braathens) has been registered in the vicinity of the accident site. This is not correct, but at this point, the Norwegian F-16's movements are still classified. The Braathens dataset contains only 10 points during the time frame of the accident, and shows that the Braathens aircraft was then 7,000 feet higher and somewhat south of the Partnair aircraft.

On the same day, 19 September, the E-3A Component sends radar data and sketches to the operations division at Vedbæk CRC. One week has now passed since they had filtered out data for the relevant aircraft and printed it. Together with the written radar data, plotted radar data is enclosed which, due to "technical explanations," looks quite different from the actual flight paths. The plots are based on the very limited number of points for the F-16 that had been released from the otherwise strictly classified radar data.

The F-16 is Revealed

The Civil Aviation Authority transmits the audio tape recording of the conversation between Oslo Control and the Norwegian F-16 to the accident investigation board on Friday 22 September (day 14). The accident investigation board now understands that a close pass between Partnair and the Norwegian F-16 probably took place, but chooses to disregard this. They also do not request a report from the F-16 captain.

It is decided that the Norwegian accident investigation board for civil aviation shall investigate the accident, despite the fact that international conventions dictate that it is Denmark that should investigate the accident, with support from Norway and the USA (the nation of the airline and the aircraft manufacturer respectively). The close ties between the accident investigation board and the Armed Forces, including resources at Mågerø, give the Norwegian Air Force significant influence with the accident investigation board, while simultaneously creating an apparently good distance from the radar data originating from Denmark.

Tuesday 26 September (day 18), Sigve Barvik collects three pages of data printout from the Danish accident investigation board on behalf of the Norwegian accident investigation board. The data printout was produced by the Danish Air Force, which Barvik also visited on his trip to Denmark.

VG publishes an article revealing that a Norwegian F-16 flew from Aalborg to Rygge, and the Armed Forces must now admit that a Norwegian F-16 encountered the Partnair aircraft. The radar dataset for the F-16 has already been prepared in the same manner as for Partnair and Braathens, and can therefore be quickly delivered to the accident investigation board.

Wednesday 27 September (day 19), Neråsen sends F-16 radar data to the accident investigation board. As shown in the radar analysis, this radar data does not correspond with reality, and much suggests it has been fabricated.

Pilot Reports and Wreckage Recovery

Now that the information about the F-16 is public, it is no longer possible for the accident investigation board to pretend the pass had not occurred. They request a report from the captain of the Norwegian F-16, which according to regulations should have been submitted immediately in such a situation.

Thursday 28 September (day 20)—the day after Neråsen has formally admitted that there was a Norwegian F-16 in the air over the Skagerrak—the F-16 captain writes his report to the accident investigation board. To lend the report additional weight, the other pilot also signs it.

The search for wreckage is in full progress. Friday 29 September (day 21), the search teams find parts of the horizontal stabiliser and the elevator. The vertical fin has already been found, but the rudder is missing. The accident investigation board is particularly interested in the tail control surfaces, since damage to any of these could result in loss of pitch control. The spread of the wreckage across a large area makes it obvious that the aircraft broke up in the air.

AWACS Video

As representatives of the Norwegian accident investigation board, Pran and Barvik travel to Geilenkirchen in the autumn of 1989. They are shown a playback of radar data from the AWACS aircraft, which recorded all the aircraft over the Skagerrak when the Partnair aircraft was in the air. Pran and Barvik see that the F-16 is constantly changing heading and continuously approaching the Partnair aircraft. Finally, the points merge, and the radar operator reports that the F-16 at that time is flying directly above the Partnair aircraft with a vertical separation of 2,000 feet. The next radar plot shows that the F-16 carried out a turn at high speed in connection with the pass. Pran and Barvik take with them a video recording of what they have just witnessed on the radar screen.

Barvik's Radar Analysis

Sigve Barvik works with radar data for the accident investigation board. He separates the radar data and creates printouts with one dataset per aircraft. To make the altitude data as clear as possible, he adds a column showing the aircraft's pressure altitude (Mode C). This is the most reliable registration, something the accident investigation board is also fully aware of.

Barvik's main challenge is that the work must be done manually, and this opens the door for human errors. Another challenge is explaining the cause of abnormalities in the radar data in connection with the pass. Barvik marks where the scan interval changes from 12 seconds to 10 seconds for the F-16 aircraft as a transfer to Mågerø. He sends the datasets and map sketches to the accident investigation board on 7 February 1990.

The accident investigation board relies on the expertise of Sigve Barvik and has no one else to verify the work done with the analysis of radar data. They therefore overlook details such as the time intervals for the registration of the F-16 not being consistent in connection with

the pass, and that the F-16 apparently stands still in the air for several seconds. Checking that the values in the altitude column actually correspond with what is registered in the radar data is something they have no capability to do. This is knowledge that only Barvik possesses at this point.

What has now happened is that Barvik has delivered the radar printouts from both Mågerø and Skagen. The Mågerø dataset was probably not intended to be shared, as it contains revealing information about the F-16's speed.

The Speed Discrepancy is Uncovered

With two sets of data printouts in the same format, but from two different radar stations, it is now straightforward for the accident investigation board to compare the speed values for the F-16. They can then see that there is a significant discrepancy between the two datasets. The Mågerø data shows that the F-16 was averaging 620 knots in connection with the pass, while the speeds in the Skagen radar data have been adjusted downward to an average of 540 knots. On the day in question, the F-16's ground speed—that is, the speed in the radar data—would probably have needed to exceed 600 knots to correspond to supersonic speed.

The AIR Report

The accident investigation board entrusts the technical analysis to Accident Investigation & Research Incorporated (AIR) in Canada. The work is extensive and extremely time-consuming. AIR works with everything from wreckage analysis to Flight Data Recorder and radar data. The AIR report is completed on 10 March 1992, and the accident investigation board now has a thorough analysis to rely on as they finalise their report.

The Canadian analysis points to only one difference between other flights and the accident flight: that the APU was in operation while the aircraft was in the air. They therefore anchor the causal conclusion to precisely this one detail, and in practice place the blame for the accident on the APU. The close pass with the F-16, which occurred a few minutes before the accident, is not mentioned.

The F-16 Pilot's Second Report

Shortly after the AIR report is completed, the F-16 pilot is asked by a superior to write an additional report for the accident investigation board. On 25 May 1992, he writes a new report that opens with:

«There exist some ideas suggesting that weapons from military vessels may possibly have been the cause of this accident. The reason nothing was mentioned in this connection in the first report is that the thought that weapons could have been used was completely foreign to me.»

The F-16 pilot goes on to explain how he, as an instructor, flew a training sortie with a student to Lahr in Germany, and then flew alone to Aalborg in Denmark where he picked up the other pilot who had participated in an exercise. In the final paragraph he writes:

«In closing, I would like to remark that I find it very regrettable that "rumours" are circulating that I may have been involved in the accident.» … «Everyone who knows the military flying community in Norway knows that armed weapons are not carried on flights abroad or on ordinary training sorties.»

New Version of Radar Data

In connection with the preparation of the accident investigation board's report, Jon Pran contacts Sigve Barvik and requests map material. Pran appears to be focused on determining whether the F-16 and the Partnair aircraft were at the same altitude, and raises questions about altitude measurements from Skagen radar. Barvik delivers map material on 19 August 1992, together with radar data and information about altitude data. He encloses a detailed explanation of the data format for the radar data.

The newest version of the dataset has clearly been processed manually. The timestamps have apparently been corrected by 15 seconds, supposedly to make them "correct." However, it is not only the timestamps that have been adjusted. Altitude data has been changed from what it was at the beginning of 1990. The error with the F-16 being stationary in the air has been removed. Repeating digits in the radar data (low entropy) provide a clear indication that a human has keyed in new numbers into the dataset.

The accident investigation board decides to place its trust in the obviously manipulated radar dataset from Skagen radar, despite the fact that the accident investigation board now has sufficient information from Barvik to be able to uncover the errors. It is difficult to uncover errors when the accident investigation board's radar expert is the same person who has processed, delivered, and explained to the accident investigation board what the radar data shows.

500 Feet

The Armed Forces' radar data from Skagen shows that the F-16 passes west of the Partnair aircraft with 1 nautical mile of lateral distance, corresponding to 6,000 feet. The F-16 pilot repeats in his final report the claim that «we get visual contact with an aircraft that passes approximately 1–2,000 feet below us.»

Since this does not harmonise with the audio recording in which the F-16 pilot says «You knew you had that airliner coming straight at us here?», Pran speaks with the F-16 pilot by telephone on 31 August 1992. During the conversation, Pran has the original report from the F-16 pilot in front of him and marks two places in the report. The places he has marked concern the fact that the Partnair aircraft was coming straight towards the F-16 at approximately the same altitude, and that the F-16 passed directly above the Partnair aircraft. In the conversation, the F-16 pilot confirms that the Partnair aircraft was not 1 nautical mile away, but only approximately 500 feet.

At this point, it must be obvious to both the F-16 pilot and Jon Pran that the Skagen radar data, which shows 1 nautical mile of lateral separation, cannot be real.

Consultation and Swedish Radar Data

The report is sent out for consultation towards the end of 1992. Several consultation bodies submit feedback on the draft, including Hans Arnegard. He points out that the communication between the F-16 pilot and the air traffic controller indicates that the aircraft were closer to each other than what is shown on the map sketches, which are based on Skagen radar data. He further raises the question of whether a shock wave from the F-16 may have had an impact on the Partnair aircraft. Others request radar data from the Swedish Armed Forces, showing the pass between the F-16 and Partnair.

Pran contacts Gunno Gunnvall on 7 January 1993 and requests radar data for the time of the pass. Gunnvall confirms on 12 January 1993 that he still has the film with recordings of the radar screen. The film consists of one image per 40 seconds, but Gunnvall explains that at the time of the pass, the aircraft were so close to each other that the image could not be used. Instead, he creates a sketch showing the F-16 and the Partnair aircraft's paths directly over a distance that the aircraft took 80 seconds to traverse. This corresponds to 24 km for the F-16 and 10.5 km for Partnair respectively.

The distance between the radar tracks is approximately 0.5 nautical miles (~3,000 feet). In the letter, Gunnvall also writes that the average ground speed between the two points is 300 m/s (583 knots) for the F-16 and 131 m/s (254 knots) for Partnair. This is physically the lowest speed the aircraft could have had, and any change of heading during the 80 seconds would result in a higher actual speed. Gunnvall refers to the rough estimates they have of altitude data and writes: «I have assessed that the F-16 departed from Aalborg at approximately 1421 and initially climbed over Jutland but decreased altitude before the encounter with LN-PAA.»

The accident investigation board publishes the final accident report in February 1993.

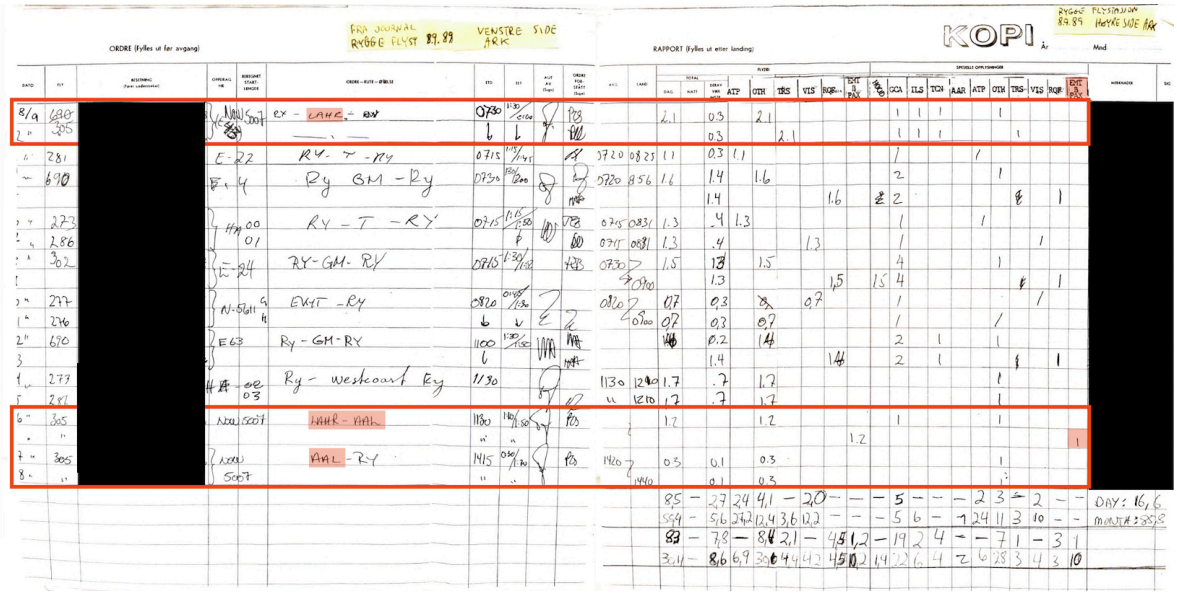
The Authorisation Log

In connection with one of the lawsuits, in the spring of 2003 information about the F-16's logbooks is requested. The then flight safety inspector writes that the aircraft's logbook, which contains a history of use and maintenance, is guaranteed to have been destroyed after one year. Instead of the technical logbooks, a page from the authorisation log is presented showing where the F-16 flew on the day in question. The flight safety inspector notes that he cannot explain what the column "EMT B PAX" in the authorisation log means. It is precisely this column that is interesting, as it seems entirely illogical to log the number of times an aircraft seat has been empty.

The most peculiar thing is that the airport codes for Lahr and Aalborg are incorrect, but only for the flights of the specific F-16 that encountered the Partnair aircraft on its way back to Rygge. A pilot would not have made the mistake of writing the name of the airport (Lahr) instead of the ICAO code EDTL. Nor would he have used the IATA code (AAL) instead of the ICAO code EKYT. There are no other corresponding errors in the authorisation log that day, despite others also having been to Aalborg. The F-16 captain would hardly have made the same error in his personal logbook, where he has logged airport codes and flight time for all his flying hours.

The only plausible explanation is that someone, lacking pilot expertise, has altered the log to support the narrative that the F-16 captain flew to Germany and then picked up the other pilot on the way back. In this way, they show that the F-16 captain and the F-16 aircraft that encountered Partnair had absolutely not participated in the NATO exercise that was underway that day.

…but then why does this appear on forsvaret.no?:
«The fighter jet had participated in a major exercise and was on a transit leg back to Rygge when it passed the Partnair aircraft.» (*Partnair-Ulykken*, 2024)



Authorisation log with incorrect airport codes for Norwegian 5007, and an unexplained log column "EMT B PAX."

Evidence That Was Not Examined

Despite the fact that regulations dictated that an accident in Denmark should be investigated by the Danish accident investigation board, with support from Norway (the airline's home country) and the USA (the aircraft manufacturer), it was decided relatively immediately after the accident that the Norwegian accident investigation board would investigate the accident. Asker and Bærum Police District led the criminal investigation with assistance from Kripos regarding identification work and investigations into whether anything criminal had occurred in connection with the accident. The primary focus was on determining whether explosives had been used to cause the accident, which was reminiscent of the Lockerbie disaster that had occurred less than a year earlier.

The identification work and autopsies were carried out in Denmark, with assistance from Kripos, particularly regarding the gathering of information that could be used in the identification work. During the autopsies, some fragments were found, which were sent to Norway for further examination. Kripos also made findings that they needed assistance to investigate. They therefore contacted RARDE in England, which had assisted with the investigation of the Lockerbie disaster.

Furthermore, the accident investigation board used, among others, Veritec, a subsidiary of Det Norske Veritas, and the Canadian firm Accident Investigation & Research Incorporated (AIR) for technical investigations. With the exception of the RARDE reports, it appears that the technical investigations were released by the accident investigation board. Despite the fact that the RARDE report was not classified in the first instance, both the accident investigation board and Asker and Bærum Police District chose to withhold this report.

In contrast to the assessments made after the accident, Oslo Police District determined that both parts of the RARDE report could be released. Although the RARDE report does not provide any leads as to what the triggering factor of the accident was, there are some significant findings that have not been addressed in the accident report. This may help to understand the secrecy.

High-Velocity Fragment

One of RARDE's most interesting findings is a hole from a projectile that has passed through a shelf panel inside the aircraft. Already in the initial examinations, RARDE took an interest in this hole and established that it had not occurred as a result of the impact. It is worth noting that no parts of the aircraft move so fast—not even the tips of the propeller blades, which remain below the speed of sound—and it is therefore unlikely that the fragment originated from the aircraft.

«Item B117 has less obvious damage, although trials so far completed suggest that the velocity of the fragment or projectile that penetrated the sandwich structure were greater than expected from any event associated with the breakup and impact of the aircraft. There is thus the possibility that a fragment formed by an explosion or, more likely, a secondary projectile may have caused the hole.» (RARDE, 1990, p. 8)

In part two of the report, RARDE describes more about their conclusions after firing tests, in which they attempted to recreate a corresponding hole in the same panel:

«With all the evidence obtained and reported we conclude the following: The penetrative object was probably of irregular shape. The mass was approximately 5 grams. The object was probably of composite nature, ie hard core with a softer outer covering. The velocity at impact was in the region of 650 m/s.» (RARDE, 1991, p. 10)

FIGS. 80–81

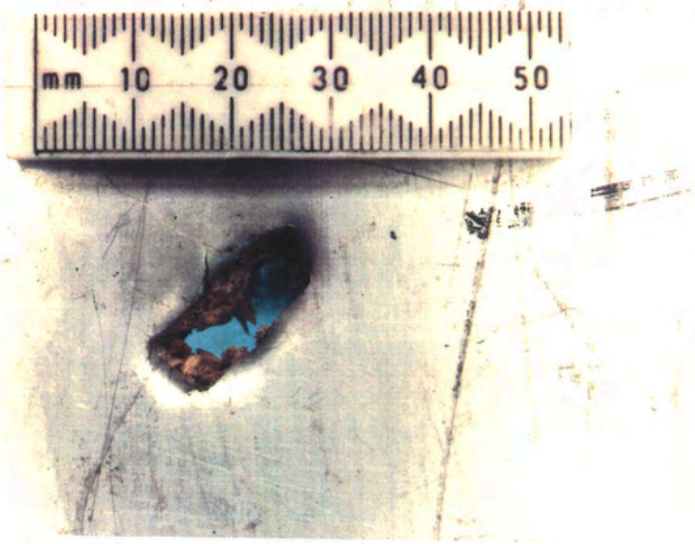


FIG. 80 ENTRY HOLE x1.5

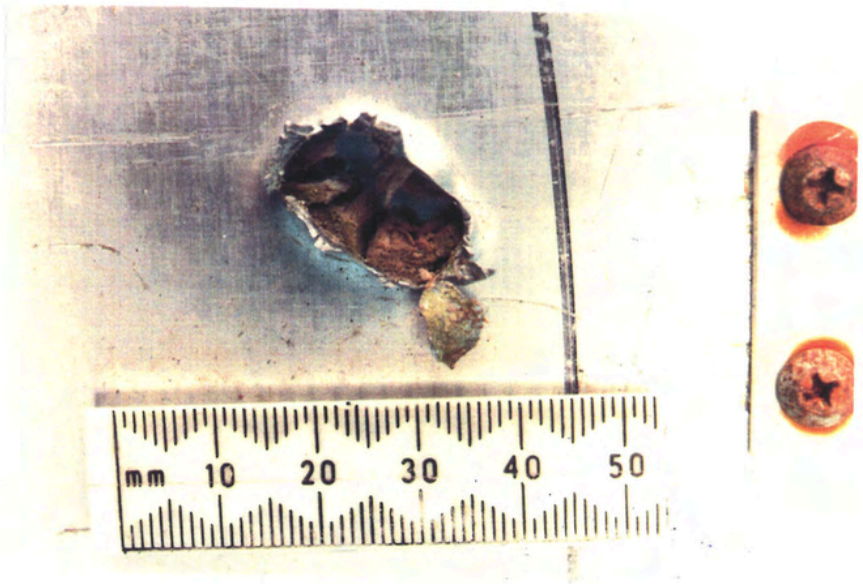


FIG. 81 EXIT HOLE x1.5

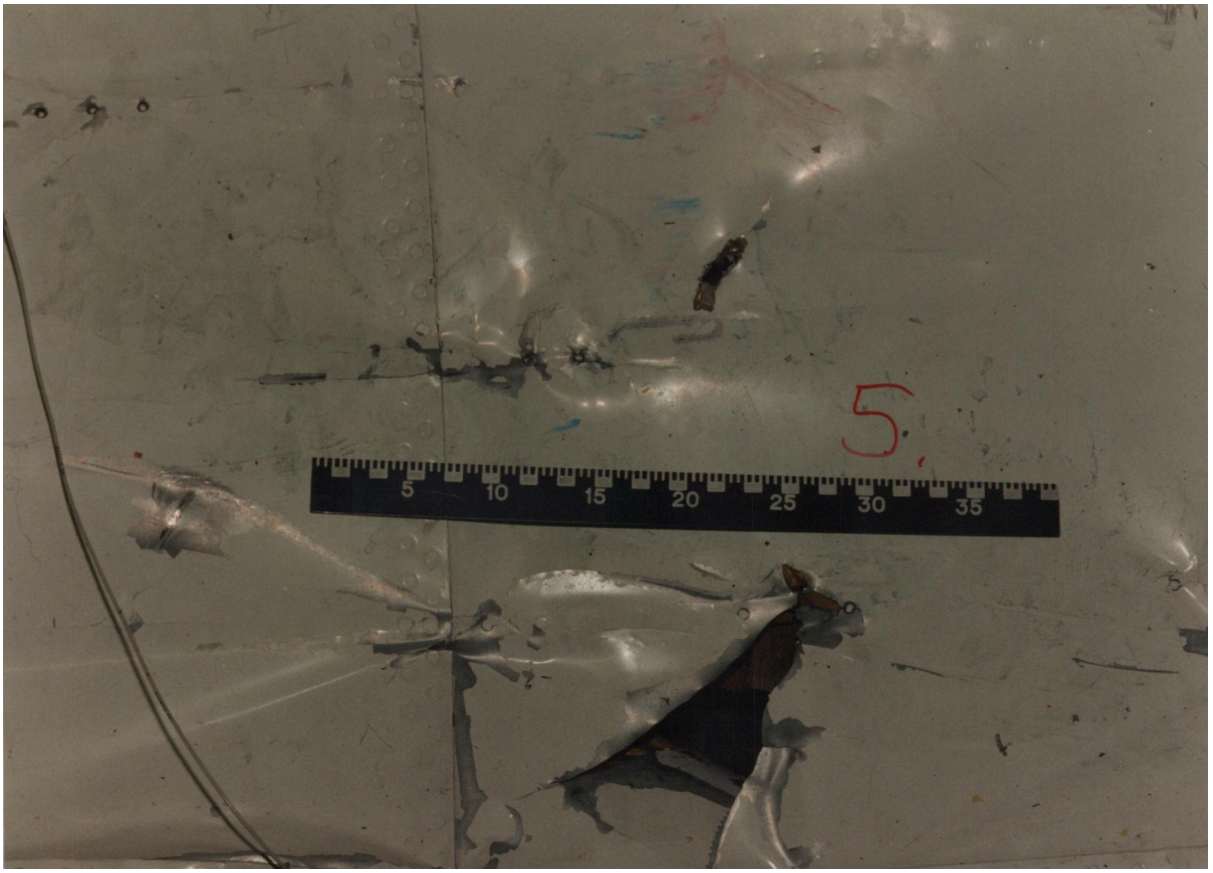
SAMPLE B117

(RARDE, 1990, Figs. 80–81)

Holes in the Fuselage

A high-velocity fragment that has travelled at 650 m/s through a shelf panel inside the aircraft cannot in practice have originated from the accident sequence itself. An explosion is required to accelerate a fragment to that velocity. When there are no traces of explosion or fire in the aircraft, this means in practice that the fragment must have come from outside the aircraft and, in that case, penetrated the fuselage. Wreckage with entry holes or exit holes of corresponding size would be observations that strengthen the hypothesis that the aircraft was struck by fragments from the outside.

If one studies the photographs that Kripos took in connection with the recovery of wreckage, there are several images showing holes that may be consistent in size with the fragment hole from the shelf panel on the inside of the fuselage.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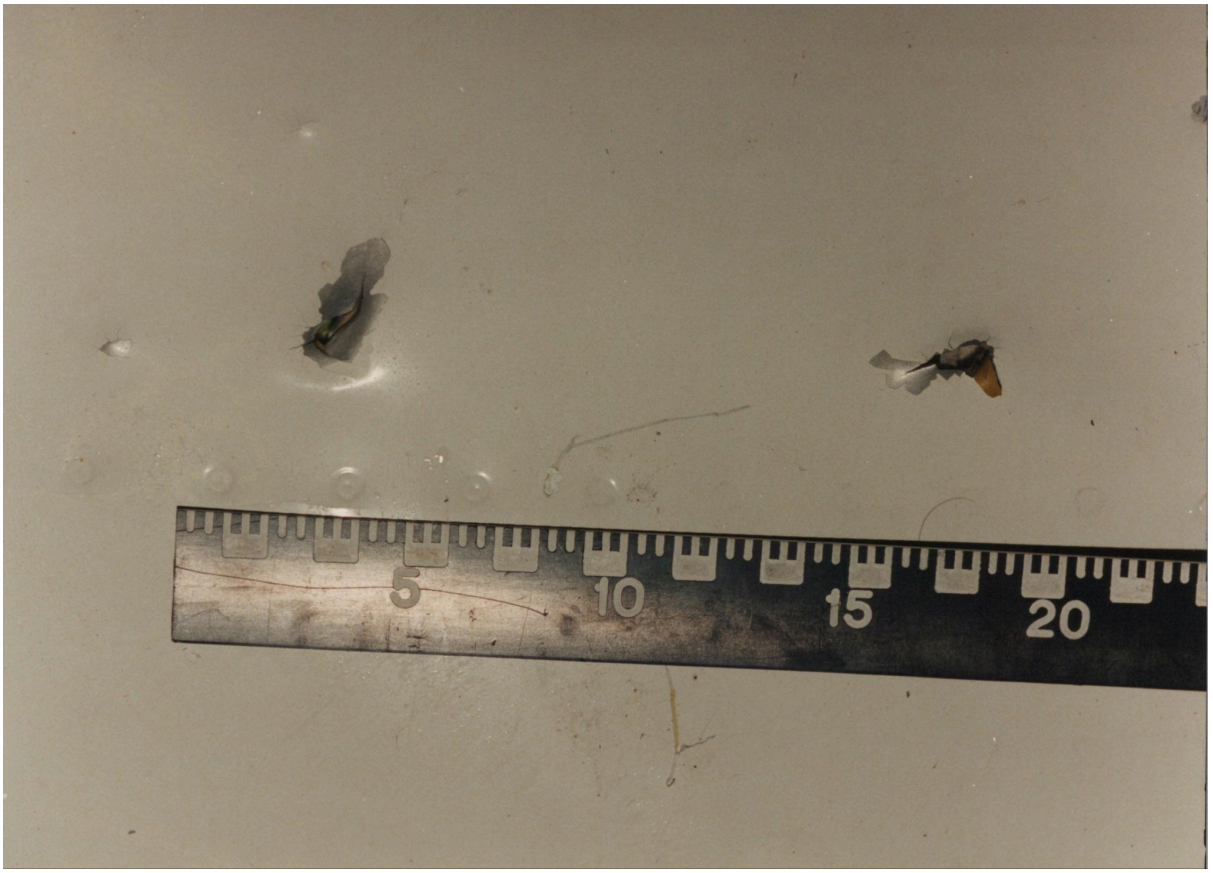
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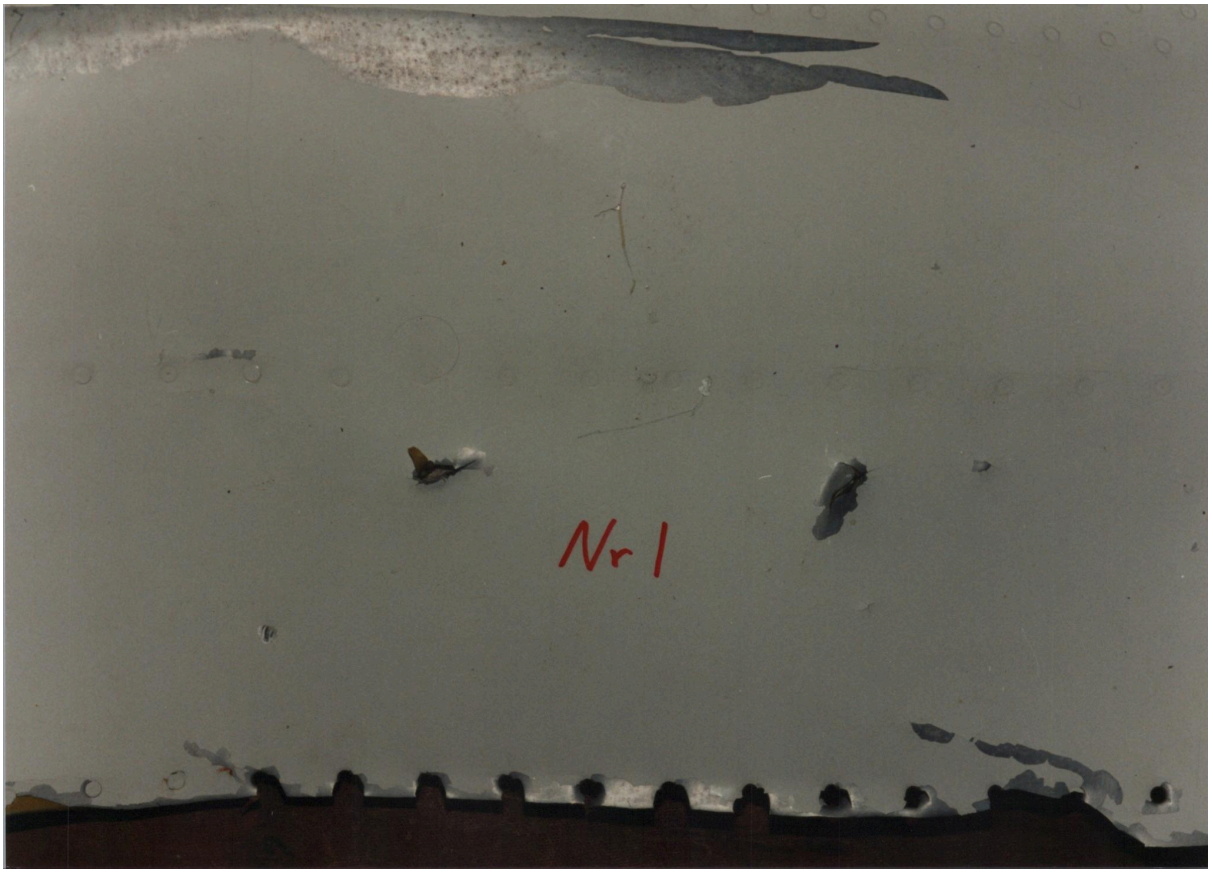
Nr 1

Break-Up in the Air

The aircraft broke in two during the final part of the accident sequence. Although the aircraft was out of control, it does not seem logical that the aircraft breaks in two without the fuselage having been damaged in a way that weakens its structural integrity.

If the aircraft was struck by many fragments on the left side, the structure will be weakened such that a natural consequence may be that the aircraft breaks apart to the right. It will be difficult to find fragment holes in an area that breaks apart, since the break-up will naturally occur through where the fuselage has been weakened by holes. When the Partnair aircraft's nose section was additionally the part that hit the water first, it was also where the parts were torn into the smallest pieces. The reconstruction shows that many parts were not recovered from the relevant area on the left side forward.

The Partnair aircraft, reconstructed, left side forward.

«All of the physical evidence therefore supports in-flight separation of the nose section of the fuselage starting at the left side at Station 261 and propagating to the right side. Analysis of the panel fragmentation and fractures from the left to the right side on the nose section remains confirms this failure progression.» (Accident Investigation & Research, 1992, pp. 10–11)

RDX

Findings of RDX were made on a total of two aircraft parts. Only trace amounts of RDX were found, and RARDE could not exclude that this was due to contamination. In the accident report, reference is only made to trace amounts of RDX being found on one part. In the RARDE reports, however, it is described that findings of RDX were made on two parts. Contamination cannot be ruled out in any case, but if RDX is present on two parts, it is less likely to be due to contamination than if it is on only one part—particularly if the parts were not recovered at the same time and transported together.

B115

B115 is a part of the interior, specifically the panel with the air duct above the passenger seats. All parts examined by RARDE for part 1, including B115, were delivered in December 1989:

«All the material was delivered by Det Inspector Leif Oren on 13th December 1989.» (RARDE, 1990, p. 1)

«Recovered from sea-bed … B115 Part of panel with cabin lights.» (RARDE, 1990, p. 2)

«Approximately 6 nanograms of RDX were found in the swabbing from Item B115. The identity of the explosive detected was confirmed in a second GC/TEA system.» (RARDE, 1990, p. 10)

«The quantity of RDX detected was, however extremely small. It is considered that, whilst such a trace could have originated from an explosion, the levels are so low that the possibility of innocent contamination cannot be excluded.» (RARDE, 1990, p. 11)

FIGS. 71-72

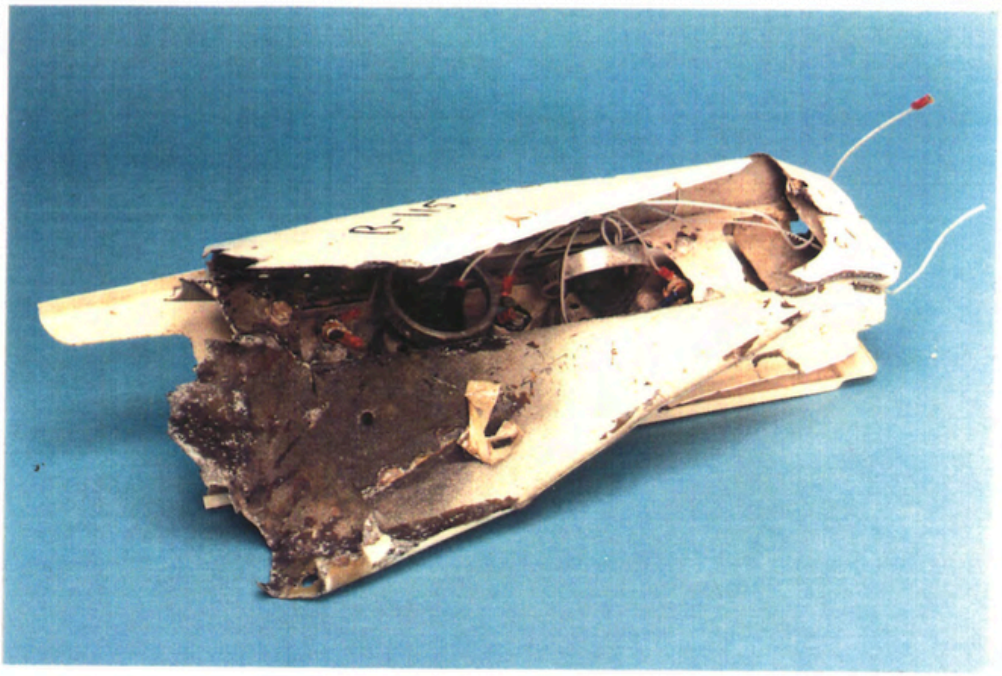

FIG. 71 INTERNAL VIEW SHOWING BLACKENING

FIG. 72 TORN END SHOWING CORROSION AND DAMAGE

SAMPLE B115

(RARDE, 1990, Figs. 71–72)

B142

«B142 – Part of ventilation/heating tube above seats on left of cabin.» (RARDE, 1991, p. 1)

«A response corresponding to RDX was observed on all three GC/TEA systems for the item identified as B142. However, the response equated to a level more usually encountered as background contamination.» (RARDE, 1991, Annex A, p. 2)

Contamination

If only one part with trace amounts of RDX is found, the probability is high that it is due to contamination. The probability decreases considerably when two parts are involved. In this case, findings were made on two parts. The two parts were recovered by two different vessels at two different times, one of which was a fishing boat. They were transported to RARDE at different times. This makes it highly unlikely that the RDX findings are due to contamination.

It seems plausible that RARDE raised questions regarding the RDX findings, as Kripos sent a letter to RARDE following a meeting between Kripos and Veritec at RARDE in England in September 1990. The letter describes how the parts were found and transported:

«B. 115 was found during search of the bottom in Skagerak in September/October 1989. It was taken on board the rescue vessel "Bergen Surveyor" and kept there for a few days, after which it was brought to Norway with other fragments of the wreck by trailer from Hirtshals/Denmark to Norway.» (Bjørkås, 1989, p. 2)

Regarding parts B141 and B142, Bjørkås writes:

«Both items have been brought up from the bottom by a trawl in January 1990, and brought to Norway from Hirtshals in Denmark by the Board on aviation accidents. The material was transported by trailer.» (Bjørkås, 1989, p. 1)

KRIMINALPOLITISENTRALEN

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S.M. WINN
AAI Division
RARDE
Fort Halstead
Sevenoaks
Kent TN14/BP

27.9.90

CONCERNING CONVAIR LN-PAA DISASTER 8. SEPTEMBER 1989.

First, thank you for a useful and pleasant meeting between Det. Sgt. Leif Oeren and Civil engineer Knut Stengelsrud of Veritec, at Fort Halstead 10.9.90.

As requested, please find enclosed the following reference material to be used in RDX.

B.141: Part of the cabin light fittings above seat 8 on the left side of the cabin.
B.142: Part of the ventilation/heat tube above the seats om the left in the cabin. On the exterior of the tube there is a blackened area (through heating?) that also should be examined.

Both items have been brought up from the bottom by a trawl in January 1990, and brought to Norway from Hirtshals in Denmark by the Board on aviation accidents. The material was transported by trailer.

Items B.139 and B.140 (tin foil) which were handed over to you during our meeting 10.9.90, also ought to be examined. These items have been secured from the inside of the hull in the area between the pantry and the main entrance on the left side front. allegedly very close to the main entrance.

As agreed, we also enclose the only extra photography of item A.5.2 taken by Veritec.

As suggested, we have decided, in collaboration with Asker og Baerum Politikammer and based on your assessment of items B.36.6 and B.101, that examination of items B.41, B.42, B.102, B.103 and B.104 is not necessary.

(Bjørkås, 1989, p. 1)

Item B.115 was found during search of the sea bottom in Skagerak in September/October 1989. It was taken on board the rescue vessel "Bergen Surveyor" and kept there for a few days, after which it was brought to Norway with other fragments of the wreck by trailer from Hirtshals/Denmark to Norway. In Norway it was stored on the ground by the landing field of Kjeller air station near Oslo. The investigation has not revealed that RDX explosives have ever been kept on board the ship "Bergen Surveyor". However, back in 1986 the vessel did contain TNT slurry, but the storing places had been sandblasted and painted since that time. Whether RDX has ever been stored in the plane, on the storing place at Kjeller or on the trailer from Hirtshals is difficult to rule out.

Thank you for the excellent assistance you have given us so far.
Best regards.

KRIMINALPOLITISENTRALEN
Laboratorieavdelingen
Oslo, 27. september 1990.

Enclosures.

- Letter dated 24.9.90 from Veritec, and photography of item A.5.2.
- Item B.141
- Item B.142

Arne Bjørkås
politiavdelingssjef

Leif Øren
politibetjent

(Bjørkås, 1989, p. 2)

Soot-Covered Parts

There are several parts from the interior and insulation material in the area of the main door that show traces of brief heating. Although the aircraft was from the 1950s, the interior was brand new and had only been in use for two weeks when the accident occurred. It is therefore highly probable that the sooting occurred as part of the sequence of events. No findings of explosion or fire have been made, so there is no natural reason why any parts of the aircraft should have been soot-covered.

Photograph from the installation of the interior, July 1989.

B115, as depicted in the RDX section, shows clear traces of sooting. RARDE also examined:

«B139, B140, B143, B144, B145 – Aluminium-backed insulation material taken from inside the fuselage in the region of the main cabin entrance door.» (RARDE, 1991, p. 1)

«Examination of Items B139 and B140 showed that the darkened areas appeared to be regions of thickened oxide but there was no evidence of prolonged heating when the insulating material behind the dark area was examined. However, it is possible that the area could have been subjected to transient heating.» (RARDE, 1991, p. 11)

In the letter from Bjørkås, it is clear that Kripos also noted the soot-covered parts. About B142, he writes:

«On the exterior of the tube there is a blackened area (through heating?) that also should be examined.» (Bjørkås, 1989, p. 1)

Insulation material with discoloured surfaces was also examined by the Centre for Industrial Research. In their report, which was sent to the Air Force Supply Command, Analytical Division, they wrote:

«Given the considerable amount of carbon on the aluminium surface, this suggests that there has been heat exposure.» (Windsland, 1990, p. 1)

Molten Metal

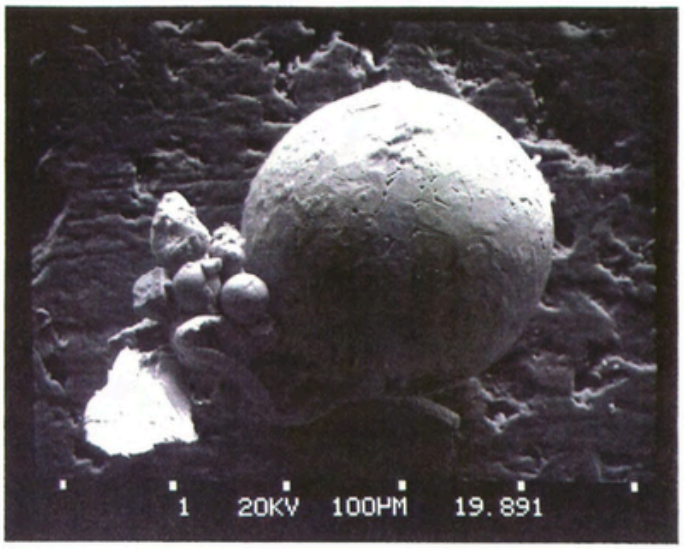
Due to its heavy weight, iron is not a material normally used in aircraft, and it is therefore not expected to find this metal during the investigation of an aircraft accident. When iron is found, it is natural to question where it may have originated. Particles of molten iron that solidified in the air were found. This may have a natural explanation, but it cannot be ruled out that it is related to the accident.

«B114 Part of flight engineer's cockpit seat.» (RARDE, 1990, p. 2)

«Samples recovered by RARDE from B114

This item was submitted for explosives trace detection, but a large number of fragments were recovered as loose debris from the seat cover before the screenings were performed. These fragments were passed to Metal Physics for examination.» (RARDE, 1991, p. 2)

ITEM B114/A



SAMPLE (ii) x 200

FIG. 33 FRAGMENTS EXTRACTED FROM B114/A DEBRIS BY MAGNET

(RARDE, 1991, Fig. 33)

«The presence of the very small spheroidal iron particles on the surface of the bright and the darkened aluminum foil samples is puzzling. They are similar to those recovered from Item B114 (above) and may perhaps have had a common source.» (RARDE, 1991, p. 11)

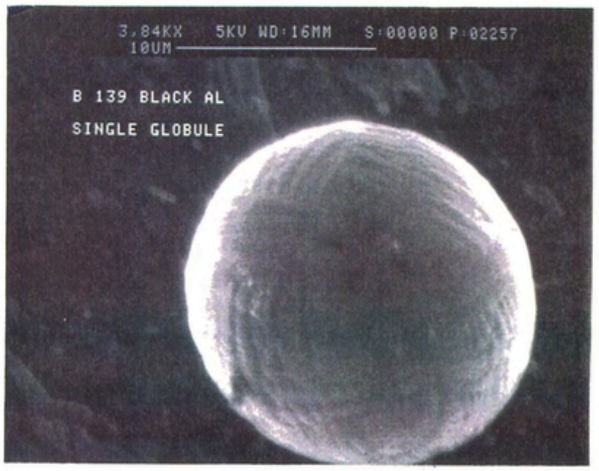
«Small iron-rich spheroidal particles were observed among the B114 fragments and on the surface of B139 and B140. Their presence in the aircraft is not easily explained, but some possibilities such as debris from welding or grinding operations or some metallurgical process involving melding are suggested.» (RARDE, 1991, p. 13)

FIGS. 45 & 46

BLACKENED ALUMINIUM FOIL ITEM (B139)

x 3,050

FIG. 45 DETAILED VIEW OF SPHERULE (OR GLOBULE)



x 3,800

FIG. 46 FURTHER EXAMPLE OF GLOBULE

(RARDE, 1991, Figs 45 & 46)

Fragment Shower

During the autopsy, fragments were found in the skin of two passengers. These fragments were examined by RARDE, but the origin could not be established with certainty. More interesting are the nearly invisible fragments, which were also not visible on X-ray, but which the same two passengers were struck by.

Although no conclusions could be drawn regarding the fragment findings, the findings from two passengers are of interest because they are observations that may support certain hypotheses.

«One must conclude from these lesions that the deceased was probably struck by a shower of particles of unknown nature and at least one metal fragment from the right side.» (Institute of Forensic Medicine, 1989, p. 7)

«This deceased was also struck by a shower of particles, but from behind. It is not possible to determine whether they originate from an explosion or a disintegration of the aircraft.» (Institute of Forensic Medicine, 1989, p. 7)

Stippling

When a high-velocity fragment penetrates the aircraft fuselage, high heat is generated which melts metals and other materials the aircraft is made of. From this, microscopic particles can be ejected and strike the passengers inside. Based on the pathological findings, it is reasonable to assume that this type of micro-fragment may have struck passengers who were seated closest to where the fragments penetrated the fuselage. Due to the low weight of the particles, they will only travel a short distance, so in practice only passengers near the point of impact can sustain such injuries.

«Powder tattoo marks are produced by the impact of powder grains on the skin. They are not “powder burns”, but rather are punctate abrasions. Similar markings can be produced by noncombustible particles such as poly-ethylene granules.

The term “powder burns” should never be used because unquestionably and exclusively due to powder grains. If the marks are due one does not know to what phenomenon the term is being applied. Some individuals use the term “powder burns” to signify powder tattooing, whereas others use it to signify searing and blackening of the skin due to the hot gases that occur from combustion of the propellant.

The term “powder burns” dates back to the black powder era, when burning grains of black powder emerging from the muzzle, were deposited on the skin and clothing, where they smoldered, apparently producing actual burns on the skin. Black powder grains could also penetrate into the dermis and produce literal tattooing. The burning grains of black powder were capable of setting clothing on fire, a characteristic not possessed by smokeless powder.

Some authorities use the term “stippling” synonymously with “powder tattooing.” The author prefers to use the term “stippling” in a more generic manner to indicate punctate abrasions of the skin, which while they may be due to powder, may also be due to other materials, e.g., shotgun filler, fragments of intermediary targets. In other words “powder

tattooing” is just one form of stippling with the term “powder tattooing” used to refer to stippling to material other than powder or if one is not certain of their origin, then, one uses the term “stippling.”

The punctate abrasions of powder tattooing cannot be wiped away. Powder tattoo marks usually heal completely if the individual survives. This is logical, as the injuries are generally confined to the superficial layers of the epidermis.»
(Di Maio, 1999, kapittel 4: Stippling)

Malaysia Airlines Flight MH17

In 2014, a Boeing 777 from Malaysia Airlines (MH17) was shot down over Ukraine. There are certain findings from MH17 that are coincident with the unexplained findings made after the Partnair accident. In contrast to the Partnair accident, the cause of these findings is known, and it may therefore be helpful in understanding what may have happened to the Partnair aircraft.

After both accidents, trace amounts of RDX were found, holes from fragments that passed through the aircraft, sooting from brief high-temperature heating, and molten metal. Both aircraft broke in two.

Smeltet metall

When a warhead explodes, fragments are ejected at several times the speed of sound. Upon impact with the fuselage, large amounts of energy are converted from kinetic energy to thermal energy. This heat was high enough to melt metals and other materials in the aircraft.

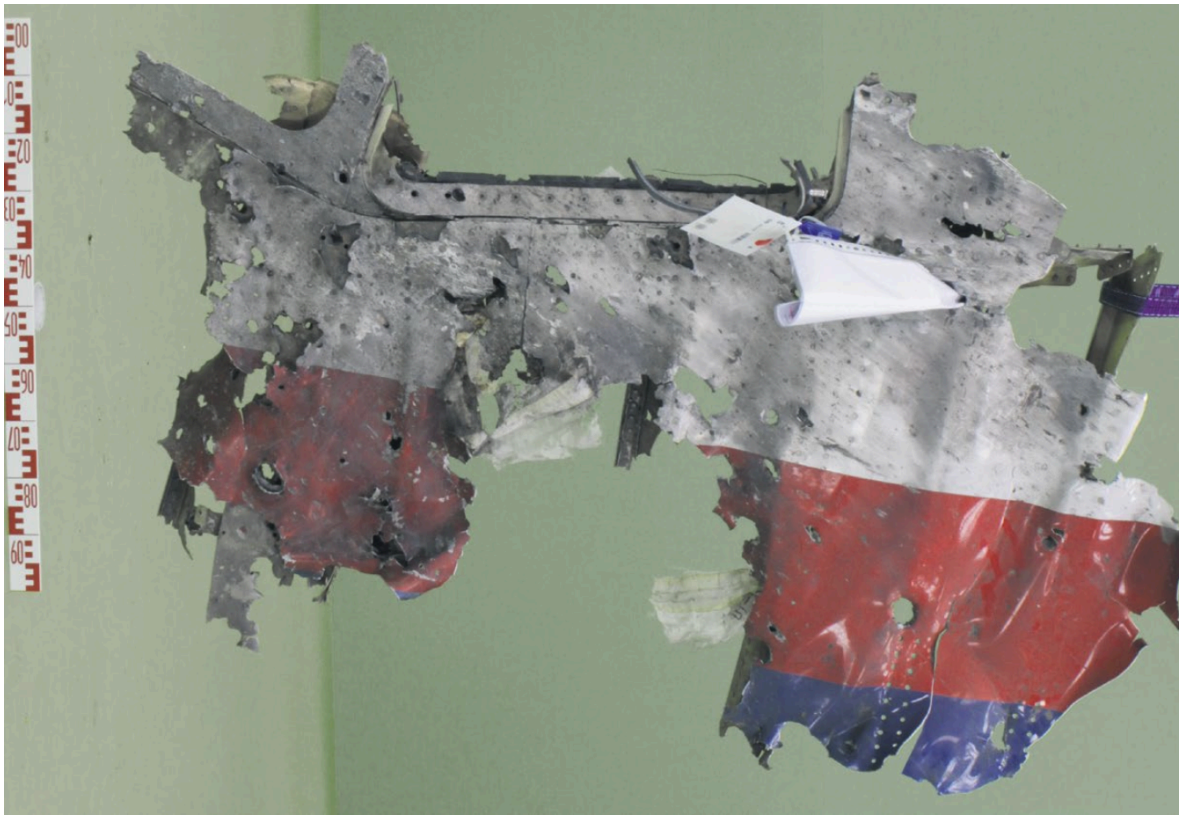
«The investigation concluded that these fragments impacted the aeroplane at a very high velocity, thereby deforming the object at the side of the impact. The consequential frictional heat melted the aeroplanes materials (glass, aluminum etc.) and a thin layer of solidified aeroplane material was deposited to the heavily deformed side of the object.» (Dutch Safety Board, 2015, p. 91)

RDX

«Approximately 30 of the 126 swab samples showed traces of mainly two different explosives; the nitroamine RDX and trinitrotoluene (TNT). A few of the 30 samples showed traces of PETN. On the tested missile parts traces of RDX was found.» (Dutch Safety Board, 2015, p. 93)

Fragment Holes

A number of elongated fragment holes were visible in the fuselage panels.



(Dutch Safety Board, 2015, Figure 33) Fragment holes in the fuselage of MH17.

Sooting

«The floor part left of and below the captain's seat was recovered. This part of the floor was punctured extensively and was also covered in soot and showed signs of heat damage.» (Dutch Safety Board, 2015, p. 65)

Break-Up in the Air

«The cockpit and the front fuselage separated at approximately STA888 from the centre fuselage. Fractures in the cockpit and the forward fuselage were examined because these fractures indicate the start of the break-up.

Multiple perforations were present in the cockpit region (i.e. forward of STA236.5). The left hand side of the cockpit was fractured into small pieces. Therefore, the perforations had probably acted as a crack initiation sites. Due to the presence of these perforations, the fractures in the cockpit region could not be analysed.» (Dutch Safety Board, 2015, p. 150)

The Propellers

The Partnair aircraft's propellers tell an important story. When an aircraft enters a dive, as the Flight Data Recorder showed the Partnair aircraft did, the pilots will invariably pull the engine power all the way back. For certain aircraft types, one can read the pitch of the propellers and determine what engine setting was in effect when the accident occurred. The accident investigation board evaluated the measured pitch of the propellers and interpreted the blade angle:

«A blade angle of 40° is in the upper part of the pitch range for operation with engine settings for cruise speed and with an indicated airspeed of approximately 200 KT.» (The Accident Report, 1993, p. 68)

This is an erroneous conclusion. Propeller pitch was controlled entirely automatically by a mechanical system that ensured the propellers rotated at 1,020 RPM. Without knowing what power setting the engines had, one cannot deduce the aircraft's speed by interpreting the blade angle. The aircraft was flying uncontrolled, and the right propeller was "windmilling" when it hit the water. Given that it was a mechanical mechanism that controlled the propeller angle based on centrifugal force, the system would have controlled pitch all the way down to the stop upon impact with water regardless of the pilots' input.

The right propeller was windmilling when it hit the water, but the left propeller fell off in the air at a relatively low altitude. The left propeller was found approximately 250 metres from the left engine. In practice, there are only two things that can cause a propeller to fall off:

1. The gearbox fails and the shaft locks while the propeller continues to rotate
2. The propeller is struck by something and deforms so that it tears loose due to its asymmetric shape

Right Engine

«From the visual examination of the L/H power turbine assembly it was found most likely that the FWD shaft end of the rotor had suffered a serious torque overload before the final (water) impact of the engine.

The estimate of the torsional moment required for twisting the shaft permanently fully supports this assumption. The torque values brought to light are far above what can be produced at a water impact when the energy of rotation at this moment is found to be at – or rather close to – zero (referring to rotor blade deformations).» (Veritec, 1990, 90-3015, p. 15)

«From the general follow-up work of the main engine dismantling and the specific examinations carried out, it can be concluded that the L/H engine has been brought to a complete stop before the sequence of major impact occurred.

The R/H engine, however, has still possessed some rotational energy when being impacted, but the level of this energy has been far below the one corresponding to an ordinary service operation. The R/H engine has rotated at least one and a quarter of a turn after the

sequence of major impact, suffering serious rotor blade and vane segment deformations and fractures.» (Veritec, 1990, 90-3015, p. 16)

Left Engine

«Before – or when – the L/H engine was brought to a complete stop the P.T. rotor suffered a serious torque overload which led to a permanent deformation (twisting) of the FWD end spline coupling. The torsional moment necessary to cause this deformation is – based on hardness measurement results – estimated to be at the level of 8000 – 10000 Nm. These values are found far above what could be obtained at impact when the appearance of the P.T. rotor blades is taken into account. Only some mechanical obstruction when the rotor was still above a certain level of rotational energy can have caused the observed twisting of the shaft.

It has been established that the mechanical obstruction mentioned has not occurred within the power section or the compressor section of the engine, (bearings and bearing surfaces O.K., all internal damages found to be of a secondary nature, etc.). This indicates that the main cause of the mechanical obstruction could be either some gear transmission failure, or an external strike towards the propeller unit.» (Veritec, 1990, 90-3015, p. 16)

Right Propeller

«All evidence indicates this propeller was operating normally up to the moment of impact and no evidence has been found that could have caused this accident. The blade angles at impact correlate very close to each other and are in the upper cruise range.

All evidence indicates this propeller, gearbox and engine were all intact at the moment of impact because (1) the propeller, gearbox and engine were found in close proximity to each other, ie, within an area of 30 meters square (see attachment "B") and in close proximity to the #1 engine (within 67 meters – see attachment "B"), (2) the two blades that separated from the Hub were also found within the same 30 meter square area, (3) the fractured surfaces of the two detached blades which were microscopically examined by Det Norske Veritas of Hovik, Norway showed a single cycle overload fracture, with no evidence of fatigue. This indicates that the blades separated from the Hub due to a massive impact force. Had this impact force occur during flight, the blades would have been severely distorted and/or accrued multiple fractures along their lengths. As neither of these conditions occurred, as seen by attached photos of blades serial numbers B10641 and B11042, the only possible answer is the blades fractured from the Hub at impact with the water and (4) the separation break of the gearbox from the engine was totally different from engine/gearbox separations that occur during flight.» (Hamilton Standard, 1990, p 5)

Right propeller.

Blade from right propeller.

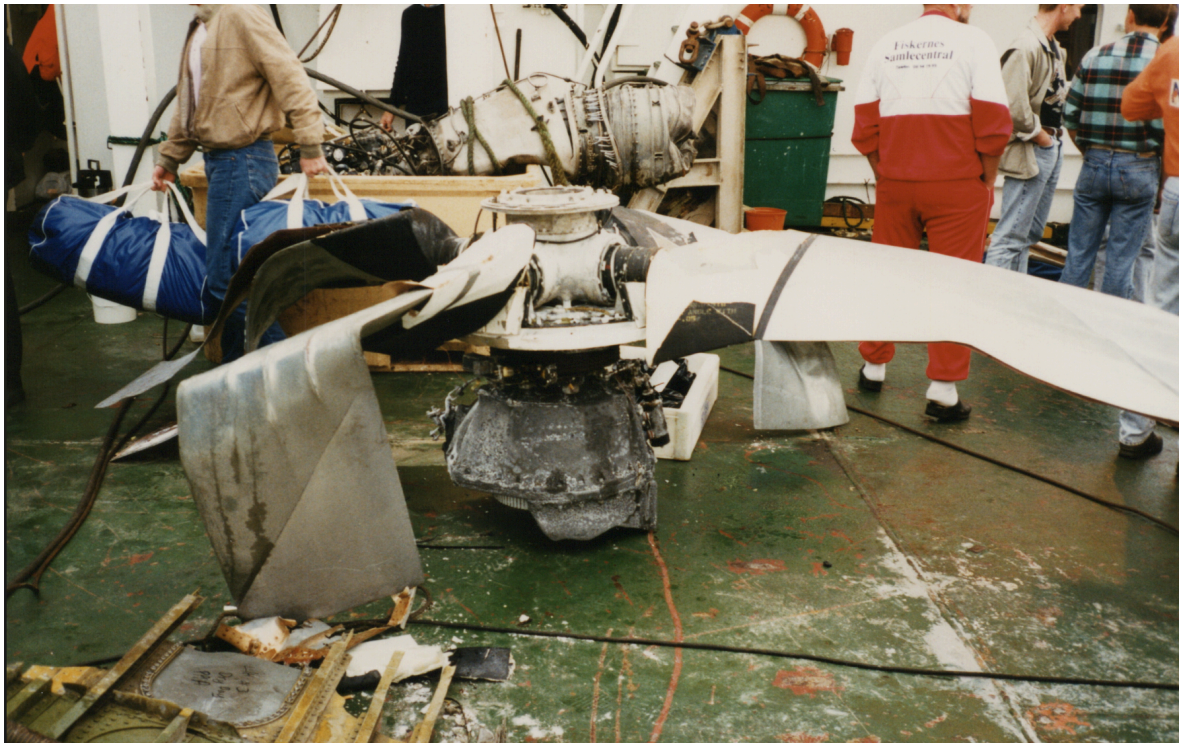
Left Propeller

«The L/H propeller was found on the seabed and brought on deck September 26th. All the four blades of this propeller were found present and properly connected to the center hub.» (Veritec, 1990, 89-3506, p. 2)

«It should be noted that no prominent scratches or indentation marks were observed when examining the steel section of the blades, neither on the leading edge nor at the trailing edge region.» (Veritec, 1990, 89-3506, p. 4)

«All evidence indicates this propeller was operating normally up to the moment of impact and no evidence has been found that could have caused this accident. The blade angles at impact correlate reasonably close to each other although they have a wider variation then those of #2 propeller. However, this is not unusual as parts, associated with the measurements for calculating the blade angle, may have distorted from the impact of the crash. The impact blade angles calculated are in the upper cruise range with two blades slightly higher.

All evidence indicates this propeller, gearbox and engine were all intact at the moment of impact because (1) propeller/gearbox were in close proximity to the engine (275 meters apart – see attachment "B") as found on the floor of the sea, (2) the separation break of the gearbox from the engine was totally different from gearbox/engine separations that occur during flight and (3) propeller/gearbox engine were found in the general location of much of the aircraft. For these reasons, propeller/gearbox separation could not have occurred during flight.» (Hamilton Standard, 1990, p. 5)



Left propeller.

«Since the left propeller ripped out of the left engine and trajectoried some 200 to 300 meters from initial impact to the south-east it is probable the left propeller was rotating at high RPM to produce the required energy for this trajectory.» (Accident Investigation & Research, 1992, p. 11)

Discussion of the Propellers

Veritec, Hamilton Standard, and AIR have each offered hypotheses that are partially contradictory.

Veritec has established that the left engine was stationary at the time of impact, and that the propeller must therefore have been separated from the engine before impact with the water. The propeller was not feathered, which would have been a requirement for it to be stationary in the air. With a blade angle that is not 90 degrees, the propeller would have been driven around by the air, and the left propeller and engine would have sustained the same types of damage as the right engine and propeller.

Hamilton Standard apparently focused on whether the propeller could have caused the accident, and they concluded that it could not. They also concluded that the left propeller had not fallen off in the air, but it is reasonable to assume that they were focused on this as a triggering cause—not whether the propeller fell off as part of the accident sequence. When the right propeller was a few metres from the engine, while the left propeller was 275 metres away, they conclude that the propeller must have been on the aircraft when it hit the water. This does not agree with the technical findings of Veritec, which prove that the left engine shaft was not rotating at the time of impact.

AIR references several Veritec reports in their report, but not the Veritec reports on the engine and propellers (89-3506 and 90-3015). Their conclusion is that the engine was running at full power when the water impact occurred, in order for the propeller to have enough force to be sent 275 metres further. This conclusion is directly contradictory to the physical findings in the engine.

Based on the reports from Veritec and Hamilton, the following seems clear regarding the left engine and propeller:

1. The propeller detached before the aircraft hit the water
2. The gearbox did not fail
3. There are no traces of the propeller being struck by anything

The propeller blades are bent backwards, but this is not consistent with impact against the water. The propeller, after tearing loose from the engine, will fall with the heaviest part downward: the remains of the gearbox. The propeller does not have torsional damage indicating it was rotating at high speed, as the right propeller did. It seems unlikely that the propeller could have hit the water and bent the blades backwards.

Veritec also concluded that there are no scratches or notches in the propeller blades themselves, which one would expect to see if the propeller had been struck by a physical object. That the gearbox would fail when the propellers were merely windmilling and the engine was providing no power is highly unlikely.

One could envision a scenario where the left propeller was struck by wreckage when the nose section of the aircraft was separated from the rest of the fuselage, but there is a logical flaw since the aircraft broke in two from left to right.

An alternative hypothesis is that the propeller blades were bent backwards by a shock wave from an explosion, and that this created asymmetric rotational forces that immediately caused the propeller to separate from the engine. The propeller then fell freely with the gearbox/rear side first and sustained minimal further damage upon impact with the water.

Concluding Remarks

Hypotheses

Occam's Razor

Occam's Razor is a principle that states the simplest explanation—the one requiring the fewest assumptions—is generally the correct one. If one compares the accident investigation board's causal hypothesis of "counterfeit parts" with a hypothesis that a shock wave from an F-16 close pass caused the accident, it is the latter that is built on far fewer premises.

The accident investigation board chose to narrow its focus area and limit the analysis to only a small segment of the sequence of events. By regarding large parts of the sequence as "normal," the accident investigation board ignored essential information that weakens the hypothesis that the accident was caused by counterfeit parts. Despite the fact that the accident investigation board skipped over a large portion of the sequence of events, they were unable to put forward a simple causal hypothesis. Approximately 10 pages of the report are devoted to detailed descriptions of how the damage must have occurred.

The main premise of the counterfeit parts hypothesis is that vibrations built up over time, from zero vibration to catastrophic oscillations in the control surfaces. Despite the fact that a pilot will feel even small vibrations in the controls during those parts of the flight that are flown without autopilot, the accident investigation board maintains that it was only around one minute before the accident that the pilots discovered something was wrong. At that stage, it was probably too late to save the aircraft, as the damage had developed too far.

Gradually increasing vibrations in the tail, which propagate through the aircraft's control linkages, would be detectable by the pilots. A loose APU in the tail, "banging" against the fuselage or creating abnormal vibrations, would be audible and palpable to the crew in the cabin—and most likely to the pilots as well.

The hypothesis that the emergency came so suddenly that the crew did not know what was happening seems entirely improbable.

A Simpler Sequence of Events

The sequence of events can to a far greater extent be explained by a simpler hypothesis:

After "top of climb," LN-PAA encounters an F-16 at the same altitude. A small dot on the horizon grows gradually larger, but is virtually impossible to see without radar. The F-16 pilot has probably just passed one of the two oncoming Viper aircraft (Viper 20 and 71), and assumes that the Partnair aircraft approaching is the last of the fighter jets. In reality, both Viper aircraft have already passed. The F-16 pilot initiates a "merge"—a standard manoeuvre in which one passes an oncoming aircraft and begins a turn to get in behind the other aircraft. The AWACS video confirms that the F-16 turns to the left after the pass, which is consistent with the initiation of such a manoeuvre. The F-16 pilot did not complete a full merge with subsequent aerial combat, but continued towards Rygge after the turn.

A merge against a slow-moving propeller aircraft, instead of a fast fighter jet, may cause the F-16 pilot to misjudge the distance and pass much closer behind the Partnair aircraft than intended. When the F-16 turns behind the Partnair aircraft, the supersonic shock wave will strike the Partnair aircraft's tail control surfaces from nearly a 90-degree angle from the side—the angle that provides the greatest possible impact surface area and thus the greatest possible damage potential.

At 500 metres per second, the aircraft pass each other—so fast that the crew of LN-PAA have no chance of seeing the F-16, but they hear the crash of the supersonic shock wave striking the aircraft's fuselage. The aircraft has until now been functioning normally, but now it apparently loses speed and begins to fly uncoordinated. The crew makes several small reductions in speed, probably in connection with troubleshooting the problem. The damage to the rudder gradually worsens. When the crew finally understands that there is structural damage to the aircraft, it is too late. The aircraft rolls and immediately enters a dive. Speed increases rapidly, causing flutter to develop.

Without the crew managing to regain control of the aircraft, the dive continues downward and the flutter situation worsens. Eventually, the control surfaces and tail section disintegrate, and there is no longer any possibility of regaining control. The aircraft bunts and the wings break off. The aircraft continues an uncontrolled descent towards the sea surface. It is still affected by aerodynamic forces, but without any directional stability, it constantly changes direction and no longer behaves like a normal aircraft. In addition to flying unpredictably, it continuously loses altitude and flies downward towards the sea in an area where warships are present that undoubtedly follow the situation on their radars and attempt to understand what the unidentified object is, and whether it constitutes a threat.

For Reflection

In aviation, accidents and serious incidents are investigated to find the cause. When the cause is clear, regulations can be improved. This has produced an evolutionary development of laws and regulations, and the result is that it has steadily become safer to fly. The technical safety systems have become ever more advanced, and several of them have over the years become mandatory to use during flight.

Had the incident occurred today, the Traffic Collision Avoidance System (TCAS) would have ensured that both the Partnair pilots and the F-16 pilot received a warning when the aircraft were about to come too close to each other. Unfortunately, the aircraft were not equipped with TCAS in 1989.

Rules do not help if they are not followed by everyone in the aviation industry. Safety is based on many layers of protection. It is only when there are concurrent breaches in all the safety layers that things go wrong. Since several layers of safety can be breached simultaneously by a single action, it is important that all parties are extremely careful not to break any of the rules.

The Investigation Process

The accident investigation board's investigation process must be transparent, and its conclusion verifiable. To be able to verify the conclusion, one must have access to all documentation. Improved aviation safety is in practice only achieved if regulations are changed so that corresponding accidents are prevented.

Both the accident investigation board and the Armed Forces were involved in the investigation of the Partnair accident. In the documentary «Partnair – The Forgotten Tragedy,» it emerges that the accident investigation board and the Armed Forces are reluctant to grant access to the case documents or be of assistance in verifying the accident report's conclusion. The argument is that the accident has already been investigated and that the accident report "stands on its own legs." (Wisting, 2023)

It is easy to be impressed by the report's length and the extensive technical analyses. There are nevertheless several obvious and fundamental weaknesses that could have been avoided had the accident investigation board employed scientific methods correctly. If one does not content oneself with skimming the report, but also scrutinises the accompanying data, fundamental errors become apparent. When the conclusion is built on a series of premises and hypotheses, it all collapses like a house of cards when the basic premises are false.

If one were to use a chair as an analogy, it can hardly be said to stand steady on its own legs. The conclusion that the accident was not caused by any external influence, but by silent, imperceptible vibrations that did not affect the aircraft's instruments, yet tore apart the aircraft's tail structure before the pilots had time to follow the reflex to reduce engine power—seems extremely improbable. With this conclusion, the accident report is at best a wobbling chair that has miraculously remained upright on its single leg.

It is cause for concern when an investigating body, whose purpose is to help improve aviation safety, uncritically relies on information and assistance from a party that was involved in the lead-up to the accident.

Responsibility

Although it is possible to make a probable case for what may have been the triggering factor of the accident, it is important to understand that there was a long series of coinciding circumstances that resulted in the fatal sequence of events. Directing the spotlight towards a single individual or actor alone is not constructive. No one deliberately did anything to expose others to danger—neither the pilot, the airline, the air traffic service, nor the Civil Aviation Authority. Sometimes coincidences cause something to go extremely wrong. Such was the case with the Partnair accident.

It may feel best to single out a scapegoat for the accident, but when many factors have had an impact, it is wrong to point to only one thing. If one is to point to anything at all, it must be the investigation process, which even after an entire generation is still not particularly transparent.

Aviation is safer now than in 1989, both as a result of the Partnair accident and many other aircraft accidents. The development of the civilian regulatory framework is open for all to see, but the Armed Forces are far less transparent. Hopefully, the Armed Forces also change their internal rules and procedures in the aftermath of an accident or serious incident.

What If

Had there not been a focus on engine problems prior to the trip to Hamburg, or had the departure not been delayed, or had Viper 20 and Viper 71 not flown the same route a few minutes ahead of the Partnair aircraft—then LN-PAA would most likely have landed safely in Hamburg on Friday afternoon, 8 September.

Even with damage to the rudder, things could have turned out well had the crew of LN-PAA quickly understood that there was structural damage to the aircraft. They would then have immediately pulled the throttle back to idle, reduced the speed, initiated a descent, and set course for the nearest airport. They would then have transmitted a mayday call on the radio and entered the emergency code 7700 on the transponder.

This would have immediately given them the air traffic service's full attention, and on all radar screens it would have lit up that LN-PAA was in an emergency. The air traffic service would have cleared away other traffic in the air and stopped all movements at the airport in anticipation of an emergency landing. The crew of LN-PAA would have continuously received the controllers' assistance to navigate to the airport, and would have been given clearance to land on all available runways to give the crew the greatest possible freedom of action.

While the aircraft was still in the air, ambulances from across the district would be directed towards the airport to be in disaster readiness. All available rescue personnel and vehicles would have been in position by the runway, ready to reach the aircraft within seconds of it coming to a stop.

All of these procedures have been developed over several decades, after the causes of fatal aircraft accidents have been identified. Many passengers are completely unaware of how fortunate they are when the procedures prevent a serious accident. Those who were in the air over the Skagerrak on the day of the accident were unfortunately not as fortunate.

Left behind are hundreds of family members, friends, and colleagues. Many are still affected by the accident and have a need for greater openness about what happened.

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