REPORT IN-026/2004

DATA SUMMARY

LOCATION

Date and time	**Friday, 21 May 2004; 04:52 UTC[1]**
Site	**Palma de Mallorca Airport**

AIRCRAFT

Registration	**EC-ITP**
Type and model	**FAIRCHILD SA227-BC, SWEARINGEN METRO III**
Operator	**Top Fly**

Engines

Type and model	**GARRETT TPE331-11U-612G, 1,000 SHP**
Number	**2**

CREW

	Pilot in command	Copilot
Age	**32 years**	**29 years**
Licence	**CPL/IR**	**CPL/IR**
Total flight hours	**2,700 h**	**2,500 h**
Flight hours on the type	**900 h**	**180 h**

INJURIES

	Fatal	Serious	Minor/None
Crew			**2**
Passengers			**1**
Third persons			

DAMAGE

Aircraft	**Damage to the right main landing gear leg and right propeller**
Third parties	**Minor damage to a runway marker and drain cover**

FLIGHT DATA

Operation	**Commercial Air Transport – Non-Scheduled – Domestic – Cargo**
Phase of flight	**Takeoff run, prior to V1**

REPORT

Date of approval	**25 July 2007**

[1] All times in this report are UTC. To obtain local time add 2 hours.

1. FACTUAL INFORMATION

1.1. History of the flight

Top Fly flight ARL-502, a Fairchild SA227-BC, registration EC-ITP, was preparing to start its takeoff run at Palma de Mallorca Airport, en route to Ibiza, in the early morning hours of 21 May 2004, at 04:52 UTC. It was a cargo flight, and aboard the aircraft was a crew of two pilots and a third occupant, also a pilot for the company. The copilot, seated in the right-hand seat, was the pilot flying.

Once authorized by the TWR to take off on runway 06R, the aircraft started its run by accelerating normally under takeoff power and using the Nose Wheel Steering (NWS) system, which the copilot engaged by pushing the system's activation button on the left side of the power lever for the No.1 engine. As the aircraft accelerated, the pilot called out going through 60 kt, meaning they had developed enough IAS for directional control. The copilot released the activation button for the steering system, shortly after which the aircraft started veering toward the right edge of the runway without the crew noticing any power or system failure. The copilot pushed hard on the left rudder pedal but the aircraft did not change course. He warned that he was losing control. The captain took the controls and initiated a rejected takeoff. He engaged reverse thrust but was unable to keep the aircraft from leaving the paved surface to the right with a speed of some 90 kt and at an angle of about 12° with respect to the runway. The aircraft veered and skidded on the runway shoulder, turning almost completely around before coming to a stop on a bearing of 220° at a point 135 m away from the runway 06R centerline and some 950 m away from the brake release point.

The crew stopped the engines and feathered the propellers. They exited the aircraft and verified there was no fire, noting only minor damage to the landing gear and to one propeller blade. Damage to the airport infrastructure was limited to a struck runway light and a lifted drain system cover.

1.2. Aircraft information

The Fairchild SA227 Metro III aircraft is a pressurized twin turboprop for the public transport of passengers and cargo, capable of holding 19 passengers.

The type certificate holder is the M7 Aerospace company (Texas, USA).

1.2.1. *Airframe*

Make:	Fairchild Swearingen Metro III
Model:	SA227-BC

Serial number:	BC-789B
Year of production:	1992
Registration number:	EC-ITP
MTOW:	16,000 lb

1.2.2. *Dimensions, weight and balance*

The nose gear fuselage station is: Hng = 64.10
The main gear fuselage station is: Hmlg = 293.69

Note: Fuselage stations are expressed in inches from said station to a reference station in the nose of the aircraft.

The distance between the nose and main landing gear is: U = 19.1 ft = 5.8 m
The distance between the two main landing gear legs is: T = 15 ft = 4.56 m

The weight and balance sheet used in the dispatch of flight ALR-502 listed a takeoff weight of 14,876 lb and a center of gravity station at Hcg = 266.5.

The distance between the nose gear and the center of gravity is Hcg – Hng = 5.14 m.

The takeoff weight and center of gravity were calculated in accordance with company approved procedures, and used a weight of 375 lb for the crew and 4,400 lb for the payload.

A weighing of the carts used to unload the payload after the incident estimated its weight at 2,024 kg (4,462 lb), after the approximate weight of the carts themselves was subtracted.

A simple calculation reveals that the nose gear was supporting 12% of the aircraft's weight and each main landing gear leg 44%.

1.2.3. *Landing gear*

The landing gear is of the conventional tricycle type, with an NWS system installed on the nose gear.

1.2.4. *Nose wheel steering (NWS) system*

The aircraft features a variable authority nose wheel steering system. Since this system is not included on the minimum equipment list, directional control while taxiing, taking off and landing when the NWS system is inoperative is achieved through differential braking of the main gear wheels and differential thrust.

The initial design of the NWS system has been modified through various Service Bulletins. A brief list of the relevant documents is provided below:

S.B. 227-32-006 Issued to increase NWS system reliability and provide a warning system to alert the pilot of failure while in caster mode. It incorporates a pressure switch.

S.B. 227-32-030 Issued to increase NWS system reliability. Improves the design of the NWS amplifier, replaces the pressure switch with a normally-open hydraulic valve vented to the return (relief valve), and changes out the potentiometer assemblies.

A.D. 93-08-09 Forbids the use of NWS during takeoffs and landings on post-S.B. 227-32-30 modified aircraft.

S.B. 227-32-034R Issued to improve the NWS system. This bulletin rescinds the restrictions imposed by A.D. 93-08-09. Replaces the servo valve on the actuating assembly.

S.B. 227-32-040 Adds a new pushbutton on the RH power lever to provide independent control of the NWS to the pilot and copilot.

According to information supplied by the operator, S.B. 227-32-006 had been installed on the aircraft, but not S.B. 227-32-030. It was later verified that S.B. 227-32-030 had in fact been implemented at the time the aircraft was built.

No references to the implementation of A.D. 93-08-09 were found in the maintenance records, nor did the limits section of the Aircraft Flight Manual (AFM) include a copy of said directive, as required by the instructions listed in the directive for its application.

What follows is a brief overview of the NWS system outfitted on the aircraft after being modified by SB 227-32-006 and SB 227-32-030 and prior to SB 227-32-034R and SB 227-32-040.

Description of the NWS

The system features two hydraulic actuators that twist the inner cylinder on the nose strut through a rack and pinion mechanism. The system is electronically controlled and hydraulically actuated via servo valves. The cockpit controls include a control panel on the left console with ARM (arming) and TEST switches and a Park button.

The system normally provides the ability to steer the nose gear through +/– 10°, its use during takeoff and landing being authorized if SB 227-32-034R has been implemented.

Actuating the Park button increases the deflection to +/– 63°. This feature is used during taxiing and ground movements.

Within reach of the crew, on the left side of the power lever, there is a "Power lever" pushbutton, which is easier for the pilot in the LH seat to access since it is designed to be actuated with the right thumb. This pushbutton activates the NWS system when the selector on the control panel is set to ARM. Inside the pedestal, out of the pilots' reach, there is a microswitch that closes the circuit, in parallel with the button on the power lever, when the speed lever is in the LOW, or bottom, position.

When the NWS system is activated, with the system armed and the button on the power level depressed or the speed lever in LOW, the nose wheel is steered by means of the rudder pedals. A set of potentiometers mounted on the pedal hinges and on the top of the nose strut send electrical signals to an amplifier, or control box. Fault detection capability is provided by mounting two sets of potentiometers on two separate control and monitoring channels. The amplifier compares the control signal (pedal) with the slave signal (nose wheel) and sends driving signals to the hydraulic servo valve which powers the actuators in response to the commanded position. If, however, the system detects a fault or a mismatch of the electrical signals equivalent to 3° or more of deflection between the control and monitoring channels, then the system disengages.

The sole NWS hydraulic assembly incorporates actuators and hydraulic servos and is located on top of the nose strut and includes the actuating solenoids. The amplifier, or electrical control box, is mounted in the console to the left of the LH (chief pilot) seat. A power control relay located next to the circuit breaker panel actuates the solenoids on the servos when:

1.° The system is armed,
2.° Either the power lever pushbutton or the speed lever microswitch is actuated, and
3.° The landing gear is deployed.

(See the NWS electrical diagram in Appendix B-4)

The NWS system includes a set of warning lights. A green one, located in the annunciator panel and labeled NWS, indicates when lit that the system is armed and that steering control is available. A second, amber, light, labeled NWS FAIL, flashes when the amplifier's fault detection circuitry senses a malfunction.

Components of the NWS system hydraulic assembly (see diagram Appendix B-1)

The NWS hydraulic assembly, in addition to hydraulic liquid filters, restrictors and actuators, three main valves and two electromagnetically-actuated variable restrictors, includes:

- An arming valve for providing hydraulic pressure to the system or connecting the system to the hydraulic return header. It is electrically actuated.
- A mode selector valve with two positions: steering mode, in which hydraulic system pressure is directed to the actuators controlling the nose wheel; and caster mode, in which the hydraulic liquid is isolated from the hydraulic system but allowed to flow between actuators, which serves to dampen shimmy. In caster mode, the NWS system is deactivated and the nose wheel is self-aligning, and thus not controlled from the cockpit (see detail in Appendix B-2).
- variable servo valve with three positions: 1 - stops the flow of hydraulic fluid to the actuators (used when locking the wheels); 2 - turns the wheels left by exposing the liquid in the left actuator to supply header pressure, and the liquid in the right actuator to return header pressure; or, 3 - vice versa to turn the wheels right (see positions in figure, Appendix B-3). The different positions are obtained by opening or closing the variable restrictors
- LH and RH variable restrictors, electrically actuated by the amplifier via the power control relay.
- A normally-open, electrically-actuated relief valve. It vents hydraulic system pressure when the NWS system is deactivated.

1.2.5. *Propellers*

The aircraft is equipped with two constant-speed McCauley propellers measuring 2.69 m in diameter, with four variable-pitch blades with full feathering capability.

To facilitate engine start-up, the blade pitch control system features centrifugal-mechanical locks which establish a negligible pitch angle so as to minimize aerodynamic drag when the propeller is turning.

1.2.6. *Aircraft flight manual procedures*

The limits section in the AFM, on page 1-15, forbids using NWS when the arming valve fails its test or when there has been a fault in the hydraulic system.

The AFM section on normal procedures allows for operating the NWS system while carrying out the following procedures:

- Before taxi checklist.
  Step 8 arms the NWS system via the ARM switch.

- Taxi checklist.
  Step 4 performs a functional check of the NWS system by referencing the system checklist, which involves a series of steps that include placing the TEST switch in its different positions (L, R and OFF), actuating the pedals in both directions (left and right), moving the right speed lever and depressing the NWS activation pushbutton. With each step, proper operation of the warning lights is checked.

- Takeoff checklist
  Step 7, after the brakes are released, states:

  NWS Power lever Button AS DESIRED

The emergency procedures section of the AFM addresses two NWS system failure modes, namely, an electrical or hydraulic malfunction.

- In the event of electrical malfunction, as evidenced by a flashing green NWS light, by an undesired steering deflection, and/or by a lit parking light when the park button has not been pushed, the following actions are to be performed:

  1. release the 'NWS Power lever Button',
  2. push the right speed lever approximately 1/2 an inch above the LOW position
  3. use the rudder, brakes and/or throttle to steer
  4. disarm the system by placing the switch in OFF, and
  5. open the circuit breaker.

- In the event of hydraulic failure, as evidenced by the amber NWS FAIL light illuminating, press and hold the NWS Power Lever Button.

1.3. Meteorological information

In his flight clearance, the controller informed the aircraft that winds were calm.

Other data indicate a temperature of 19 °C, few clouds and light winds below 4 kt out of the SE. No precipitation had been registered in the preceding hours or days.

Sunrise for that date in Palma de Mallorca was at 04:32 UTC. At takeoff, the sun was 3° above the horizon on a geographic bearing of 66°.

1.4. Communications

Radio contact was maintained between the aircraft and TWR. A transcript of said communications was received for the investigation, the relevant highlights of which are provided below:

- The aircraft was directed to the runway 06R holding point and cleared for takeoff at 04:51:48. TWR: "ALR-502, wind calm, cleared for takeoff runway 06R."
- A minute later the aircraft radioed that it had departed the runway, after which TWR coordinated rescue efforts with the airport fire brigade.
- The aircraft, which was visible to the controller, was on the right side of the runway just in front of taxi exit S-2.

1.5. Aerodrome information

The Palma de Mallorca airport has three parallel runways on headings 06-24:

Runways 06L-24R and 06C-24C are to the north of the passenger terminal buildings and control tower.

Runway 06R-24L, used in this operation, is to the south of the airport buildings. Its geographic heading is 059°. It measures 3,000 × 45 m. It is paved and located within a 3,120 × 300 m strip.

Access to the runway 06R threshold for takeoff is via taxiway H-7 and through a holding point. The threshold for landings is 410 m down the runway.

A chart of the airport is shown in Appendix A-1.

1.6. Flight recorders

The aircraft was equipped with a Fairchild flight data recorder, model F1000, P/N S703-1000-00, S/N 00648, which correctly recorded data on IAS, pressure altitude, vertical acceleration, pitch and roll attitudes, magnetic heading, LH and RH propeller RPMs and LH and RH engine torque.

The data recorded revealed that both engines were at 100% RPM before the brakes were released, and that torque increased to 90% in the LH engine and 95% in the RH engine.

The aircraft accelerated normally to a speed of 107 kt in about 18 seconds. The decision to abort the takeoff was made some three seconds before the maximum speed was reached, as evidenced by engine thrust being reduced to ground-idle.

Reverse thrust was obtained two seconds later, the torque reaching 55% in the LH engine and 40% in the RH engine for a period of seven seconds.

The sharp fluctuations in vertical acceleration some 22 s after brake release mark the instant the aircraft left the paved surface.

The increase in the pitch and roll angles some 28 s after brake release mark the skidding and turning motion of the aircraft on the ground.

The aircraft came to a stop some 38 s after brake release. The aircraft's heading increased from the moment it left the runway, eventually settling on 220° some 4 s before coming to a stop.

Appendix C shows a graphical representation of the changing parameters during the aborted takeoff.

1.7. Tire track and aircraft examination

The tire tracks on the runway's asphalt show that the aircraft started to veer 510 m into its takeoff run.

It crossed the right edge of the runway 695 m into its takeoff run at an angle of some 12° to the right. The lower distance between the NLG and the RH MLG than between the NLG and the LH MLG confirm a slight slide to the left. The NLG tracks indicated that both were braking without sliding (Figure 1).

The ground on the runway strip was covered with grass almost a meter tall, which resulted in the wheels tracing out the aircraft's trajectory as it skidded for 260 m beyond the runway before coming to a stop.

The aircraft stopped 135 m away from the runway 06R centerline and 950 m away from its threshold (see trajectory in Appendix A-2).

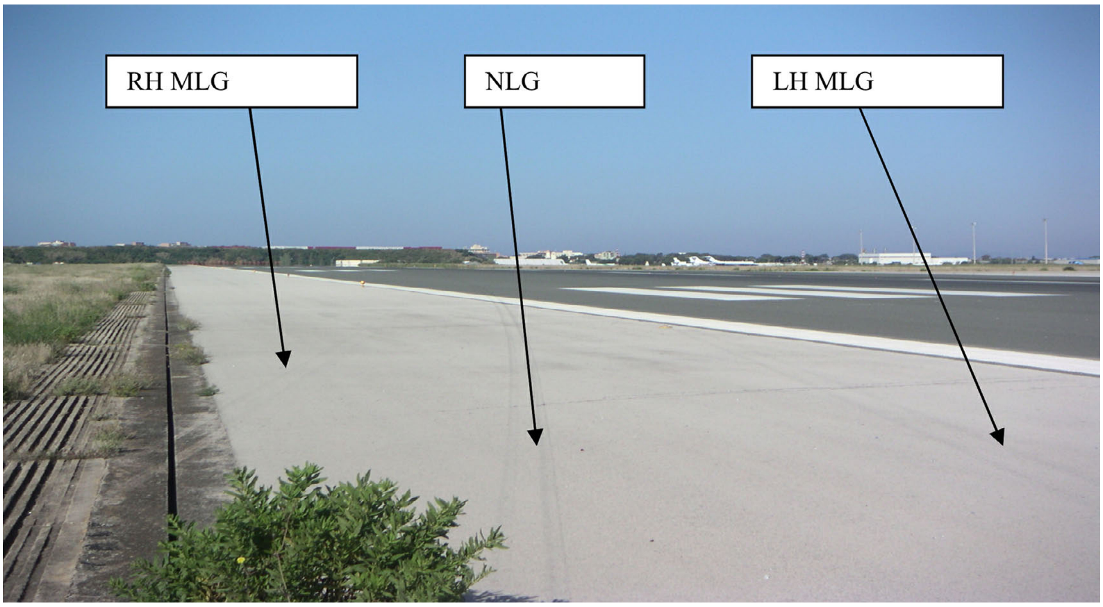


Figure 1. Landing gear tire tracks on the runway

The tires did not burst. No significant defects were found on the brakes for the four MLG tires.

The NLG tires were oriented to the right. The inboard rim of the NLG left wheel was chipped and cracked radially along its perimeter (Figure 2).

Both propellers were feathered. One of the propellers had impacted a runway marker, which bent the tip of one blade.

After the incident it was noted that the RH MLG leg torsion link lower lug, in the sliding member of the strut, was torn off (Figure 3). The fracture surface showed evidence of brittle fracture.

Figure 2. Nose gear wheels

Figure 3. RH main leg. Breakage of the torsion link

1.8. Tests and research

1.8.1. *Tests on NWS system components*

The filters and valves of the NWS system were inspected. No contamination was found which could have clogged the fluid flow.

The NWS warning lights were verified to be functioning properly.

Operational tests were performed on the NWS with the system armed and activated in both the normal and park positions. The system failed the left turn check due to improperly adjusted potentiometers, probably as a result of the incident as the aircraft rolled and skidded over the runway strip.

1.8.2. *Crew statements*

The crew stated it had commenced its operations that night in Barcelona, and that the following legs were scheduled: Barcelona-Ibiza-Palma-Madrid-Barcelona-Palma-Ibiza. Although the incident occurred on the sixth leg, they were not particularly tired. They were used to flying at night.

After landing at the Madrid airport, they noticed the amber NWS FAIL light illuminate as they approached the parking area. The crew notified maintenance personnel. Since no obvious faults were found, no further actions were taken. On the subsequent taxi and takeoff for Barcelona, the aircraft operated with the NWS system activated, with no anomalies being noted. On the following landing and takeoff, in Barcelona, and landing in Palma, all before the incident flight, the crew did not note any system failure warnings.

The following information in the crew's account of the event is of note:

- The copilot was at the controls during the incident takeoff. They recall applying throttle on takeoff and reaching 90% torque.
- During the takeoff run the captain called out 60 kt before any problems were noted. At that point, the copilot released the NWS power lever button and shortly afterward the aircraft started veering to the right, even though the copilot was applying full left rudder with his foot.
- They tried solving the steering problem by pressing the NWS power lever button, which had no effect on the nose wheel, which was apparently locked. The button was then released for the final time.
- The takeoff was rejected at a speed of between 85 and 90 kt. The predicted decision speed (V1) was 115 kt.
- They do not recall seeing the NWS amber light blinking during the emergency.

- They did not note a deceleration of the aircraft after applying reverse thrust, which led them to actuate the stop and feather controls once off the runway to stop the engines, at which time the aircraft decelerated immediately.
- Once the aircraft came to a stop, the captain ordered an evacuation.

1.9. Organizational and management information

The company's operations manual does not specify operating conditions for its fleet of Fairchild SA-227 METRO aircraft differing from those outlined in the aircraft's AFM. There are no operating procedures based on the AFM which define specific crewmember actions for those crews made up of two pilots.

It is an unwritten company practice for crew training and fleet operations to be carried out such that either crewmember may take the controls, with the pilot flying manipulating the throttle lever, regardless of his position in the cockpit. When the pilot flying is seated in the RH seat, he must put his left hand on the throttle lever so that he can operate the NWS power lever button located on the left side of the levers.

As noted in 1.2.4, the AFM did not contain a copy of the directive which prohibited the use of the NWS system while taking off and landing, as required by the aircraft's modified condition.

1.10. Additional information

No flight simulators are available to conduct crew training for this fleet, meaning emergencies can only be practiced on actual training flights.

2. ANALYSIS

2.1. Incident sequence

In the early morning hours of 21 May 2004, a Fairchild SA227-BC, registration EC-ITP, was making a Barcelona-Ibiza-Palma-Madrid-Barcelona-Palma-Ibiza run while on a commercial public cargo transport operation, with two pilots and a third occupant aboard, also a pilot for the company.

Upon reaching the parking apron on the Madrid leg, the NWS FAIL warning light momentarily illuminated. Maintenance was informed, but no obvious faults were noted. The system was verified to be functioning properly on the taxi out from

Madrid, and then again in the stopover in Barcelona and the subsequent landing in Palma.

The departure from Palma marked their sixth run, and took place with calm winds at 04:52. It was a routine flight for the crew. They were not tired.

Flight dispatch proceeded normally, with both weight and balance within limits. The slight 28-kg discrepancy between the declared payload weight and the offloaded payload weight may simply be attributed to a low estimate for the tare weight of the carts used. A weight lower than actual was used, however, when the third occupant's weight was not taken into account, resulting in a total calculated occupant weight of 374 lb (160 kg).

The sun was rising on the same bearing (six degrees to the right) as that of the runway they used (06R), which may have hindered the pilots' vision and affected their ability to keep the aircraft on the pavement without deviating. The crew statements make no mention of this, however, so its effect on the crew's ability to see outside the aircraft is thought to be negligible.

The NWS system was armed and functioned properly while taxiing to the takeoff threshold. The pilot flying for the takeoff was the copilot, who engaged the throttle levers and pushed the NWS activation button, which was difficult to access from the RH cockpit seat.

The sequence of events indicates that the aircraft accelerated normally. The captain called out passing through 60 kt, and the copilot released the NWS activation button on the throttle lever. The copilot immediately felt and warned of the aircraft veering to the right and of his inability to control it, despite pressing down hard on the left rudder pedal and depressing the NWS button on the throttle lever once again. Faced with the continued veer to the right, the captain decided to reject the takeoff and applied reverse thrust, which did not keep the aircraft from departing the runway.

FDR parameters reveal that following the rejected takeoff, engine torque remained positive and thus the aircraft kept accelerating for two or three more seconds. After reverse thrust was engaged, the aircraft did not start to decelerate until the engine torque increased, following a two-second lapse. It is worth noting that during those critical moments of the takeoff run, the brakes have little effect since the weight of the aircraft on the ground is reduced by the already high speed, near the aircraft's decision speed, and the significant lift being generated. It was not until the aircraft was near the edge of the runway that its speed started reducing appreciably.

An analysis of the tire tracks revealed that the aircraft crossed the right edge of the runway some 20 s following brake release, 695 m into its takeoff run, at an angle of about 12° with respect to the runway centerline. Once outside the runway, the aircraft skidded for another 260 m, its heading increasing to a value of 220°. The aircraft was stopped by the effect of the brakes on the wheels, which did not skid, and the application of reverse thrust. The only damage was to one propeller blade, which struck a runway marker, and to the lower torsion link on the RH leg, which very likely failed when its design stress was exceeded as the airplane skidded and rolled off the runway. The inboard rim on the left wheel of the NLG was also chipped and cracked at various points along its edge, as would be expected following a skid of that wheel to the left. The damage to the rim of the nose wheel indicates that the rubber on the NGL wheels experienced significant transversal deformation as the aircraft skidded along the ground.

2.2. Possible causes of the incident

It could be argued that, aside from minor factors capable of inducing a yaw torque that could affect the steering of an aircraft while on its takeoff run, the following four factors could be considered significant enough to explain abrupt heading changes during the takeoff run:

a) A gust of wind
b) Large differential engine thrust
c) Locking the brakes on the MLG, or a tire blowout, and
d) NLG orientation.

Cause a) can be dismissed in this case due to the prevailing wind conditions during takeoff.

Likewise, cause b) can be ruled out given the aircraft's normal acceleration, which was in keeping with the expected power output of both engines, as confirmed by the FDR readout. Nor is it conceivable that the right propeller would have its start locks engaged, as that would have halved the power available for takeoff and increased aerodynamic drag.

Cause c), namely that a brake, which is not normally used during takeoff, could have seized can also be excluded, given the acceleration values obtained and the results of the post-incident inspection, which revealed nothing to this effect.

It stands to reason, therefore, that the NLG wheel veered and locked to the right once the pilot released the NWS activation button on the thrust lever. The information collected points to this conclusion, as evidenced by the fact that the deviation started after the steering control was deactivated, as well as by the damage to the inboard rim of the left nose gear wheel, indicative of lateral skidding by the wheel. Another fact which supports this assumption is the NWS FAIL warning light observed while in Madrid and which suggests a possible intermittent fault in the steering system.

2.3. Possible NWS system failure modes and aircraft modification status

Considering the above, it must be assumed that in all likelihood the nose wheels turned to the right and stayed blocked in that position once the pushbutton on the throttle lever was released. At any rate, it has not been possible to reproduce the failure mode, nor has evidence of a malfunction been found in any of the components during functional tests made on the aircraft after the fact. It was also not possible to carry out bench tests on the NWS components. Due to the system's architecture, the fault could have resulted from a clogged restrictor; for example, if the flow path between actuators is interrupted while in caster mode, the wheel's orientation would be blocked. The same thing would happen if a fault or a delay in the steering system's control relay kept the arming valve open. The troubleshooting process in the maintenance manual also considers other possible fault mechanisms which could have occurred, though as already stated, these could not be verified.

Even if these faults had been temporary or intermittent, it would have been difficult to recover from a loss of control following the release of the throttle lever pushbutton, since the resulting mismatch between more than three signals in the control and monitoring channels would have prevented the system from being reactivated without first positioning the pedals to reflect the blocked wheel's deflection.

As for the system warning lights, if they did turn on during the takeoff run, the incident crew failed to notice them. They could have illuminated or blinked on and off without the crew noticing them during an emergency that only lasted 20 s.

NWS system operability on this type of aircraft is not relevant to the dispatching of flights. The aircraft may be operated, with or without using the NWS system, as specified by the Master Minimum Equipment List (MMEL). The aircraft's modification status, on the other hand, did prohibit the use of NWS during takeoff and landing, in keeping with the instructions of the relevant airworthiness directive. The system, therefore, should have been disconnected, which may have prevented the incident. Said airworthiness instructions were not steadfastly applied, however. During the investigation it was noted that the indications imposed by the directive had not been incorporated into the AFM, so the crews could not have known about the NWS restriction in effect. This, then, points to one deficiency affecting the operator's procedures and the control it maintains over issues involving the continued airworthiness of its aircraft. A safety recommendation is therefore issued in this regard.

The design of the NWS system has been the focus of several changes to this type of aircraft, effected through the issuance of successive service bulletins. According to information supplied by the manufacturer, the aim of these changes has been to improve its reliability in some cases, and the accessibility to the operating controls from both piloting positions in another. Yet, logically, despite these modifications, the possibility of faults in the system is still considered in the AFM's various operating procedures. Aside from faults detected during pre-flight checks while carrying out the taxi checklist, an emergency could arise from an electrical or hydraulic fault, as in this incident, while the aircraft is moving on the ground at considerable speed. Judging by the available data, the fault in this case could have been electrical, given the undesired steering deflection produced which, according to the manufacturer, seems to be related with this type of fault. But the fault could also have been of a hydraulic nature, since the NWS FAIL light, which is indicative of such a fault, had illuminated on a prior flight. In principle, then, there seems to be no easy way to differentiate between the two failure modes and thus apply the appropriate emergency procedure, especially considering that the procedures lead to opposite conditions, with the system disconnected in one and activated in the other. Moreover, if the fault is electrical, the applicable emergency procedure includes the execution of a series of steps that result in the system being disconnected and which must be carried out in very rapid succession if steering control of the aircraft is to be regained. The effectiveness of these actions in preventing an aircraft rolling near the decision velocity from going off the runway is doubtful.

It would be worthwhile, therefore, to reconsider changes to the applicable emergency procedures which might allow for a clearer identification of the problem affecting the system on the one hand, and a greater guarantee that the aircraft's safety will not be compromised on the other. A safety recommendation is issued in this regard.

2.4. Operational factors

Two overriding challenges faced the crew during this emergency as they attempted to minimize the consequences of the aircraft's deviation: stopping the aircraft as quickly as possible and controlling its heading so as not to exit the runway.

As mentioned previously, it must be realized that the effectiveness of the brakes is reduced under high speed conditions, when the lift on the wings reduces the weight of the aircraft on the wheels. If the aircraft rolls off the runway, the vibrations and jolts could keep the pilot from applying full pressure to the brake pedals. As for reverse thrust, which is effective at high speeds, it has the drawback of the delay or time interval required by the engines and propellers to supply that thrust.

Regarding steering control on the ground, in theory, even with a NWS fault, the aircraft does have effective means for correcting an uncommanded steer on the ground. The emergency arising from such an uncontrolled deflection of the nose wheel, however, would catch the crew off guard and condition the pilot's response, making it very difficult to counteract the aircraft's tendency to go off the runway.

In fact, a deflection of the nose wheel results in lateral forces which, at most, would equal the frictional force, proportional to the weight on the leg and to the coefficient of friction between the tire and the runway. On a dry runway, this force is large and its moment about the center of gravity would result in an undesired change in the aircraft's heading. The force from differential braking, however, would be greater still, due to the much greater weight on a MLG leg, and would result in a corrective moment larger than the original.[2]

In addition to the wheel brakes, the aircraft is also capable of using differential thrust with one of the propellers in reverse, a possibility that was used in this case. The moment from such a force is independent of the runway condition and may be more effective in correcting an adverse nose wheel orientation on a wet runway and less effective in correcting a deviation on a dry one, since in that case the friction between the nose wheel and the asphalt is significant.

The FDR does not record brake pressure data, so the only evidence of actions taken by the crew to try to regain steering control of the aircraft is the aforementioned use of reverse thrust. The effect of this action, however, was weak, given the small difference in reverse thrust, 55% for the LH engine and 40% for the right.

In short, although over two-thirds of the runway lay ahead of the aircraft when the trouble arose, it seems as though the use of brakes and reverse thrust was intended to brake the aircraft, rather than steer it. This may actually have been for the best since the greater the distance covered outside the runway, the greater the risk of encountering obstacles.

As a result of their training and in keeping with unwritten procedures, it may be inferred from the pilots' actions and statements that the NWS activation button was to be released upon reaching 60 kt, using aerodynamic surfaces instead to avoid possible unwanted deviations. This action is not specifically addressed in the AFM or in the operator's procedures, which reflect the AFM's guidance without complementing it by, for example, specifying the actions to be taken by each crew member depending on the situation.

The takeoff checklist in the AFM for normal operations specifies that the use of NWS by pushing its activation button on the thrust lever is left to the crew's discretion ("AS DESIRED"). There is no basis for questioning the practice of deactivating the NWS system at 60 kt, although if, as in this case, the decision is then made to abort the takeoff, having different crewmembers at the controls and on the throttle would result in valuable time lost in decelerating the aircraft.

It is therefore recommended that the manufacturer provide information to the operators on the effects of a malfunction in the NWS system while on the takeoff run, which

[2] The moment arm for the braking force from a main leg is around half that of a nose leg, but the magnitude of the force can be quadruple

would allow them to make a more informed decision regarding the proper use of this system. It is also recommended that the operator establish written operational procedures based on the AFM which define each crewmember's role in the different phases of flight, and also that it broaden the training provided to crews in a way that guarantees the memorization of checklists such as the one for a failure of NWS. It would be ideal if such a failure could be practiced on a simulator, though the lack of an available simulator precludes this possibility.

3. CONCLUSION

3.1. Findings

1. The aircraft was certified in accordance with existing regulations.

2. The payload and center of gravity were within the prescribed limits.

3. The crew was qualified for the flight.

4. The attempted takeoff took place into the sun, under clear skies in the early morning hours. It was the sixth flight of a rotation that had started during the night hours the evening before.

5. The NWS system was activated for takeoff, even though A.D. 93-08-09 prohibited its use given the aircraft's modified state.

6. The aircraft started to veer to the right while at high speed during its takeoff run after the NWS activation button on the throttle lever was released.

7. The FDR readouts show a continuous veer which was not counteracted by a decisive application of reverse differential thrust.

8. The tire tracks indicate that the wheels did not skid during braking and that the aircraft slid to the left on the runway.

9. The tire tracks on the runway and on the shoulder, along with the damage to the left nose wheel rim, confirm the aircraft slid to a stop within the shoulder area, to the right of the runway.

10. The distances involved and the FDR speed data confirm that the aircraft accelerated normally with the engines at takeoff power.

11. A inspection of the aircraft following the incident did not reveal any existing malfunctions in the NWS, wheels or brakes which could justify the runway

departure. The damage to the left nose wheel rim is consistent with a skid and an improperly facing wheel.

12. Neither an analysis of the hydraulic fluid nor a bench test of the NWS actuator assembly could be performed.

13. All the evidence gathered at the site of the incident suggests an unexplained orientation and subsequent locking in place of the nose wheel to the right, though this could not be confirmed since the failure mode could not be duplicated.

14. An NWS warning light had illuminated on one of the previous flights.

15. The AFM procedure for a sudden and uncommanded deflection of the nose wheel is unclear.

16. The operator lacked written guidance detailing which actions in the aircraft's flight procedures were to be carried out by which crewmember.

3.2. Causes

The aircraft departed the runway most likely as the result of an uncommanded turn of the nose wheels to the right and their subsequent locking in place.

The fault mechanism, whether mechanical, electrical or hydraulic, which led to the possible malfunction of the NWS system has not been determined.

A contributing factor was the fact that the aircraft was being operated with the NWS system activated despite an Airworthiness Directive prohibiting its use in the aircraft due to its modified state.

Given the average reaction times to the sudden emergency, the crew's actions to correct the aircraft's deviation did not manage to keep the aircraft from departing the right side of the runway.

4. SAFETY RECOMMENDATIONS

REC 30/07. It is recommended that the DGAC revise the system implemented by the operator to guarantee the continued airworthiness of its aircraft.

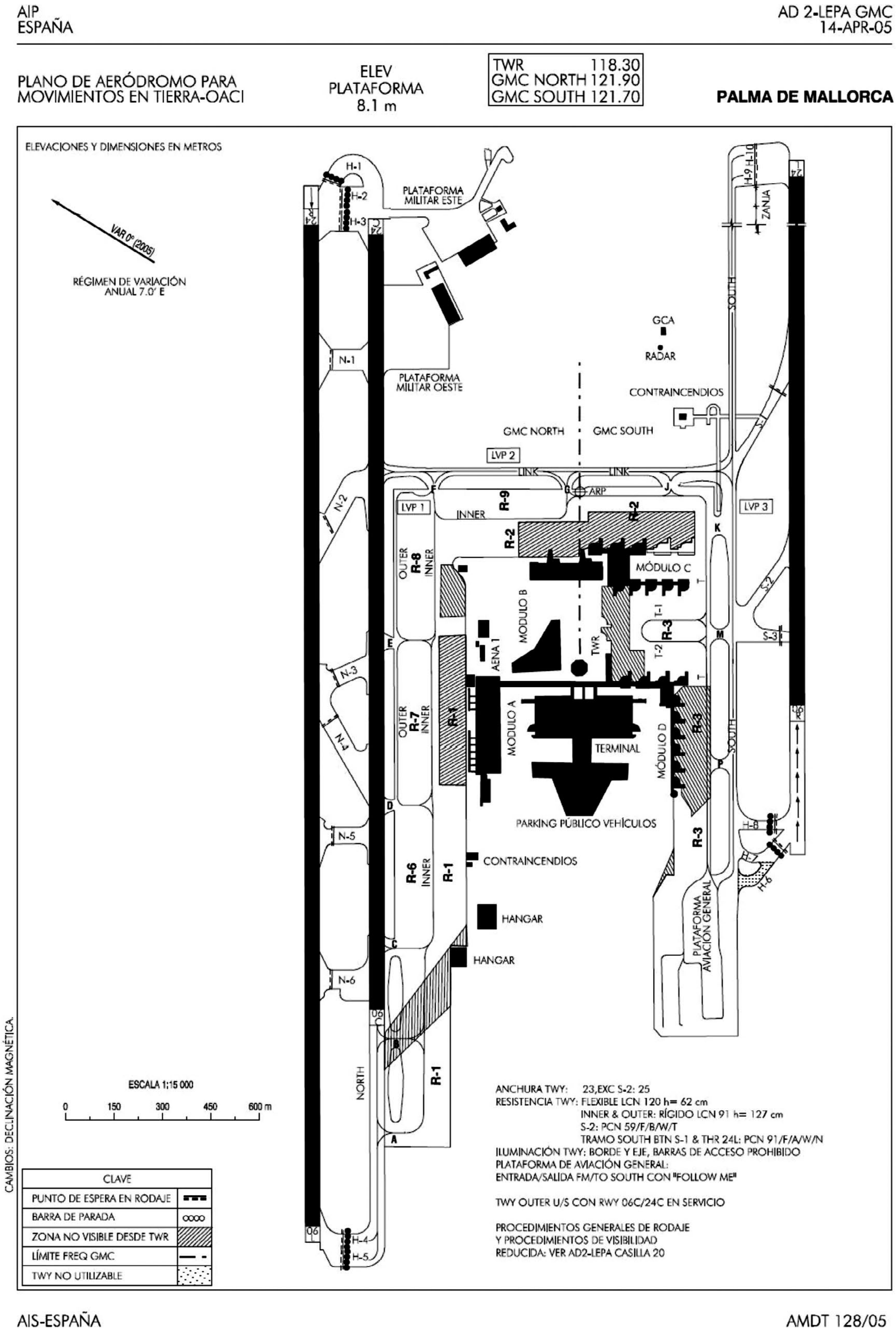
REC 31/07. It is recommended that the operator, Top Fly, establish written operational procedures based on the contents of the AFM which define the actions to be carried out by each crewmember during the various phases of flight, and that the training given to crews be expanded to ensure the checklists that involve the NWS system are memorized.

REC 32/07. It is recommended that the manufacturer, M7 Aerospace:

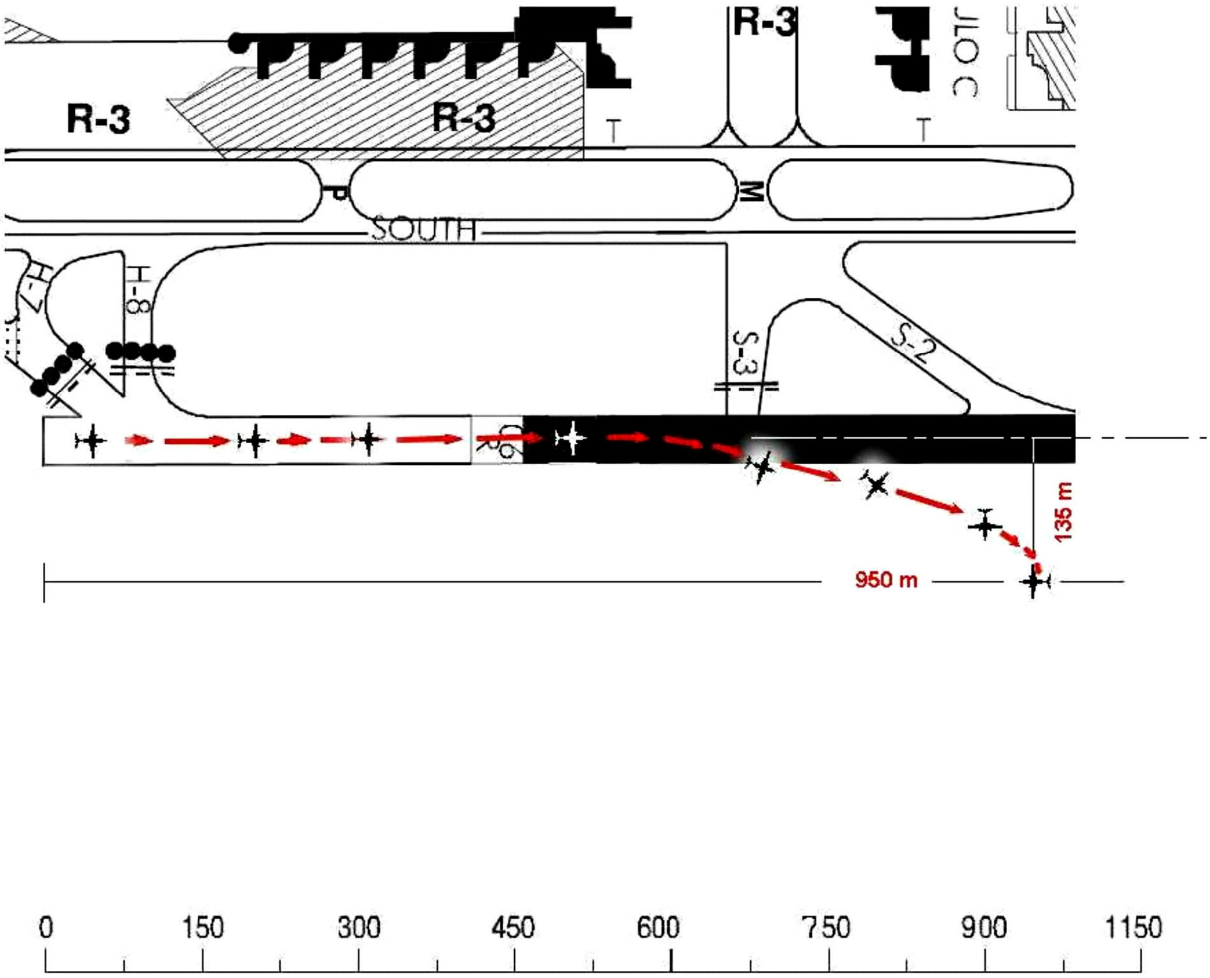
1. Draft supporting information for operators of Fairchild SA227-BC aircraft on the effects of an NWS system malfunction during the takeoff run, and

2. Reevaluate Fairchild SA227-BC emergency procedures involving a failure of the NWS system so as to aid in more clearly identifying the cause of the malfunction, and that the actions to be taken specified in said procedures be adequate to ensure the safety of the aircraft.

APPENDIX A
Airport chart and trajectory of the rejected takeoff

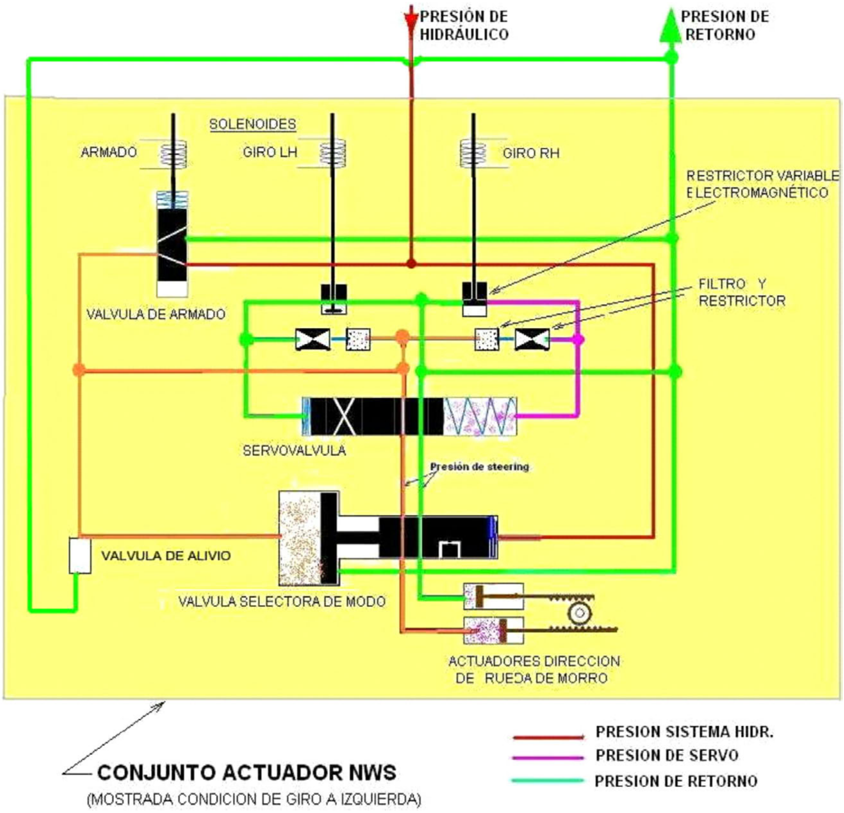


A-1. *Palma Airport chart*

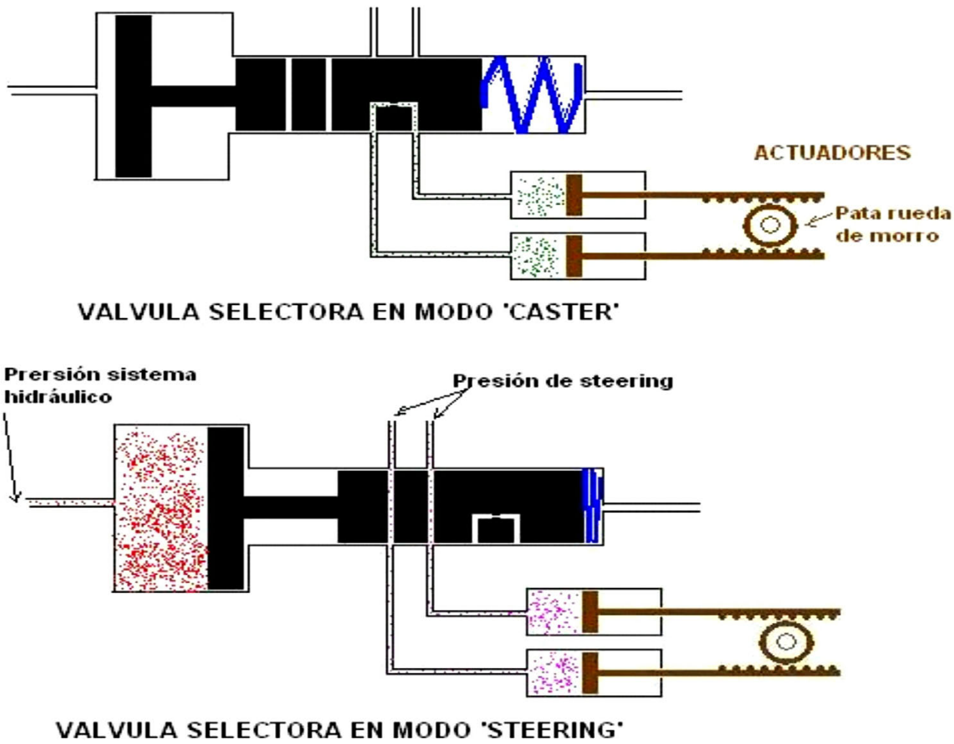


A-2. *Partial view of runway 06R and trajectory of the acceleration-stop*

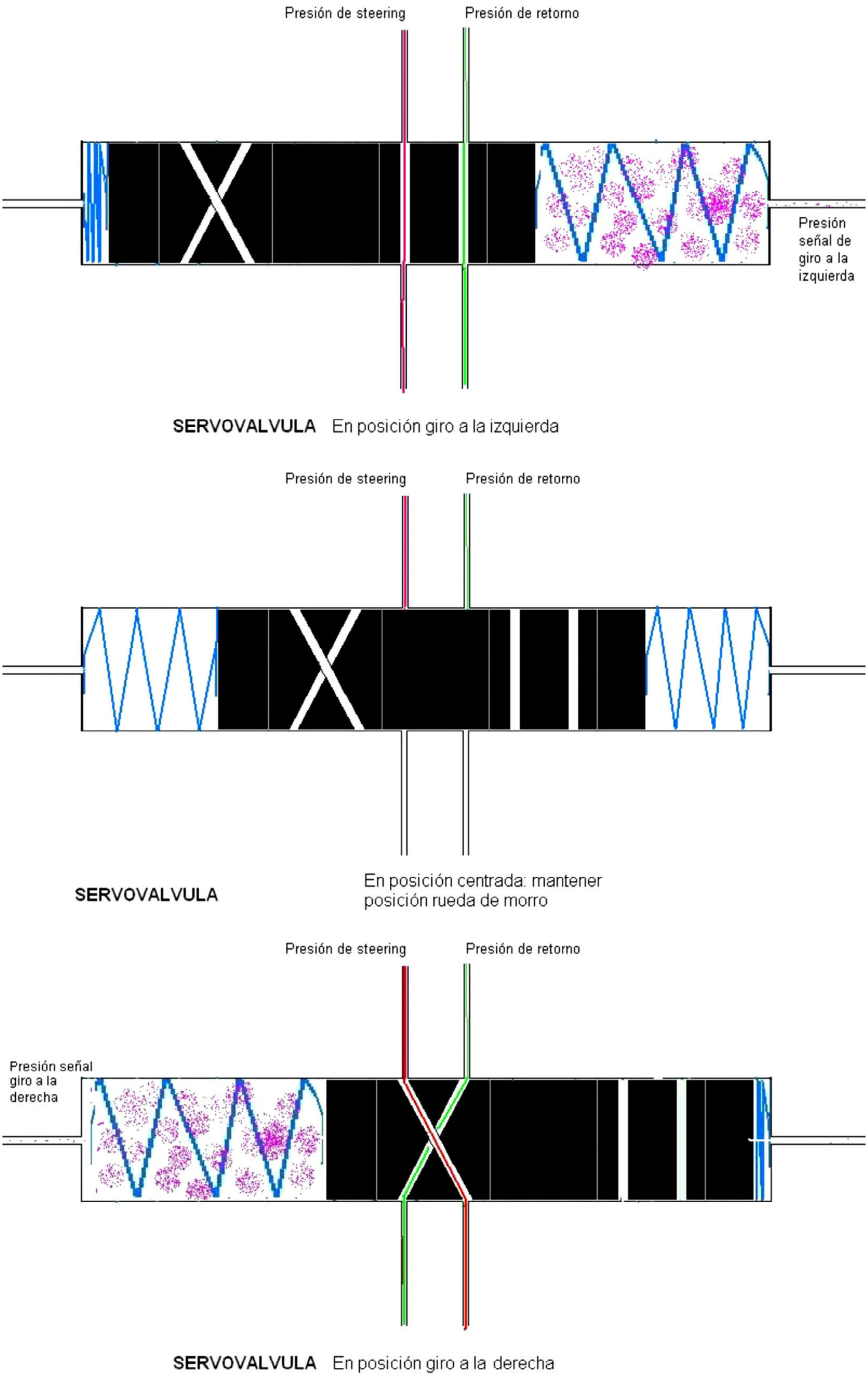
APPENDIX B
Hydraulic and electrical diagrams



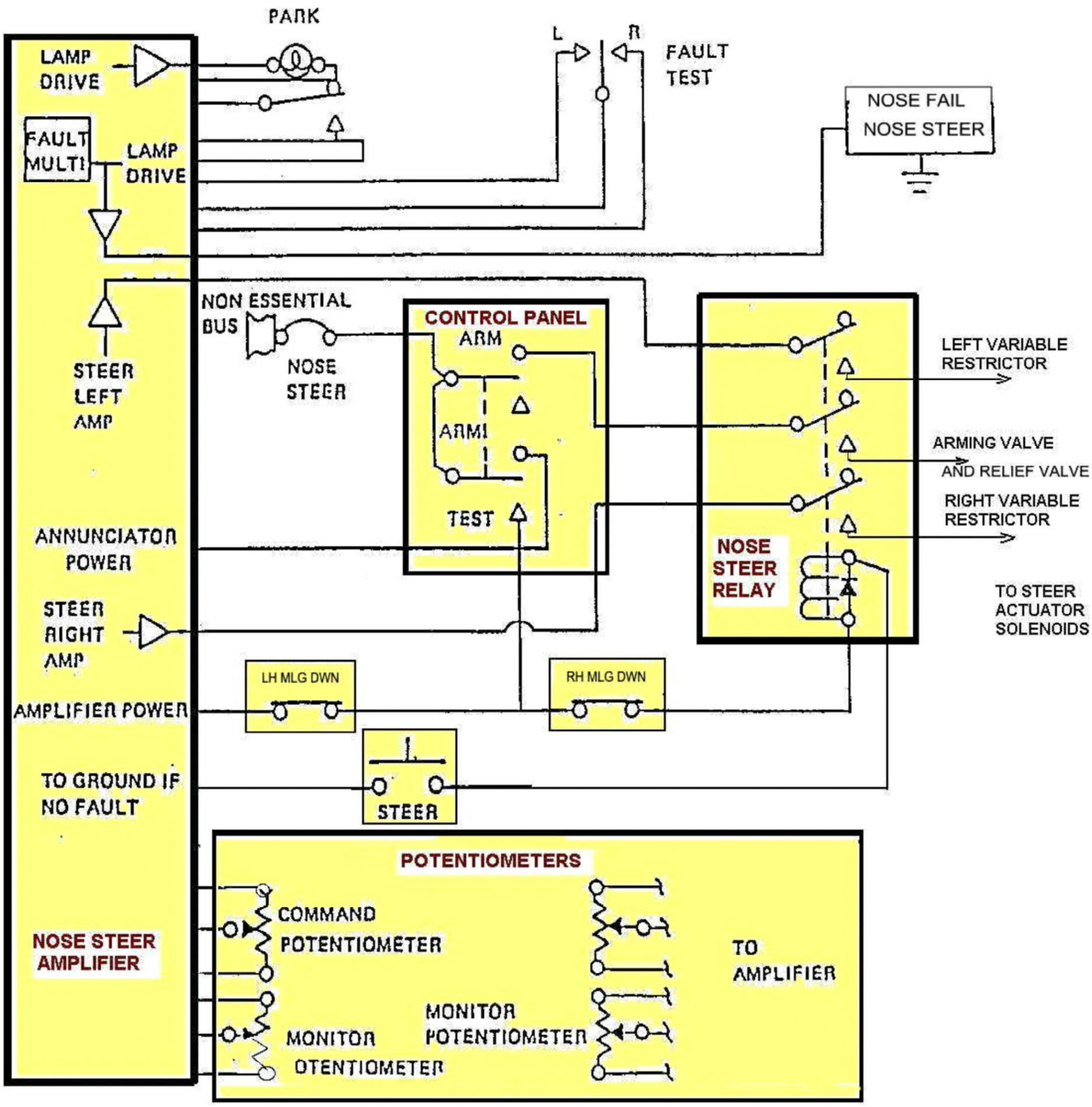
B-1. *Hydraulic diagram*



B-2. *Mode selector valve details*

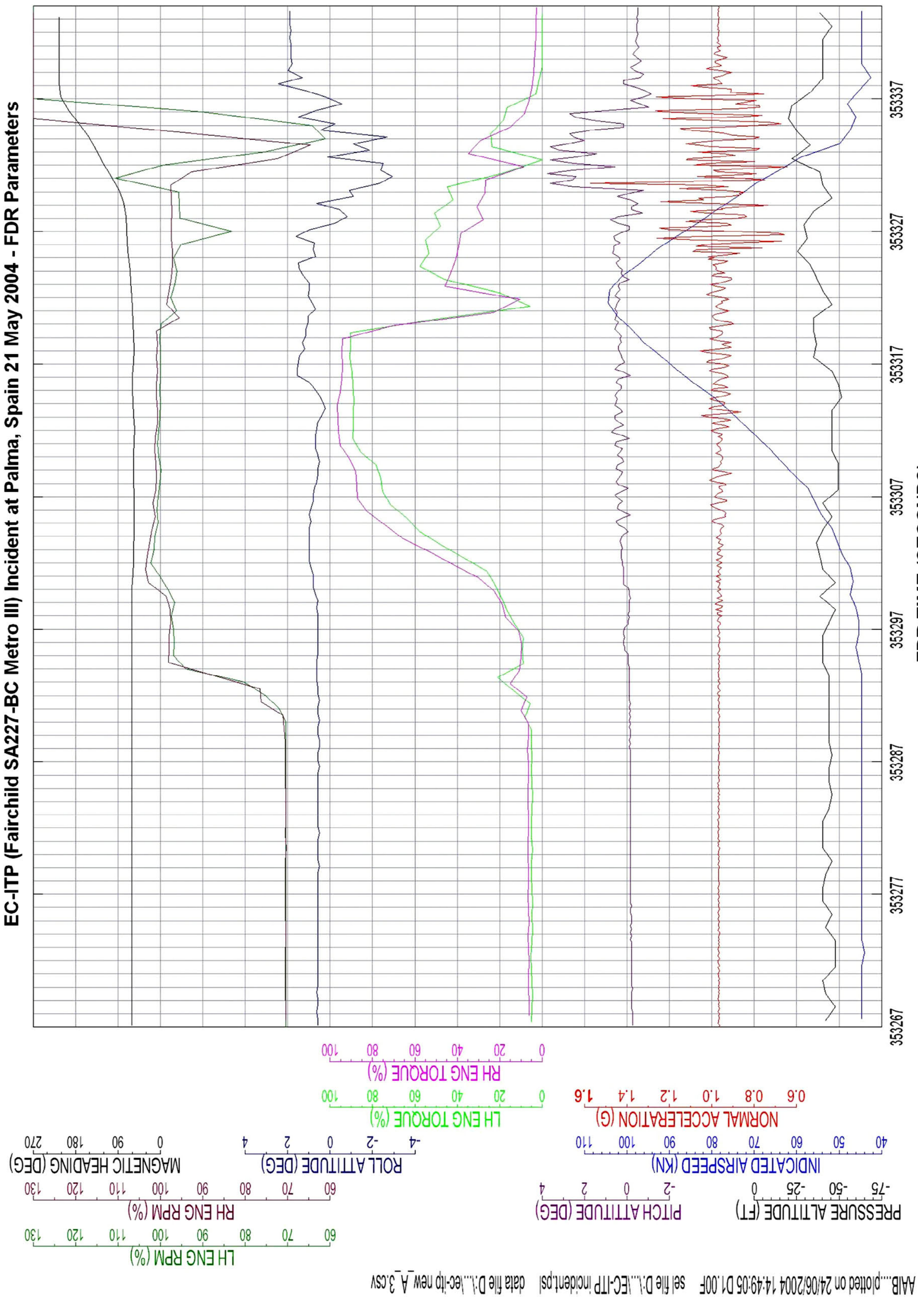


B-3. *Servo valve positions*



B-4. *NWS electrical diagram*

APPENDIX C
FDR graphs



C-1. *FDR parameter graphs*