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PENGUIN TECHNICAL EVALUATION PROGRAM MISSILE TEST FIRINGS

by

Arne Schjetne

Approved
Kjeller, 30 July 1971

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SECRET

Contents

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SUMMARY

This report gives a detailed description of the Penguin technical evaluation program. The procedures for testing and launching are described, and the test and launcher performance story of each of the 10 missiles is given. A summary of technical problems and errors is presented in the last chapters

1 INTRODUCTION

The Penguin development program has been a major task for the Norwegian Defence Research Establishment over the years 1962 - 1970. The weapon system is to be installed on the torpedo and gun boats of the Royal Norwegian Navy. The Penguin system is now in production by Kongsberg Våpenfabrikk

An important part of the Penguin development program has been missile test flights. This report describes the final part of the missile test flight program, the Penguin technical evaluation program, in which 10 complete missiles, produced by Kongsberg Våpenfabrikk, were launched from the motor gun boat KNM "Traust" during Feb 1970 - Jan 1971.

2 DESCRIPTION OF THE WEAPON SYSTEM

Penguin is a ship to ship guided missile weapon. A Storm-class motor gun boat is armed with 6 Penguin missiles. Each missile lies on a launcher in fixed position and orientation, ready for launch. Control and launching of the missiles is executed by means of an automated fire control system.

The missile trajectory has three different phases:

Boost phase - A solid propellant booster motor accelerates the missile to its cruising speed (270 m/s) in 2.1 seconds.

Mid-course phase - A solid propellant sustainer motor maintains constant speed. Guidance is by a 3 axis gyro stabilized platform, aided by an optical altimeter to maintain correct altitude (80 m). The missile is cruising on collision course towards the target. Deviation from the preset course due to wind is corrected by the platform.

Terminal phase - The target seeker is activated at a preset distance (3 km) from the target. The seeker detects the target at a distance of about 1100 m. The terminal phase starts at this decision point. Signals from the seeker are fed to the control unit in the guidance section. The missile homes to impact.

Prior to launch, the stable element of the platform is set horizontally, and the IR-detector is cooled to $77^{o}K$ by means of liquid N_2. 1.5 seconds before take-off, the platform azimuth is set to target bearing and the lateral guidance correction system in the platform is given initial velocity equal to target relative velocity across target bearing. The distance to the target is fed to the seeker. The missile is independent of own ship after launch, and will seek for and home against the target using passive observation of the target's infrared contrast against the sea surface. For further description of the weapon system see (1) and (2).

2.1 Summary of characteristics

2.1.1 Operational

Range	Min	2.5 km
	Max	20 km

Midcourse flight altitude	Below 100 m
Flight speed	270 m/s
Target seeker scanning width	± 600 m
Flight direction	± 30° from launcher direction > 40° from the sun
Weather	Sea state 5 Optical horizontal sight > 1200 m Optical vertical sight > 150 m

2.1.2 Technical

Weight	336 kg
Length	2962 mm
Wing span	1410 mm
Body diameter	280 mm
Warhead	115 kg, 46 kg explosives, penetration and delay

3 DEVELOPMENT MISSILE FIRING PROGRAMMES

The Penguin development program started in 1962 and was completed primo 1971. The development has been carried out in 2 phases:

Phase 1 - Development of a flight tested engineering prototype of the missile, completed ultimo 1965.

Phase 2 - Modification of missile, design of a prototype launching and control installation, and manufacturing of a small number of missiles for technical evaluation. Completed primo 1971.

During phase 1, 15 test flights were performed. The 15 test flights had a varying degree of completness from pure ballistics without any form of guidance up to flights with a preliminary guidance system. All missiles were launched from land based launchers.

The phase 2 program consisted of 19 ballistic and 27 guided flights. 17 of the 27 guided flights were performed by complete missiles with optical altimeter and infrared target seeker connected to the guidance system of the missile. 13 of the guided missiles were launched from a land based launcher at Vigdel firing range, and 14, including the 10 missiles in the technical evaluation program, were launched from the motor gun boat KNM "Traust". For informations of the missile test flights prior to the technical evaluation program see (3).

4 TECHNICAL EVALUATION MISSILE FIRING PROGRAM

4.1 Aim

The aim of the technical evaluation program was:

a) With a limited number of missile flights to verify that the weapon system performs according to the main specifications. Relevant main specifications:

- Max range 20 km
- Min range 2.5 km

- Nominal width of seeker scanning 600 m
- Operational in bad weather conditions, up to sea state

b) Detect missile errors, both system errors and errors due to workmanship

c) Evaluate the launching on control system for the Storm-class Fast Patrol Boats

The aims of the remaining test firings were changed during the period according to the results of test firings carried out at that moment.

4.2 Summary of the missile test flights

The planned 10 missiles were launched from KNM "Traust" in the period Feb 1970 - Jan 1971. 9 of the missiles had inert and 1 had live warhead. 4 of the missiles, including the one with the live warhead, hit the target.

4.2.1 Summary of each missile test flight

Missile Richard - Launched against ex-KNM "Stavanger" 5/2-1970 at a distance of 5200 m. The target was detected, but lost due to seeker error.

Missile Sigurd - Launched against M/K "Carl Erik" 18/3-1970 at a distance of 2900 m. Sea state 5. Hit the target.

Missile Tore - Launched against ex-KNM "Reinøysund" 25/4-1970 at a distance of 5400 m. The real relative target velocity across target bearing was 0 m/s , but was of the launching and control system set to 22 m/s. This was done to make the target seeker detect the target in the fringe of the searched field. The missile hit the target.

Missile Ulrik - Launched against ex-KNM "Stavanger" 27/4-1970 at a distance of 5500 m. The bow of the target pointed at KNM "Traust". The missile hit the target.

Missile Victor - Launched against ex-KNM "Stavanger" 30/4-1970 at a distance of 15 000 m. The target was detected, but lost due to seeker error.

Missile Wilma - Launched against ex-KNM "Reinøysund" 21/8-1970 at a distance of 15 100 m. The target was detected, but the seeker decision circuit was activated too late. When the decision circuit was activated, the missile homed against false IR-targets generated by the seeker itself.

Missile Xantippe - Launched against ex-KNM "Reinøysund" 22/8-1970 at a distance of 15 400 m. The missile hit the sea surface after a flight of 1800 m. This was due to a misalignment of the platform pitch axis of -2.8°. An amplifier in the platform alignment electronics was affected by high frequency noise.

Missile Q - Launched against ex-KNM "Reinøysund" 8/12-1970 at a distance of 16 000 m. The missile climbed to an altitude of 300 m due to an altimeter error. The sustainer motor pressure increased to more than twice the normal value, and the motor bursted.

Missile Yngve - Launched against ex-KNM "Reinøysund" 12/1-1970 at a distance of 16 800 m. The missile hit the sea surface after a flight of 1800 m. Same error as for missile Xantippe.

Missile Zorba - Launched against ex-KNM "Reinøysund" 16/1-1971 at a distance of 4500 m. Missile with live warhead. The missile hit the target and the warhead detonated.

4.3 Results

The missile test flights have indicated that the weapon system meets 3 of the 4 specifications mentioned in 4.1 a). In spite of 5 test flights at a distance ≥ 15 000 m no missile hit at long range has been demonstrated. This was due to technical errors only. With no such errors the missile will without doubt hit the target at max range. The mid-course guidance system of the missile and the firing control system have proved to be very accurate.

Two different operational launching and control systems, one developed at NDRE and the other at KV, are evaluated and successfully used for launching of missiles. The launching and control system developed at KV is now under installation onboard the Storm-class Fast Patrol Boats.

During the missile test flights there were 7 different errors, 4 of which were system errors. During the testing of the missiles, there were a number of errors, partly due to workmanship. The system errors discovered during testing and test flights were removed as soon as they were discovered, and are not present in the missiles now delivered to the Royal Norwegian Navy.

5 LAUNCHING AND CONTROL SYSTEMS

The Penguin weapon system on a Storm-class motor gun boat consists of:

a) 6 box launchers with missiles and containers for liquid N_2

b) Launching and control system consisting of

- Control electronic cabinet (including a digital computer)

- Launcher control cabinet
- Power supply cabinet

c) Control panel (on the bridge)

d) Target data system (HSA-M26 gunfire control system)

e) Cabeles between the various units:

- a to b
- c to b
- d to b

The data from HSA-M26 to the launching and control system are:

- Target bearing
- Target course
- Target speed
- Own ship's course
- Own ship's speed
- Own ship's Pi and Ro angle

All operational controls are carried out by means of the control panel on the bridge. By means of the orders from the control panel and the data from the HSA-M26, the launching and control system carries out the following:

- Starting, testing and keeping the weapon system alert
- Programming the missiles for flight
- Launching sequence control

During the technical evaluation program 3 different launching and control systems have been used.

5.1 Traustin

1 missile type. Analog fire control computations, test sequence, launcher control sequence and platform slave electronics. For more informations see (4).

Used for launching of 4 guided missiles in phase 2, before the technical evaluation program started. In the technical evaluation program used for launching of the missiles R, S, T, U and V.

5.2 NDRE NOR2

1 missile type (easily extended to 6 missiles). Digital fire control computations, test sequence and launcher control sequence. Analog slave electronics. For more informations see (5).

Evaluated as a part of the technical evaluation program. Used for launching of the missiles W and X.

5.3 KV MK1 MOD 1

6 missile type. Digital fire control computations. Analog testsequence, launcher control sequence and slave electronics. For more informations see (6).

Evaluated as a part of the technical evaluation program. Used for launching of the missiles Q, Y and Z.

6 MISSILE PRE LAUNCH TESTING, MODIFICATION AND INSTRUMENTATION

The missiles used in the technical evaluation program were produced at Kongsberg Våpenfabrikk and Raufoss Ammunisjonsfabrikk. The production system and control system were different from what are now used for serial production. The missiles were not assembled, but delivered to NDRE as follows:

- Guidance section (without gas generator charge)
- Warhead section (explosives removed)
- Motor section (without charge)
- Motor charge
- Gas generator charge
- Wings
- Canard fins

The guidance section was tested at KV Penguin lab by NDRE before it was accepted.

The prosedure for modification, instrumentation, assembling, testing and calibration is described in 6.1 to 7.10.

If a defect was discovered in the missile, the defect submodule was sent to KV for repair. No repairs were done at NDRE.

The test stands used for testing of guidance section and warhead section at KV and NDRE are the same as used for all guided missiles in the phase 2 program.

6.1 Acceptance test of guidance section at KV Penguin lab

The acceptance test was mainly the same as the test of the guidance section done by KV. For information see (7). The guidance section consists of the following main components:

- Target seeker
- Hot gas rudder servo
- Optical altimeter
- Gyro-stabilized platform
- AC power supply
- Control unit
- Thermal batteries

The following tests were done on the main components except the batteries:

- Functional test
- Static test
- Dynamic test

Static and dynamic test of:

- Main control loops
- Lateral control loop
- Seeker azimuth control loop
- Seeker pitch control loop
- Altimeter control loop

Test of:

- Platform self alignment and drift
- Seeker slaving to platform and cooling position
- Gas servo pressure switch
- Battery circuits and firing circuits

Simulation of the missile's target tracking: Tracking of a moving IR-target, the gas generator supplied with compressed air and the canard fins put on.

6.2 Modification and test of guidance section subsystems

When the guidance section arrived at NDRE it was demounted. Separate tests and modifications were done at the target seeker, altimeter and control section.

6.2.1 Target seeker

- Telemetry equipment mounted
- Black painting to avoid undesirable reflexes of sun illumination
- Modifications introduced
- Functional test
- Detector test
- Gas tightness test
- Vibration test

6.2.2 Altimeter

- Href and noise level adjusted
- α_t increased from 0.95° to 1.15° on the missiles W, X, Q, Y and Z
- Functional test.

6.2.3 Control section

- Firing circuit resistors changed on the missiles V, W, X, Q, Y and Z
- Vibration accelerometers and telemetry amplifiers mounted on missile T, U, V, Y and Z
- Fuse telemetry circuit mounted on missile U and V.

6.3 Warhead section instrumentation

6.3.1 Telemetry and sustainer puncture

Telemetry equipment and sustainer motor puncture electronics were mounted in the empty warheads of all the missiles except Zorba, who had a live warhead. Missile Z had no sustainer puncture equipment, and the reduced telemetry equipment was mounted in the warhead section, around the warhead tip.

The normal telemetry equipment consists of:

- Commutator
- Subcarrier oscillators
- Summing amplifiers

- 224 MHz radio transmitter

- Antennas

This gives 31 commutated channels with an information bandwidth of 30 Hz and 9 exclusive channels with information bandwidth from 59 Hz to 3700 Hz. For further information see (2). The following list is typical for the missiles with inert warheads:

Com ch	1	Lateral integrator 1 A
"	2	Gas servo pick-off 1
"	3	" " " 2
"	4	Platform resolver Az, B
"	5	" " Pi, B
"	6	" " Az, A
"	7	" " Pi, A
"	8	" " Ro
"	9	Gas servo input 1
"	10	" " " 2
"	11	Seeker deviation angle Az
"	12	Gas generator pressure
"	13	Flapper motor current 1
"	14	" " " 2
"	15	Seeker deviation angle Pi
"	16	Lateral integrator 1 B
"	17	Altitude command
"	18	Positive main supply
"	19	Tracking command Az
"	20	" " Pi
"	21	Negative main supply

Com ch	22	Seeker gimbal motor Pi
"	23	" " " Ro
"	24	Lateral integrator 2 A
"	25	Altimeter ΔH
"	26	Lateral integrator 2 B
"	27	Sustainer puncture
"	28	Booster motor pressure
"	29	Sustainer motor pressure
"	30	Platform gimbal motor Az
"	31	" " " Pi
Ex ch	9	" " " Ro
"	10	Platform axial accelerometer
"	11	Platform lateral accelerometer
"	13	Platform vibration accelerometer, axial
"	14	Platform vibration accelerometer, lateral
"	15	IR-pulse + track flip-flop
"	16	Az sector I + track window + Az track pulse
"	G	Seeker IR-signal

The sustainer motor puncture electronics consist of:

- 35 MHz receiver
- Antennas
- Decoder

The sustainer motor is punctured if a coded 35 MHz signal is received from the command tower at Vigdel firing range. For information see (2) and (8).

6.3.2 Transponder

A transponder was mounted in the warhead section around the warhead tip of missiles R, S, U and V. The transponder was part of a radio tracking system for giving data of the horizontal projection of the missile trajectory soon after the flight. For information see (9). The reasons for not having transponders in the last 5 missiles in the technical evaluation program were:

- Transponder sometimes affected platform self alignment
- Long time for data evaluation
- Lack of accuracy for range over approximately 8 km
- Data from platform lateral integrator 2 gives immediate data of the missile trajectory with reasonable accuracy.

6.3.3 Antennas

Antennas for the following units were mounted in the wing tips and adjusted:

- Telemetry transmitter, 2 antennas to give circular polarization
- Sustainer puncture receiver and transponder receiver
- Transponder transmitter.

6.4 Motor section assembling and instrumentation

- Sub modules of motor section assembled
- Sustainer motor puncture charge mounted
- Pressure transducers for telemetry of sustainer motor pressure and booster motor pressure mounted.

6.5 Guidance section testing

When the modifications and tests mentioned in 6.2.1 - 6.2.3 were completed, the guidance section was re-assembled. It was then tested as follows:

6.5.1 AC-power supply

- Amplitude
- Frequencies.

6.5.2 Platform

- Functional test
- Platform drift
- Integrator drift
- Scale of accelerometers, integrators and resolvers
- Self alignment accuracy
- Coordinate transformation of input orders to gas servo
- Step response.

6.5.3 Control unit

- Functional test
- Gain of the 6 control loops
- Step respons (Transfer functions of the 2 main control loops)
- Track indication.

6.5.4 Altimeter

- Functional test
- Dynamic test of θ_{RH} and ΔH
- α_t
- α_H
- Href
- Trigger angle
- Effect of transmitted light pulse
- Track indication.

6.5.5 Gas servo

- Functional test with compressed air
- Step respons
- Pressure switch
- Pick-off scale
- Trim (Canard fin angle = 0 when servo input signal = 0).

6.5.6 Seeker

- Functional test
- Slaving to platform (pitch and roll alignment)
- Locking
- Cooling
- Timer

- Artificial IR-target
- Az tracking command
- Pi tracking command
- Tracking of moving IR-target
- Signals on seeker test plug.

6.5.7 Special tests

- Simulated missile test flights with umbilical cable removed, compressed air to gas generator and tracking moving IR-target
- Long time tests (for finding errors due to high temperature etc).

6.6 Warhead section test

Warhead section with wings was electrically connected to the guidance section.

6.6.1 Telemetry

- Functional test
- Limitations (VCO inputsignal shall not exceed ± 2.5 V)
- Calibration .

6.6.2 Sustainer puncture

- Functional test (Output signal when correct coded 35 MHz signal is received, no output signal when the received signal is not correct).

6.6.3 Transponder

- Functional test (Transmission of 105 MHz when 35 MHz is received, no transmission if no 35 MHz signal is received).

6.7 Vibration test of assembled guidance/warhead section

Guidance section and warhead section were assembled to an unit. At KV environmental lab a dummy motor section was mounted to this unit. The missile unit was then mounted on a vibrator. The following vibration tests were performed:

Runs : 4 runs with axial acceleration
4 runs with lateral acceleration

Frequency range: 20 - 2000 - 20 Hz

Sweep rate : 1 octave/min

Test level : 1 g peak

The missile was energized during the vibration tests, and continuously monitored via teststand and telemetry. When the vibration tests were completed, the dummy motor section was demounted and the guidance/warhead section carefully tested. Faults were detected on 6 of the 10 missiles. Some of the faults were induced by the vibrations and some detected because of the vibrations.

6.8 Assembling and mounting in launcher

The guidance/warhead section was taken to NDRE dep X. The motor section was mounted and the complete missile mounted in a box-launcher. A protection bag was mounted around the guidance sections of missile R, S, T, W and X. This protection bag was ment to be torn off when the missile started to move on the launcher in the boost phase. Evaluation of the protection bag was ment to be a part of the technical evaluation program. Due to different reasons the protection bags were removed before launching, and no launch tests were done with the protection bags. The missiles now delivered to RNN have no protection bags.

6.9 Transport and mounting onboard KNM "Traust"

The box-launcher with the missile was sent to Bergen by train or by military airplane. The launcher was mounted onboard KNM "Traust" at the navy base Haakonsvern.

7 TEST OF COMPLETE WEAPON SYSTEM AT HAAKONSVERN

The tests mentioned in 7.1 - 7.4 were done with the ship alongside quay.

7.1 Launching and control system

The launching and control system was tested as much as possible before it was connected to the missile. The umbilical cable was connected to a dummy load and every pin of the umbilical plug was measured. The following was tested:

- Supply voltage
- Start sequence

- Test stimuli signals
- Platform compensation signals
- Firing sequence.

7.2 Launcher

- Firing circuits
- Firing sequence (including return signal for launcher opening OK)
- Cooling unit
- Artifical IR-target.

7.3 Missile

The signals on the missile umbilical cable and the test cables were available at the launching and control system Traustin, and were made available on the two other launching and control system also used during the technical evaluation program. The launching and control systems did not give the same testing posibilities as the test equipment at NDRE, but the parameters which could be tested were tested. The tests were much more comprehensive than the automatic tests of the launching and control system, and errors not detected by the automatic tests were found.

Telemetry receiver and discriminators were installed in the check-out room onboard. This was done to test all the telemetry channels, but the telemetry signals also were very usefull to monitor the missile.

7.4 HSA M26

The fire control computations were tested by simulations on HSA M26 and the dummy log. As function of:

- Own ship's speed
- " " acceleration
- " " course
- " " rate of course change
- Target speed
- " course
- " bearing
- Distance to the target

The following were tested:

- Platform alignment
- Platform azimuth setting
- Target speed across target bearing (V_{yeo})
- Seeker timer setting.

7.5 Complete weapon system test at sea

KNM "Traust" and a target ship were taken to Bjørnefjorden outside Haakonsvern. Several test runs were done by the target ship and own ship to generate the situations previously simulated on HSA M26 and the dummy log, as mentioned in 7.4.

8 TANANGER

25 TKB squadron including KNM "Traust" left Haakonsvern to go to Tananger in the morning the day before the planned day of the missile test flight. The missile was energized and tested during the transit. When arrived at Tananger, the firing circuits were connected, tested and short circuited. Flares were mounted on the wings, this to make it easier for the four cinetheodolites to track the missile during the flight.

25 TKB squadron stayed at Tananger until the missiles onboard KNM "Traust" were launched or the expedition was suspended. Due to technical reasons and weather conditions this sometimes could be for some time.

9 FIRING RANGE

During the technical evaluation program, the same firing range was used as for the other missile test flights of phase 2; Vigdel firing range south-west of Stavanger. Vigdel firing range has the following facilities:

- Command tower
- Communications
- Telemetry station
- Radio tracking system
- 4 cinetheodolites
- Mess

For more information see (8) and (10).

10 LAUNCHING DAY

Before launch, the following had to be OK:

- Weather conditions satisfactorily
- Target ship in position
- No boats in the danger area of the firing range
- No airplanes in the area
- Telemetry station OK
- Chinetheodolites OK

The control of this was the responsibility of the 25 TKB squadron and the firing officer in the command tower.

Usually there was a test run before the real missile firing run. The test run was exactly equal to the firing run, and the fire button was pressed, but the firing circuits were not armed. The reasons for having a test run were:

- Drill of crew and cinetheodolite operators
- Test of telemetry station
- Last sea test of weapon system.

A typical time table of the launching day onboard KNM "Traust" was as follows:

X - 4 hours	Test of weapon system
X - 2 hours	Launcher Fill liquid N_2 Clear up after deck

X - 90 minutes	Radio and radar silence Firing circuits connected Mount missile motor nozzles
X - 60 minutes	Radio and radar permitted used
X - 50 minutes	Departure Tananger
X - 40 minutes	Start test run
X - 30 minutes	Test run completed
X - 10 minutes	Start missile firing run
X - 5 minutes	Firing circuits armed
X - 105 seconds	KNM "Traust" at correct course
X - 90 seconds	HSA M26 tracks the target
X - 60 seconds	Counting from command tower
X	Fire
X + 11 seconds	Take-off.

11 DATA PROCESSING

11.1 Telemetry

11.1.1 Vigdel

2 telemetry receivers and 2 tape recorders were used during the missile flight. Data were recorded from X - 4 minutes to the end of the missile flight. One tape was sent by air to NDRE as quick as possible, the other tape was used for data processing at Vigdel. Data processing at Vigdel was done for the following reasons:

a) Determine what was wrong if it had been an unsuccessful missile flight

b) Find irregularities, if any, in an apperently successful missile flight

c) Get telemetry data a few hours after the launching of the missile.

If it was more missiles to be launched on the expedition, the results of a) and b) determined if the other missiles could be launched as planned.

11.1.2 NDRE

Data processing of the other tape was done at NDRE data laboratory and at the Kjeller Computer Installation (KIRA). The IRIG-format magnetic tape was reproduced and encoded to digital form at the data laboratory. Data were transferred on a data link to KIRA, where they were recorded on standard 7-track computer tape. Calibrated graphs were produced by KIRA using Calcomp plotting machines. These graphs were normally available 3 - 5 days after launching, but because of difficulties with the data laboratory and the data link, it sometimes took considerably more time to get the data.

Further processing could be done of the data. For error tracing and simulation studies the following could be done:

- Filtering
- Coordinate transformations
- Computing of non-telemetered quantities from telemetered signals using known transfer functions.

11.2 Cinetheodolites

A cinetheodolite produces a film record, 5 frames per second. Missile data were manually read from each frame and punched on paper tape. The resulting tapes were used by KIRA, who produced calibrated plots of:

- Missile trajectory in X-Y plane
- Missile trajectory in Z plane
- Missile acceleration in X, Y and Z direction
- Missile total acceleration
- Missile velocity in X, Y and Z direction
- Missile total velocity.

Because of the timeconsuming manual data reduction, the plots were not available till 3 - 4 weeks after launching.

12 MISSILE R, DESCRIPTION

12.1 Aim

To hit a relastic target at medium range.

12.2 Technical description of the missile

12.2.1 Motor

12.2.1.1 Booster motor charge

Double base propellant, VU (British)	41.21 kg
Inhibitors	1.85 kg
Start thrust	4700 kp
Final thrust	2500 kp

Burning time	2.41	seconds
Total impulse	8670	kps

12.2.1.2 Sustainer motor charge

Double base propellant, X-35 (Norwegian)	44.92	kg
Inhibitors	1.88	kg
Thrust	120	kp
Burning time	74	seconds
Total impulse	8940	kps

12.2.2 Warhead

Inert warhead.

12.2.3 Guidance section

E-04

Protection bag mounted at NDRE, removed onboard KNM "Traust".

12.2.3.1 Seeker

E-02 (Electronics E-02, Optical unit E-02).

Modifications at NDRE:

- Telemetry electronics mounted
- Unit to prevent down corrections till 0.5 seconds after decision mounted
- Capasitor C12 on module 1702 changed from 15 µF to 0.1 µF.

12.2.3.2 Gas servo

E-05 (Electronics E-09, Gas generator E-09).

12.2.3.3 Altimeter

E-04

Modifications at NDRE:

- Href adjusted by means of external resistors
- Converter stop module mounted
- R19 on module 1804 changed from 1/4 W to 1 W.

12.2.3.4 Platform

E-08 (E-04 originally mounted at KV).

12.2.3.5 AC-power supply

E-04.

12.2.3.6 Control unit

E-02.

12.2.3.7 Thermal batteries

32

40

94.

12.2.3.8 Control section

E-04.

12.2.3.9 Control parameters

Main control loop Az	$6.13^{o}/o$
Lateral compensation	$0.136^{o}/m$
Tracking com Az	$K\psi_{\varepsilon n} = 2.37^{o}/o$ $K\psi_{s1} = 0.57^{o}/o$
Main control loop Pi	$6.76^{o}/o$
Altitude com	$0.19^{o}/m$ $\alpha_H = 1.3^{o}$ $\alpha_t = 1.15^{o}$
Tracking com Pi	$K\theta_{\varepsilon n} = 2.32^{o}/o$ $K\theta_{s1} = 0.46^{o}/o$
Href	82 m

12.2.4 Telemetry

Telemetry channels as listed in 6.3.1, except for ex ch 13 and ex ch 14 which were not used.

12.2.5 Transponder

Transponder mounted.

12.3 Equipment onboard KNM "Traust"

12.3.1 Launching and control system

Traustin.

12.3.2 Launcher

Selco I

Aft starboard position

Elevation 19.97°

Azimuth 14.63°.

12.3.3 Recording equipment

The following signals were recorded on a tape recorder:

Own ship's roll	ϕ_s
Own ship's pitch	θ_s
Own ship's course	ψ_s
Target bearing	ψ_T
Yaw velocity	
Axial acceleration	axs
Lateral acceleration	ays
Vertical acceleration	azs
Launcher actuator pressure	P_1
Launcher actuator pressure	P_2.

12.4 Target

ex-KNM "Stavanger", a class C destroyer.

12.5 Photography

High speed camera onboard KNM "Traust"

2 Bolex cameras onboard the target

Camera onboard escort boat 1

Camera onboard escort boat 2.

12.6 Missile test at NDRE and KV

12.6.1 Acceptance test

12 - 14/11 - 69

Because of electrical transients due to the recording equipment of the teststand, Q11 and Q12 on module 1809 of the altimeter were destroyed. Altimeter E-04 was exchanged with an other altimeter but the same happened again. Because of this, the altimeter design was changed: 1 kΩ resistors were connected to AH and θ_{RH} for protection. Altimeter E-04 was repaired and mounted.

12.6.2 Subsystem test

12.6.2.1 Seeker

- + 28 V was not decoupled
- Az sector I and II were exchanged on the seeker threshold electronics input
- Mounting cylinder was not gas tight
- Gas leakage between IR-dome and dome barrel.

12.6.2.2 Altimeter

OK.

12.6.3 Guidance/warhead section test

12.6.3.1 Test at NDRE

- No connection between A03 J02-B and Z03 Po8-T because of bad soldering
- Misconnecting of gas generator pressure telemetry signal

- Misconnecting of negative battery
- Seeker fault because the insulation of roll motor wire was damaged of slip-ring screws
- Underdimensioned decoupling capasitor.

12.6.3.2 Vibration test at KV

20 - 22/1 - 1970

4 runs lateral

3 runs axial

20 - 2000 - 20 Hz

1 octave/minute

1.5 g peak

The following happened before the missile was vibrated, because of teststand faults:

- Seeker module 1704 E-02 was destroyed and exchanged with 1704 E-10
- Platform E-04 tumbled, some wires were torn off. Platform E-04 exchanged with platform E-10

No faults detected during or after the vibrations.

12.7 Complete weapon system test at Haakonsvern and Tananger

Launcher with missile mounted onboard 21/1 - 1970.

Platform E-10 tumbled (28/1) because of bad connection between gyro spinmotors and the spinmotor exitation voltage on FEP 1. Platform E-10 was exchanged with platform E-08 (29/1).

Arrival Tananger 2/2.

Launching and control system faults (3/2 - 4/2) due to a 5 V power supply in the KV predictor. The power supply was exchanged with a laboratory power supply.

12.8 Launching attempts

A launching attempt was done 5/2 1130, but the firing sequence stopped because the rear cover of the launcher was not opened. This was due to a leakage in the launcher firing circuit. KNM "Traust" returned to Tananger. It was decided to open the launcher manually, because it would have taken too much time to mount a new launcher firing circuit if the missile was to be launched the same day.

12.9 Launching

The fire button was pressed as soon as the two men who opened the launcher was under deck.

Date		5/2 - 1970 1234
Distance to target		5200 m
Direction to target		271.9°
Weather:	Sight	15 km
	Cloud cover	7/8
	Wind	8 m/s from SE
	Temperature	- 3°C
	Sea state	< 1

13 MISSILE R, VALUATION

13.1 Data systems

13.1.1 Telemetry

Good data.

13.1.2 Transponder

Good data.

13.1.3 Cinetheodolites

T1 and T2: Medium quality during 0 - 2.5 sec and 24.5 - 25.5 sec. Good data from the rest of the flight

T3 : Bad data. These data are not used for calculation of the missile trajectory

T4 : Good data.

13.1.4 Photography

KNM "Traust", high speed camera: Take-off

Escort boat 1 camera : The whole missile trajectory

Excort boat 2 camera : - " - " -

Target cameras : Nothing, the missile did not hit the target.

13.1.5 Recording equipment onboard KNM "Traust"

Good data.

13.2 Equipment onboard KNM "Traust"

13.2.1 Launching and control system

OK.

Total fire control accuracy 0.25° (including launcher alignment).

13.2.2 Launcher

Opened manually.

13.3 Missile flight

See 13.5.5.

13.3.1 Boost phase

Normal. Missile velocity at the end of the boost phase was 266 m/s.

13.3.2 Mid-course phase

The missile lost altitude between each altitude correction from the altimeter. This was due to a platform pitch misalignment of approximately -0.7°. Because of this the average altitude during the mid-course flight was only 69 m and the altitude at the decision point 66 m.

The lateral guidance was OK. If the missile had not homed against the target, it would have passed 25 m to the right of the target center.

The missile rolled clockwise, 0.47 Hz.

13.3.3 Terminal phase

The seeker took decision on the target, the missile started to home against it, but due to seeker errors the seeker lost it. The missile passed 45 m over and 10 m to the right of the target center and hit the sea surface 1200 m behind the target.

Decision distance was only 850 m. This was because of the platform pitch misalignment: The altitude at decision point is too low and the seeker depression angle -4.7° instead of -4°.

13.4 Missile subsystems

13.4.1 Motor

See 13.5.3.

13.4.1.1 Booster motor

Burning time	:	2.55 sec
Velocity at burn out	:	266 m/s
Pressure	:	Normal, max 90 kp/cm^2
Acceleration (start)	:	132 m/s^2

13.4.1.2 Sustainer motor

Normal pressure till 16 sec. From 16 to 25.5 sec (splash down) the pressure increased from 74 to 96 kp/cm^2 with increasing rate of pressure growth. If the missile flight had been longer, the pressure could have stabilized on a higher level or caused a motor burst.

During the period 5 - 17 sec the pressure was 70 - 74 kp/cm^2. This gives a thrust of 101 kp (nom 120 kp). The missile velocity was 264 m/s during this period.

This fast pressure increasing is not known from static motor firings. The pressure increasing is to slow to be due to stopping up of the nozzles, moreover the missile accelerated during the period with high pressure.

The inhibitors can be locally burnt through during the flight. The burning area will then increase, and the pressure will increase. Possible explanations of the pressure increasing are:

a) The charge slides backwards over the hot motor chamber.

b) Hot gas flows around the charge because of a leakage in the motor cover.

c) Hot gas flows around the charge because the free volume between the charge and the motor shell is to large.

13.4.2 Platform

Platform Pi misalignment of approximately -0.7°, probably because of high frequency noise during the alignment period. The high frequency noise affects the axial accelerometer amplifier. This amplifier is modified for the platforms now in production at KV.

13.4.3 Altimeter

See 13.5.2 and 13.5.3.

6 altitude samples, 1 of these was a no return measurement. The 5 other measurements differ 1 - 6 m from the altitude calculated from the cinetheodolite data. Altitude command according to the measurements.

13.4.4 Seeker

See 13.5.4.

The seeker detected the target, but lost it. There were 2 different seeker system errors, each of them probably would made the missile miss the target:

- The seeker track threshold was 80 - 90% of max IR-signal instead of 50%. Because of this the IR-signal from the target generated IR-pulse only at the first scan after decision.

- The seeker had a circuit to prevent down corrections till 0.5 sec after decision. Because of too low altitude, too great depression angle and an up correction due to the IR-pulse disappearance, the IR-signal passed sector II during the 0.5 sec period.

The 2 system errors, (faulty track threshold setting and too long time of down correction barring) were removed from the succeeding missiles.

13.4.5 Control loops

13.4.5.1 Az control loops

See 13.5.1.

Mid-course guidance:

V_{yeo}	0 m/s
Average ψ_{MP} (Az angle)	- 1.5°
Lateral int 2	11 m
Oscillation	1.5° pp 3.2 Hz
Lateral wind	7 m/s
Average missile velocity	265 m/s

Normal oscillation. ψ_{MP} is according to V_{yeo}, lateral wind and missile velocity.

Terminal guidance: Tracking com Az = - 3° during the terminal phase because the seeker lost the target shortly after decision. ψ_{MP} = - 3° during the terminal phase.

13.4.5.2 Pi control loops

See 13.5.2.

Mid-course guidance:

Average θ_{MP} (Pi angle)	1.8°
Oscillation	1.0° pp 3.0 Hz

Normal oscillation. Average θ_{MP} = 1.8° (normal 1.1° - 1.2°) to keep the missile at constant altitude because of the - 0.7° pitch misalignment.

θ_{MP} is according to altitude command.

Terminal guidance: Initial tracking com Pi = - 1.8°, up-correction 0.15 sec after decision. Tr com Pi = - 0.2° during the rest of the flight. θ_{MP} = - 0.2° according to

tr com Pi. γ (trajectory slope) = θ_{MP} + misalignment angle - angle of attack (1.1°) = - 2°. This is according to the missile trajectory data.

13.4.6 Gas servo

OK.

13.4.7 AC power supply

OK.

13.4.8 Thermal batteries

OK.

Positive batteries: 30 V , constant during the flight

Negative battery: -30.5 V - " -

13.5 Telemetry and missile trajectory recordings

Lateral control signals on 13.5.1.

Altitude control signals on 13.5.2.

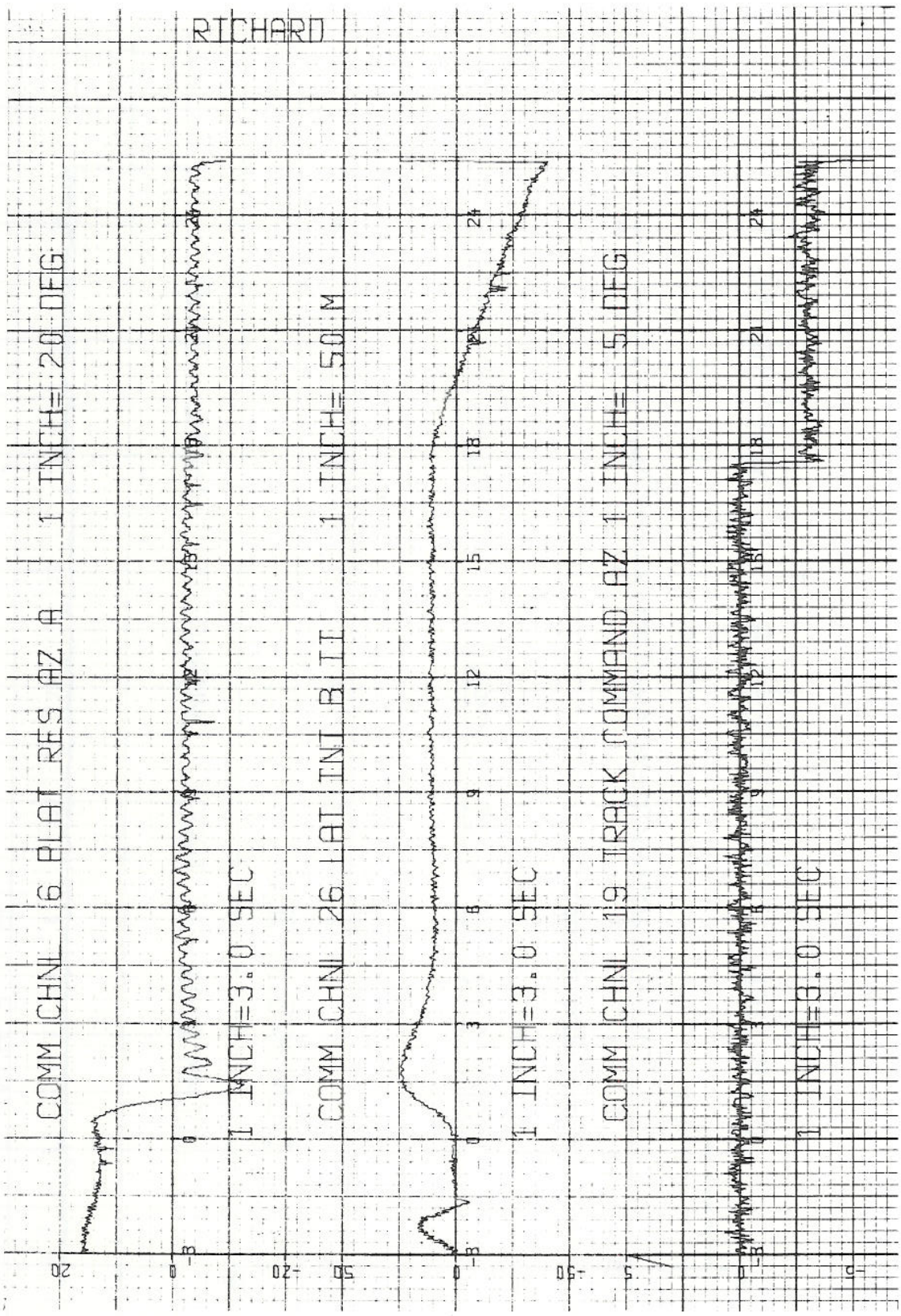
Motor pressures and altimeter ΔH on 13.5.3.

Seeker signals from 0.15 sec before to 0.15 sec after decision on 13.5.4.

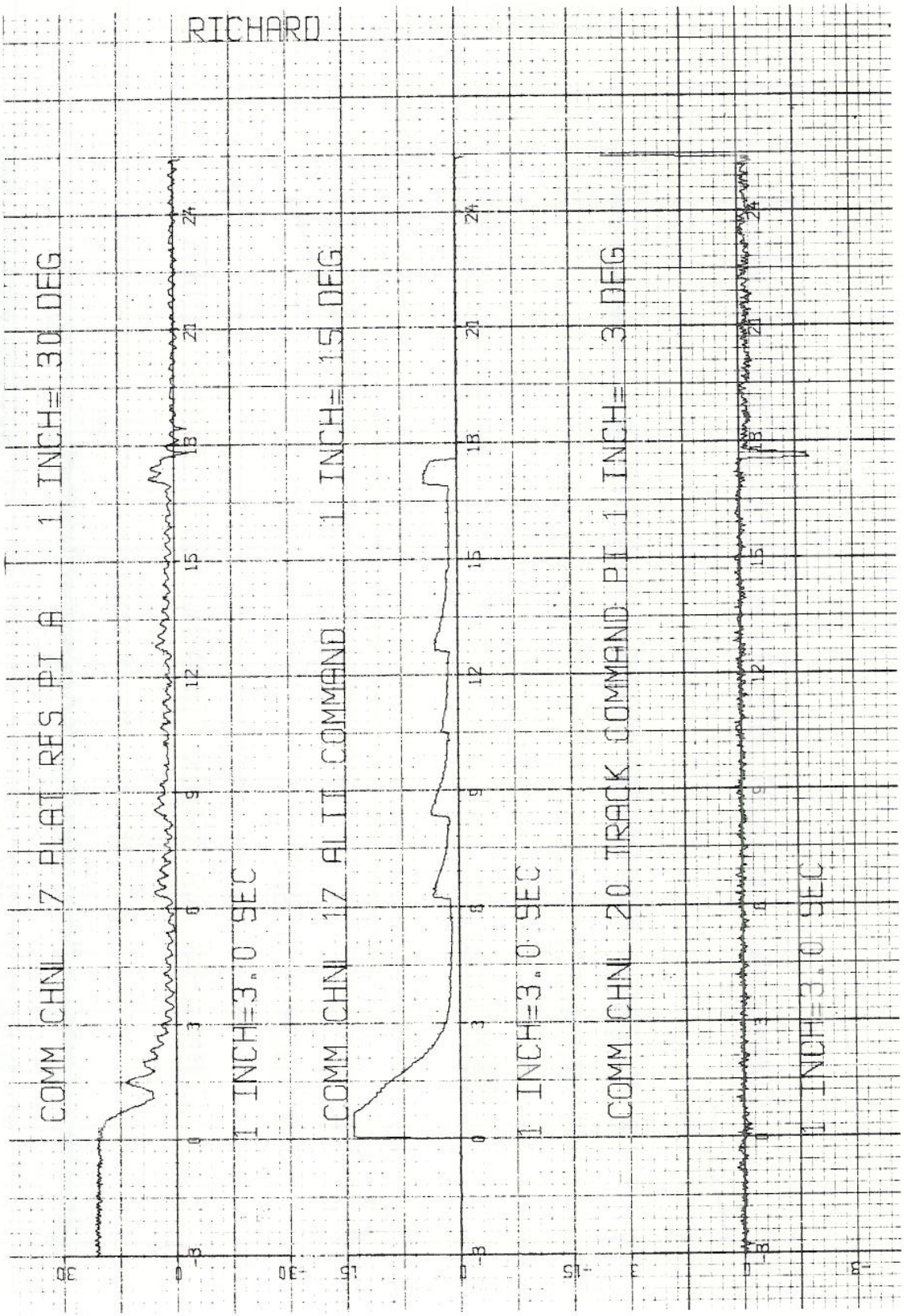
Vertical and horizontal projection of the missile trajectory on 13.5.5.

Time ref: T = 0 is take-off, except for 13.5.4 where T = 0 is decision.

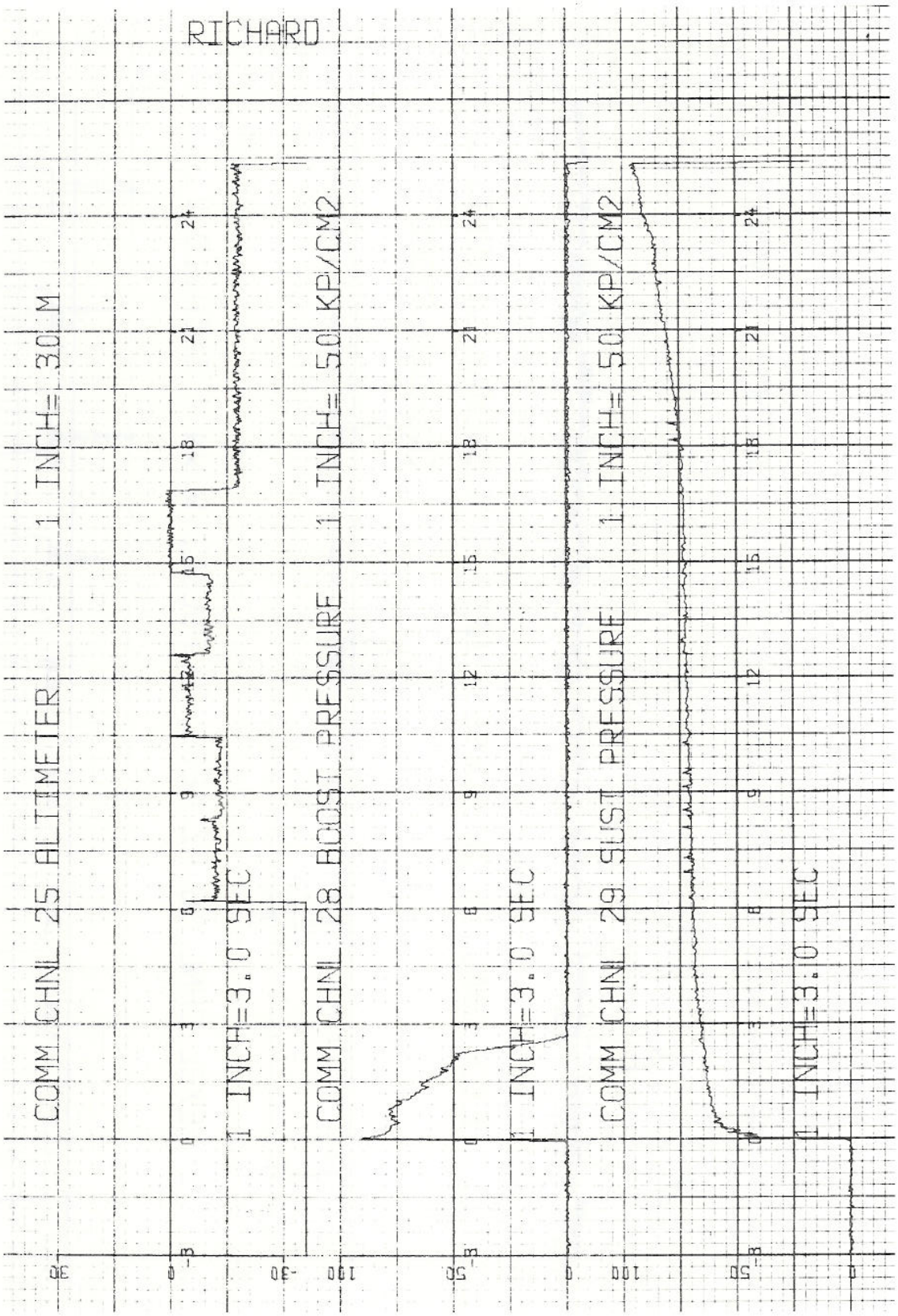
13.5.1 Lateral control signals



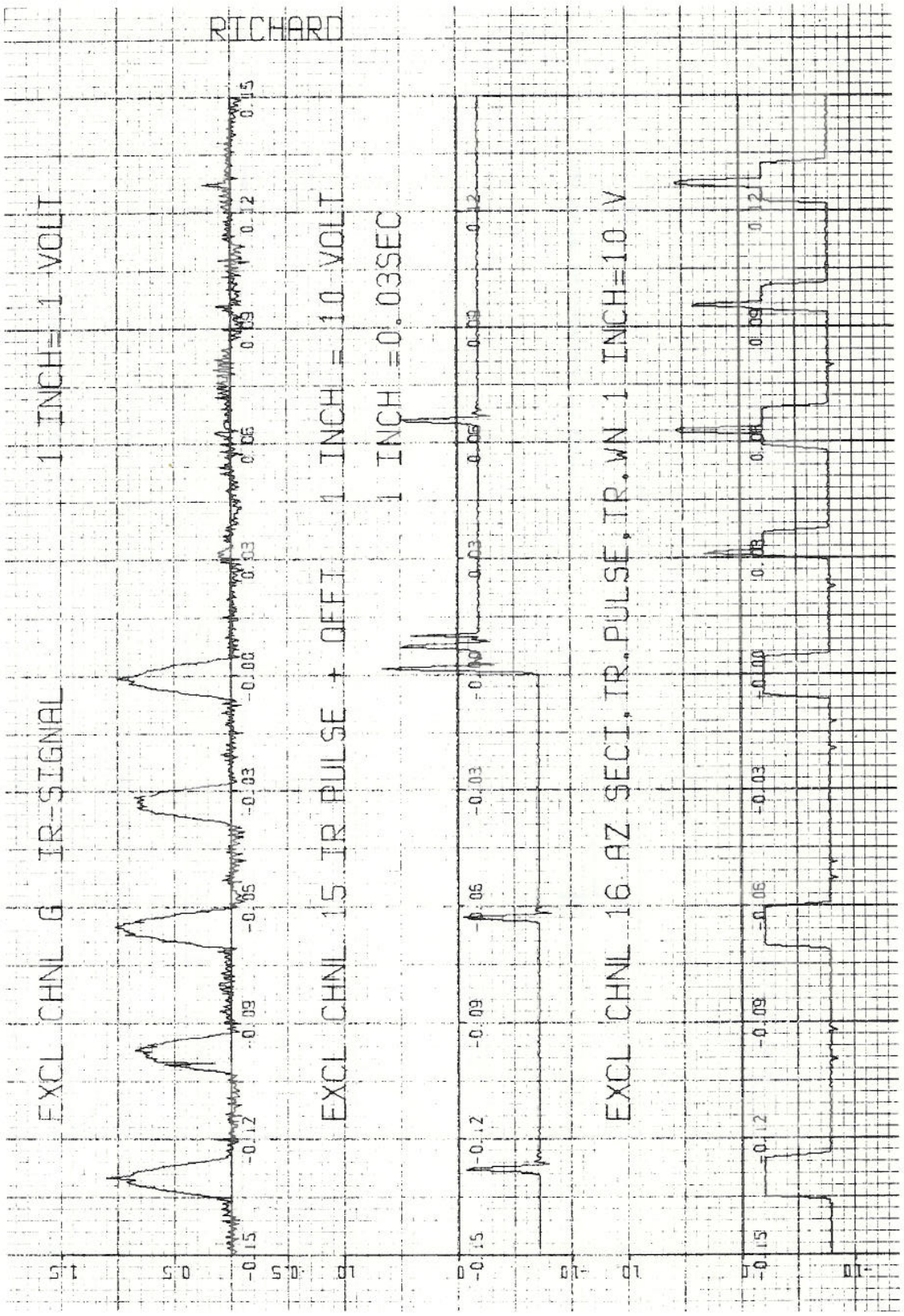
13.5.2 Altitude control signals



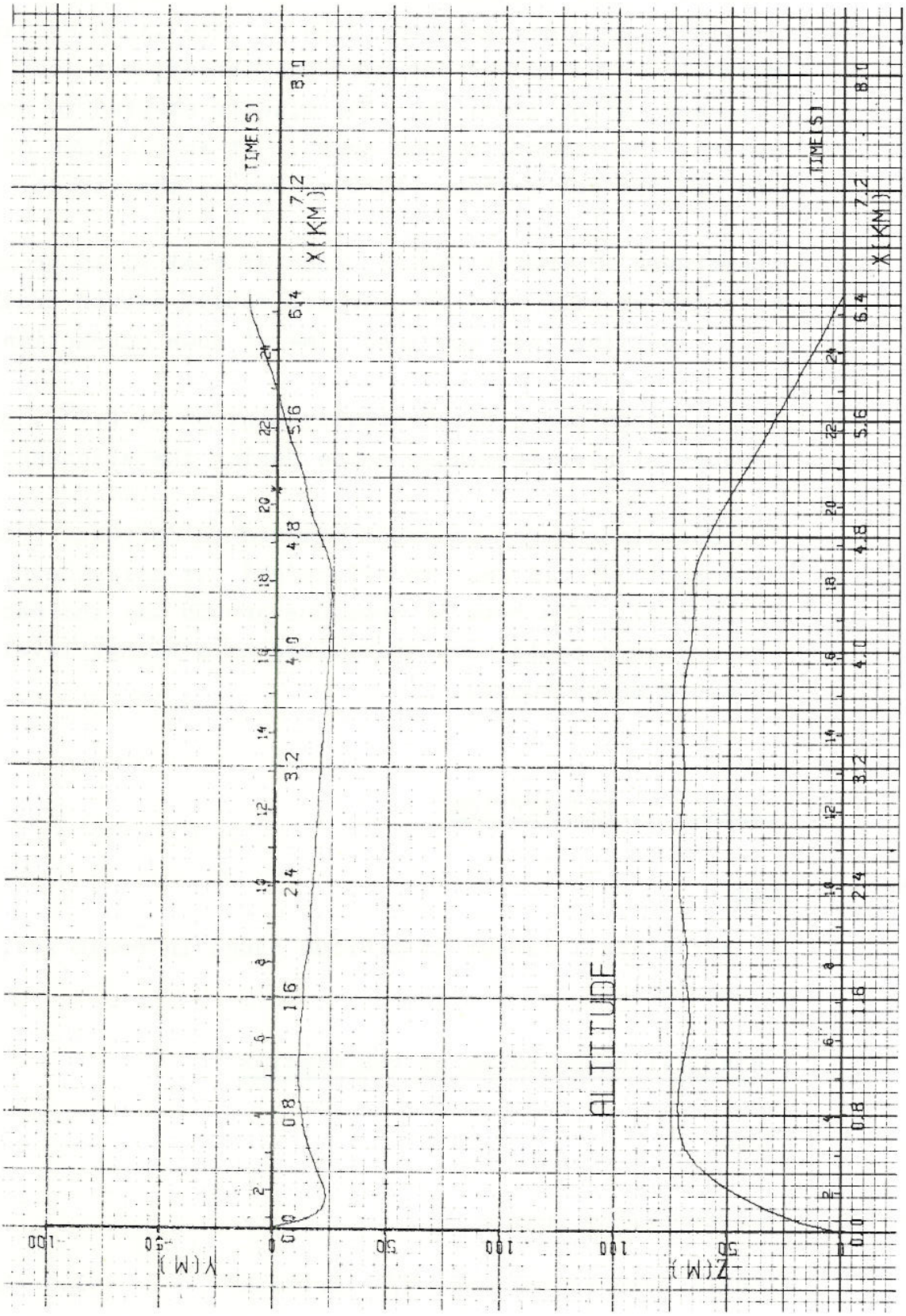
13.5.3 Motor pressures and altimeter ΔH



13.5.4 Seeker signals



13.5.5 Missile trajectory



13.6 Summary

Missile R was launched against ex KNM "Stavanger" 5/2-1970 at a distance of 5200 m. The launcher was opened manually. The seeker detected the target, but lost it 0.15 sec after decision. The missile started to home against the target, passed over it at an altitude of 45 m and hit the sea surface 1200 m behind the target.

There were 2 seeker faults, each of them would probably made the missile miss the target: faulty seeker track threshold setting and too long time of down correction barring.

The platform had a pitch misalignment of -0.7°, probably because of high frequency noise during the alignment period.

The sustainer motor pressure started to increase from 74 kp/cm^2 at 16 sec to 96 kp/cm^2 at splashdown (25.5 sec). The rate of pressure growth was increasing. The pressure could have stabilized on a higher level or cuased a motor burst.

14 MISSILE S, DESCRIPTION

14.1 Aim

To hit a small target at minimum range in rough sea.

14.2 Technical description of the missile

14.2.1 Motor

14.2.1.1 Booster motor charge

Double base propellant, VU (British)	41.2 kg
Inhibitors	1.85 kg

Start thrust	4700 kp
Final thrust	2500 kp
Burning time	2.41 sec
Total impulse	8670 kps

14.2.1.2 Sustainer motor charge

Double base propellant, X-35 (Norwegian)	44.9 kg
Inhibitors	1.88 kg
Thrust	120 kp
Burning time	74 sec
Total impulse	8940 kps

14.2.2 Warhead

Inert warhead.

14.2.3 Guidance section

E-02

Protection bag mounted at NDRE, removed onboard KNM "Traust".

14.2.3.1 Seeker

E-09 (Electronics E-08, Optical unit E-09). Seeker E-04 originally mounted at KV.

Modifications at NDRE:

- Telemetry electronics mounted
- Track threshold electronics modified.

14.2.3.2 Gas servo

E-08 (Electronics E-03, Gas generator E-02).

14.2.3.3 Altimeter

E-07 (Altimeter E-02 originally mounted at KV).

14.2.3.4 Platform

E-02.

14.2.3.5 AC-power supply

E-06.

14.2.3.6 Control unit

E-04.

14.2.3.7 Thermal batteries

31

38

36.

14.2.3.8 Control section

E-02.

14.2.3.9 Control parameters

Main control loop Az	$6.35^{o}/o$
Lateral compensation	$0.145^{o}/m$
Tracking command Az	$K_{\psi_{\varepsilon n}} = 2.34^{o}/o$ $K_{\psi_{s1}} = 0.56^{o}/o$
Main control loop Pi	$6.10^{o}/o$
Altitude command	$0.187^{o}/m$ $\alpha_H = 1.3^{o}$ $\alpha_t = 0.95^{o}$
Tracking command Pi	$K_{\theta_{\varepsilon n}} = 2.30^{o}/o$ $K_{\theta_{s1}} = 0.46^{o}/o$
Href	82 m

14.2.4 Telemetry

Telemetry channels as listed in 6.3.1, except for ex ch 13 and ex ch 14 which were not used.

14.2.5 Transponder

Transponder mounted.

14.3 Equipment onboard KNM "Traust"

14.3.1 Launching and control system

Traustin.

14.3.2 Launcher

Selco I

Aft starboard position

Elevation 19.97^{o}

Azimuth 14.63^{o}

14.3.3 Recording equipment

Recordings as listed in 12.3.3.

14.4 Target

M/K "Carl Erik", a 50 feet fishing boat with 2 artificial IR-targets (propan stoves).

14.5 Photography

Camera onboard escort boat 1.

14.6 Missile test at NDRE and KV

14.6.1 Acceptance test

28/1 - 1970 OK.

14.6.2 Subsystem test

14.6.2.1 Seeker

- Cooling hose exchanged
- 4 Helicoils on the mounting cylinder exchanged
- Mounting cylinder gas tightened
- Az sector I and II exchanged on the seek threshold electronics input.

14.6.2.2 Altimeter

OK.

14.6.3 Guidance/warhead section test

14.6.3.1 Test at NDRE

OK.

14.6.3.2 Vibration test at KV

3 - 4/3 - 1970

4 runs lateral

4 runs axial

20 - 2000 - 20 Hz

1 octave/min

1.5 g peak

No missile errors induced or detected except that the seeker telemetry plug was not sufficiently fastened.

14.7 Complete weapon system test at Haakonsvern and Tananger

The missiles S and T was mounted onboard 7/3.

Seeker E-05 was not properly cooled (10/3), and was exchanged with seeker E-09 (taken from missile T). The reason of the cooling problem appeared to be gas leakage in the N_2 container in the launcher, but seeker E-05 was not remounted.

Arrival Tananger at midnight 10/3.

Launching and control system NDRE NOR2 was to be used for launching of missile S and T if it was operative in time. It was first tested separately onboard, and was then connected to missile S 10/3 - 12/3. The computer program was some-

times destroyed by internal computer errors, and it was decided to use launching and control system Traustin on this expedition.

Altimeter breakdown (13/3) because of an underdimensioned resistor in the high voltage converter (the design was changed on the succeeding altimeters). Altimeter E-02 was exchanged with altimeter E-07 (taken from missile T).

14.8 Launching attempts

13/3. Missile S was planned to be launched against ex KNM "Stavanger" at 15 km. A test run showed that HSA gave correct data only up to 13.5 km , and the range was reduced to 13 km. Launching cancelled because of insufficient visibility for the cinetheodolites.

14/3 - 17/3. Extremely bad weather prevented launching.

18/3. Because of rough sea, it was decided to launch missile T against MK "Carl-Erik" at min. range instead of missile S against ex-KNM "Stavanger" at long range. A launching attempt was done, but the launcher upper front cover was not opened, see 16.8. When KNM "Traust" returned to Tananger, it was decided to launch missile S against MK "Carl-Erik" the same day.

14.9 Launching

Date	18/3 - 1970 1428
Distance to target	2900 m
Direction to target	286.4°

Weather:	Sight	20 km
	Cloud cover	7/8
	Wind	6 m/s from SE
	Temperature	1 - 2°C
	Sea state	5

15 MISSILE S, VALUATION

15.1 Data systems

15.1.1 Telemetry

Good data.

15.1.2 Transponder

Bad data. It was impossible to calculate the missile trajectory from the transponder data.

15.1.3 Cinetheodolites

T1: Good data

T2: No data

T3: Bad data, only 28 out of 62 photos

T4: Bad data, no altitude informations.

Because of the bad quality of the data, the calculated missile trajectory is less accurate than usual.

15.1.4 Photography

Escort boat 1 camera: The whole missile trajectory.
The target went down, this was filmed.

15.1.5 Recording equipment onboard KNM "Traust"

Good data.

15.2 Equipment onboard KNM "Traust"

15.2.1 Launching and control system

OK. The mid-course phase was too short (decision at 7 sec) to calculate the fire control accuracy.

15.2.2 Launcher

OK.

15.3 Missile flight

See 15.5.5.

15.3.1 Boost phase

Normal. Missile velocity at the end of the boost phase 265 m/s.

15.3.2 Mid-course phase

The mid-course phase was very short because the missile was launched at min. range.

The altitude was correct during the mid-course phase.

The lateral guidance was OK, if the missile had not homed against the target, it would have passed 30 m to the right of the target.

The missile rolled clockwise 0.44 Hz.

15.3.3 Terminal phase

Normal. Decision distance was 1350 m and altitude 82 m. After a terminal phase of 5.2 sec, the missile hit the target.

15.4 Missile subsystems

15.4.1 Motor

See 15.5.3.

15.4.1.1 Booster motor

Burning time	2.35 sec
Velocity at burn out	265 m/s
Pressure	Normal, max 85 kp/cm^2
Acceleration (start)	133 m/s^2

15.4.1.2 Sustainer motor

Because of a bad connection in the sustainer motor pressure transducer, there are reliable data only during 0 - 3 sec, but everything looks normally. The velocity during the mid-course flight is normal, approximately 260 m/s.

15.4.2 Platform

OK.

15.4.3 Altimeter

See 15.5.2 and 15.5.3.

Because the seeker took decision after 7 sec, the altimeter made only 1 altitude sample. This showed H = Href and was probably a no return measurement. It was sea state 5, and the no answer probability is increased by rough sea.

15.4.4 Seeker

The target was detected at a range of 1350 m, the IR-signal from the artificial IR-targets was weak. The seeker was OK during the whole terminal phase.

15.4.5 Control loops

15.4.5.1 Azimuth control loops

See 15.5.1.

Mid-course guidance:

V_{yeo}	- 1.5 m/s
ψ_{MP} (7 sec)	- 1.0°
Lateral int 2 (7 sec)	9 m
Oscillation	6° pp, 3 Hz
Spiral	1° pp
Lateral wind	4 m/s
Average missile velocity	260 m/s

The great oscillation amplitude is due to gas servo friction, probably in both gas servos. ψ_{MP} is according to V_{yeo}, lateral wind and missile velocity.

Terminal guidance:

Normal, ψ_{MP} was according to tracking com Az.

15.4.5.2 Pitch control loops

See 15.5.2.

Mid-course guidance:

Average θ_{MP}	1.3^{o}
Oscillation	5^{o} pp 3.2 Hz
Spiral	1^{o} pp

The great oscillation amplitude is due to gas servo friction as for the Az control loop. Average θ_{MP} is normal. θ_{MP} according to altitude command.

Terminal guidance:

Normal, θ_{MP} is according to tracking com Pi.

15.4.6 Gas servo

Greater friction than usual.

15.4.7 AC-power supply

OK.

15.4.8 Thermal batteries

OK.

Positive batteries: 30.5 V , constant during the flight

Negative battery: - 30.5 V - " - " -

15.5 Telemetry and missile trajectory recordings

Lateral control signals on 15.5.1.

Altitude control signals on 15.5.2.

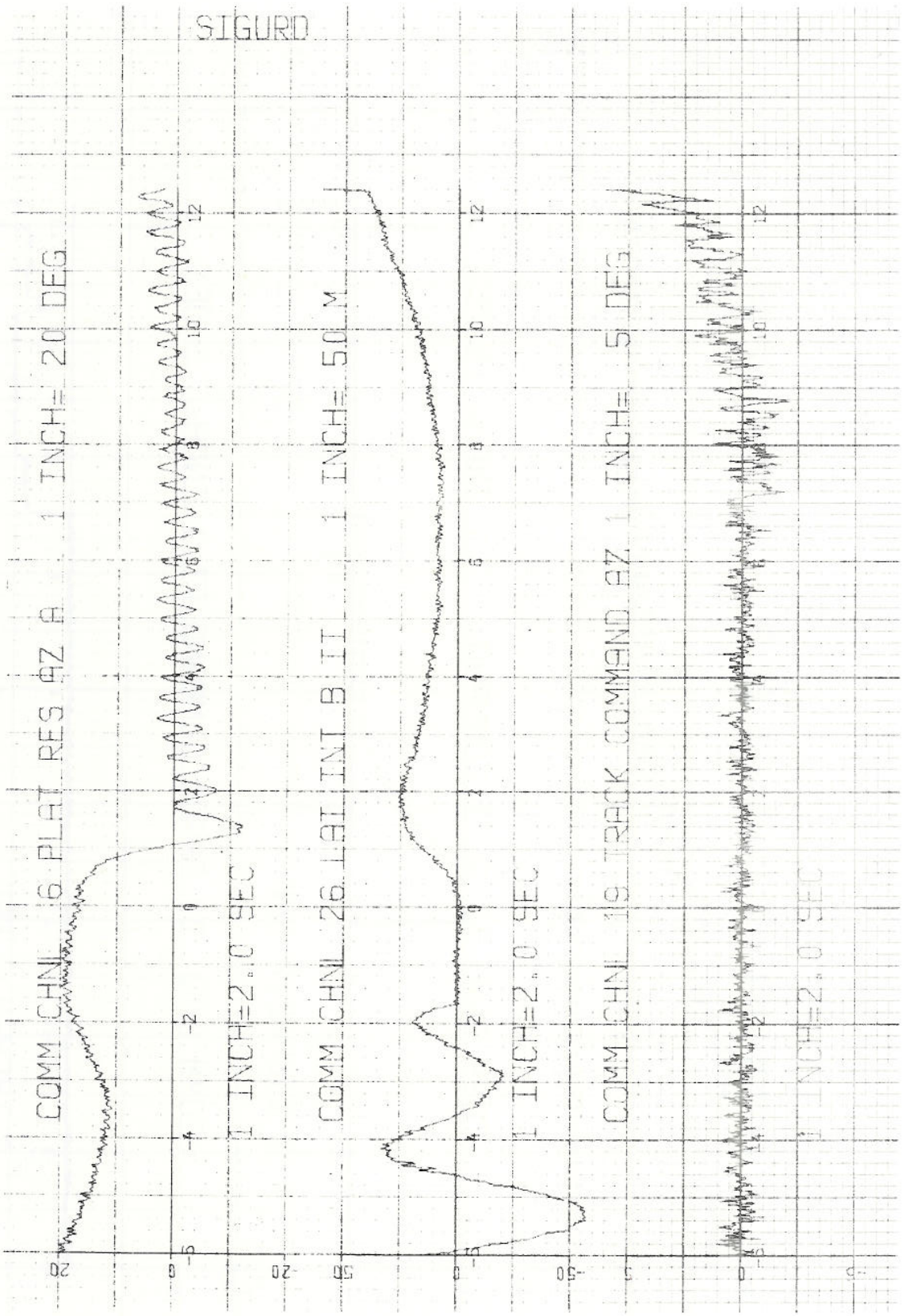
Motor pressures and altimeter ΔH on 15.5.3.

Seeker signals from 0.15 sec before to 0.15 sec after decision on 15.5.4. Ex ch G had bad quality.

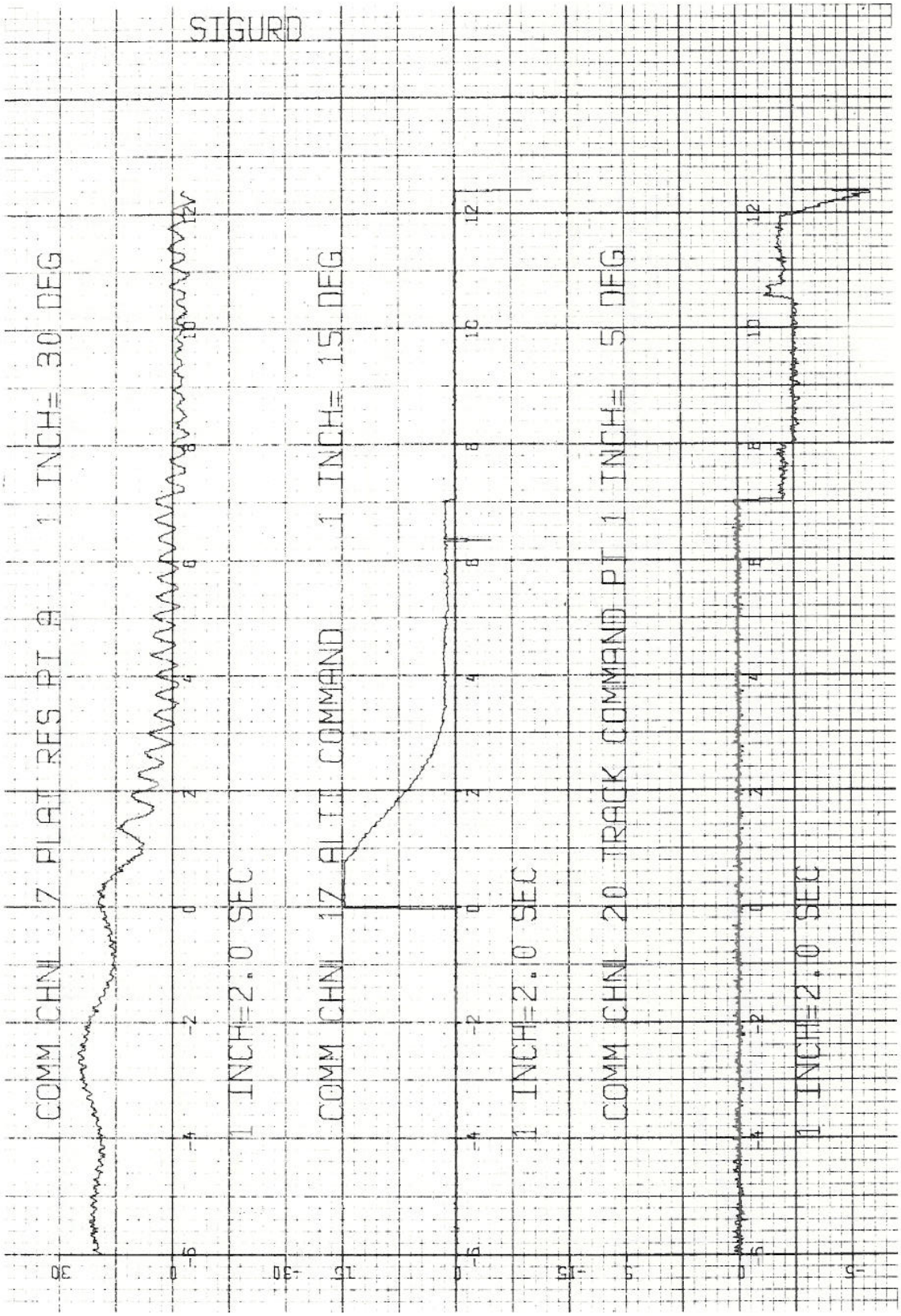
Vertical and horizontal projection of the missile trajectory on 15.5.5. The calculated trajectory is some unaccurate because of bad cinetheodolite data.

Time ref: T = 0 is take-off, except for 15.5.4 where T = 0 is decision.

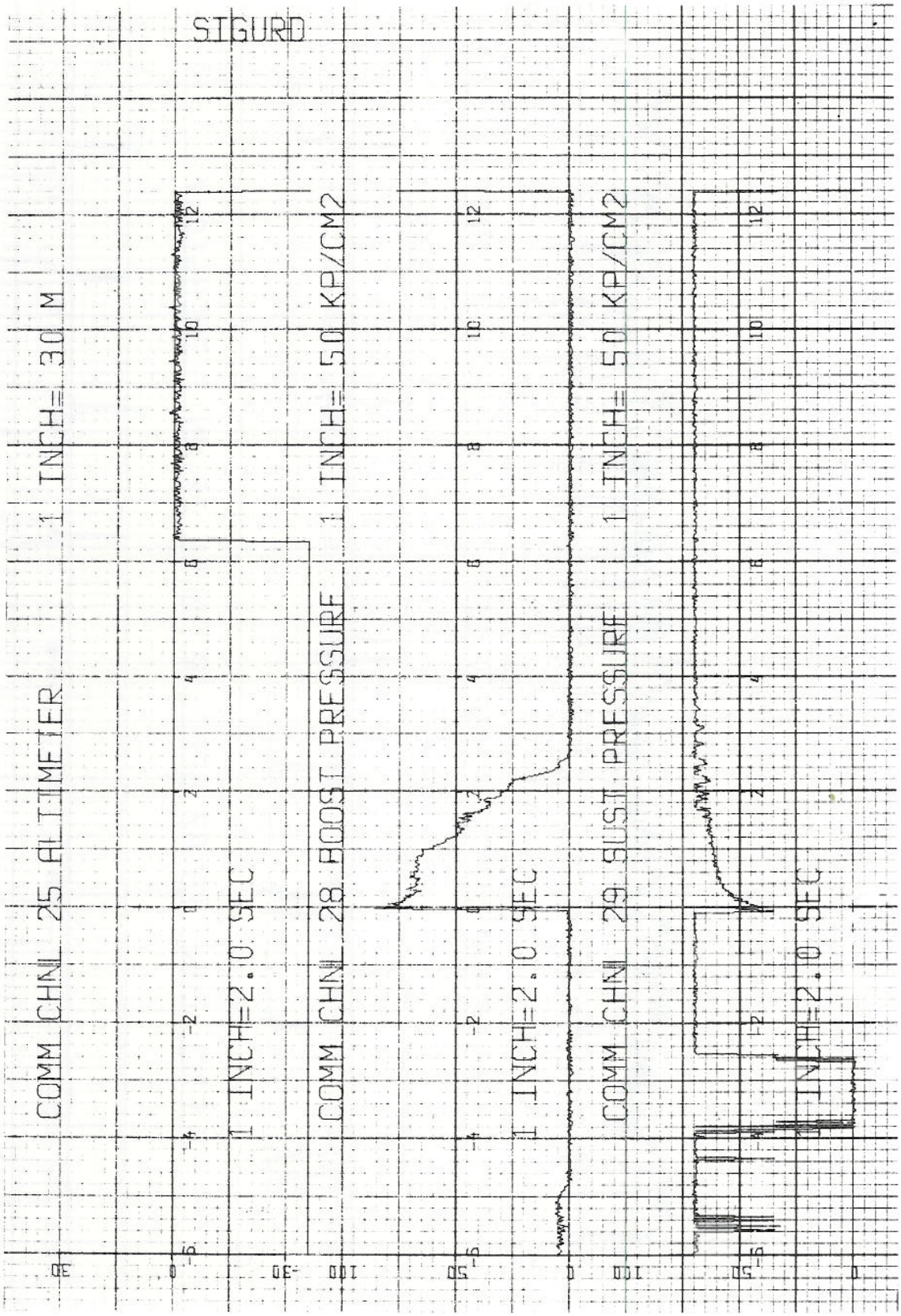
15.5.1 Lateral control signals



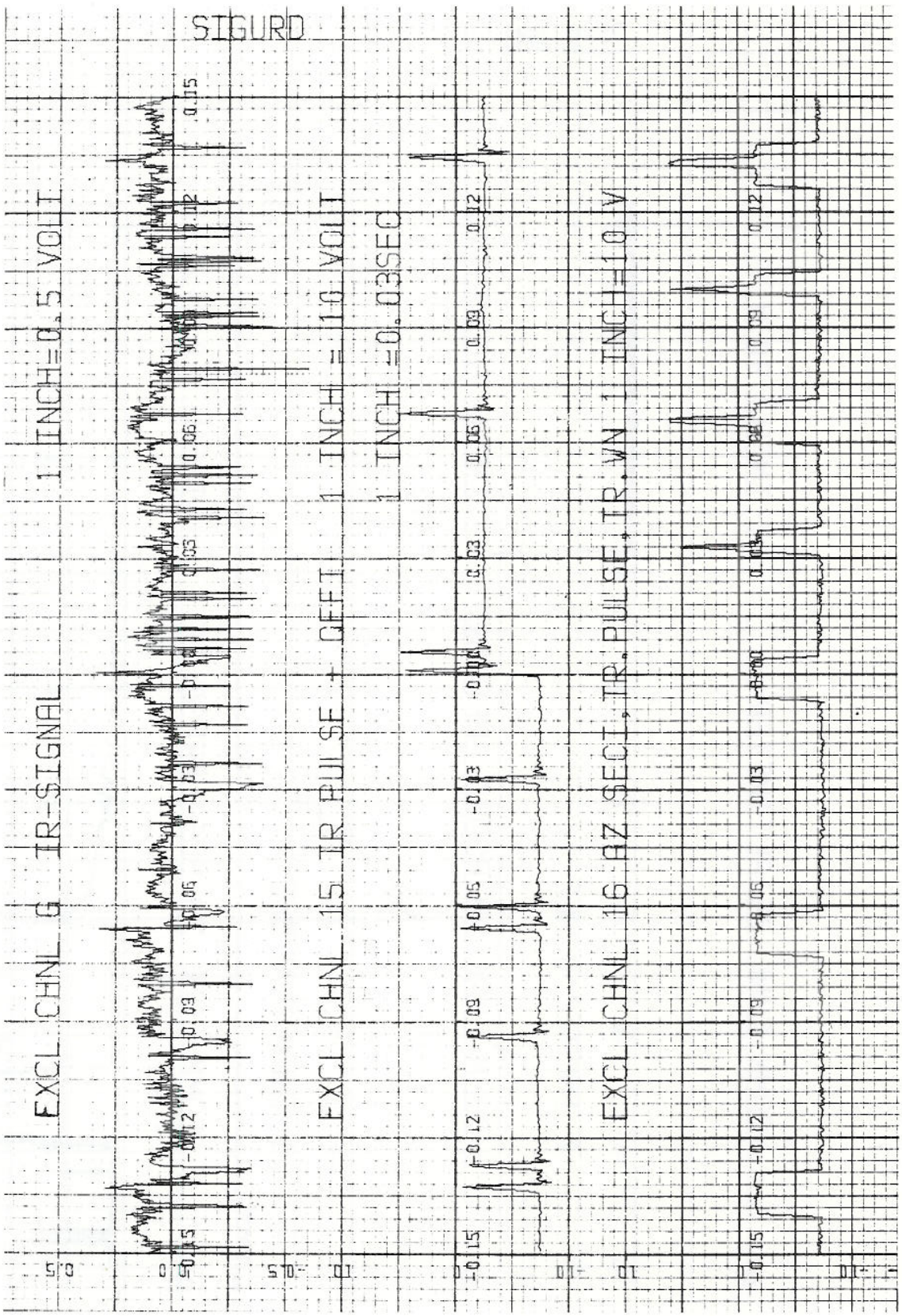
15.5.2 Altitude control signals



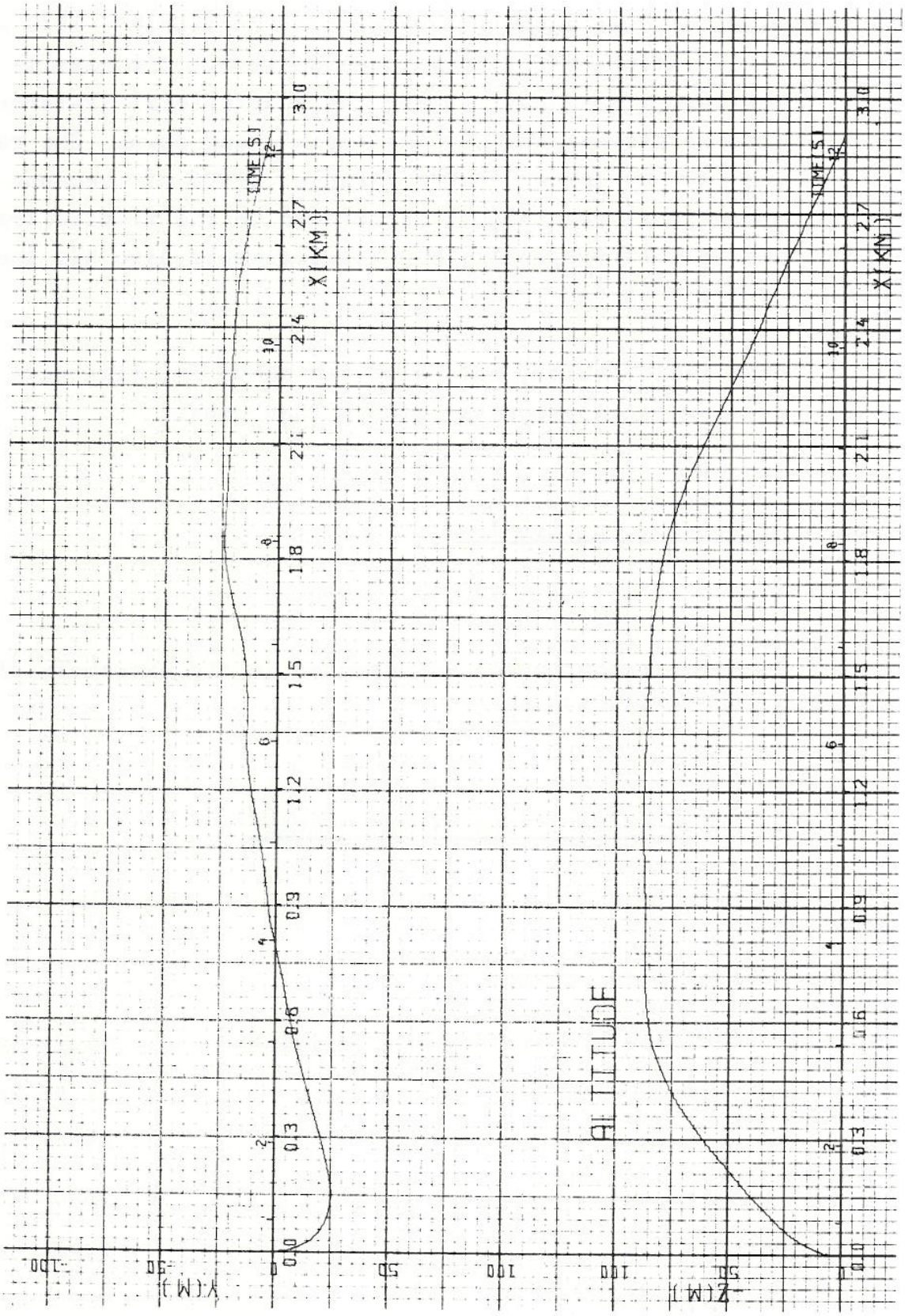
15.5.3 Motor pressures and altimeter ΔH



15.5.4 Seeker signals



15.5.5 Missile trajectory



15.6 Summary

Missile S was launched against MK "Carl-Erik" 18/3 - 1970 at a distance of 2900 m , sea state 5. The missile hit the target half way between the 2 artificial IR-targets (propan stoves), and MK "Carl-Erik" went down. The range was 400 m longer than min range (2500 m) because of operational reasons, but according to the missile trajectory and telemetry signals, the missile would have hit the target even if the range was 2000 m.

No missile faults, but high gas servo friction gave greater oscillation amplitudes than usual.

16 MISSILE T, DESCRIPTION

16.1 Aim

To hit a target which is detected in the extremety of the seeker scanning area.

16.2 Technical description of the missile

16.2.1 Motor

16.2.1.1 Booster motor charge

Double base propellant, VU (British)	41.2 kg
Inhibitors	1.85 kg
Start thrust	4700 kp
Final thrust	2500 kp
Burning time	2.41 sec
Total impulse	8670 kps

16.2.1.2 Sustainer motor charge

Double base propellant, X-35 (Norwegian)	44.9	kg
Inhibitors	1.88	kg
Thrust	120	kp
Burning time	74	sec
Total impulse	8940	kps

16.2.2 Warhead

Inert warhead.

16.2.3 Guidance section

E-06.

Protection bag mounted at NDRE, removed onboard KNM "Traust".

16.2.3.1 Seeker

E-07 (Electronics E-07, Optical unit E-07). Seeker E-03 originally mounted at KV.

Modifications at NDRE:

- Telemetry electronics mounted
- Track threshold electronics modified
- Artificial IR-target modified.

16.2.3.2 Gas servo

E-06 (Electronics E-06, Gas generator E-07).

16.2.3.3 Altimeter

E-09 (Altimeter E-06 originally mounted at KV).

Laser effect 39 W.

16.2.3.4 Platform

E-07 (Platform E-06 originally mounted at KV).

16.2.3.5 AC-power supply

E-09.

16.2.3.6 Control unit

E-10.

16.2.3.7 Thermal batteries

87

91

96.

16.2.3.8 Control section

E-06.

Modifications at NDRE:

- 2 vibration accelerometers with telemetry amplifiers mounted.

16.2.3.9 Control parameters

Main control loop Az	$6.36^{o}/o$
Lateral compensation	$0.149^{o}/m$
Tracking com Az	$K_{\psi_{\varepsilon n}} = 2.45^{o}/o$ $K\psi_{s_1} = 0.59^{o}/o$
Main control loop Pi	$6.08^{o}/o$
Altitude command	$0.186^{o}/m$ $\alpha_H = 1.3^{o}$ $\alpha_t = 0.95^{o}$
Tracking com Pi	$K_{\theta_{\varepsilon n}} = 2.30^{o}/o$ $K\theta_{s_1} = 0.46^{o}/o$
Href	82 m

16.2.4 Telemetry

Telemetry channels as listed in 6.3.1.

16.3 Equipment onboard KNM "Traust"

16.3.1 Launching and control system

Traustin.

16.3.2 Launcher

Selco I

Aft starboard position

Elevation 19.97^{o}

Azimuth 14.63^{o}

16.4 Target

ex-KNM "Reinøysund", a landing craft.

16.4 Photography

Camera on escort boat 1.

Camera in the command tower.

16.6 Missile test at NDRE and KV

16.6.1 Acceptance test

11 - 12/2 -1970 OK.

16.6.2 Subsystem test

16.6.2.1 Seeker

- Module 1705 exchanged
- Module 1701 destroyed by a testing failure, repaired
- Complete seeker electronics exchanged
- Slip-ring defect, seeker E-03 exchanged with E-08.

16.6.2.2 Altimeter

OK.

16.6.3 Guidance/warhead section test I

16.6.3.1 Test at NDRE

Altimeter E-06 destroyed (- 10.24 V supply module 1802) because of a teststand fault. Altimeter E-06 exchanged with altimeter E-09.

Altimeter E-09 exchanged with altimeter E-07 (2 avalanche transistors in the transmitter defect).

Seeker breakdown because of the slip-ring. Optical unit E-08 exchanged with E-09. The seeker of missile T was now E-09 (Electronics E-08, Optical unit E-09).

16.6.3.2 Vibration test at KV

5/3 - 1970.

3 runs lateral

4 runs axial

20 - 2000 - 20 Hz

1 octave/min

1.5 g peak

Platform axial accelerometer defect (not operative for $t > 50^{\circ}C$).

Platform E-06 exchanged with E-04.

Platform pitch gyro defect (the gyro could not be torqued).

Platform E-04 exchanged with E-07.

16.7 Complete weapon system test at Haakonsvern and Tananger I

Launcher with missile mounted onboard 7/3.

Platform E-07 tumbeled 9/3. (Roll power amplifier defect).
Platform E-07 exchanged with E-09 (10/3).

Arrival Tananger midnight 10/3.

Seeker E-09 exchanged with E-05 (13/3) because of an imaginary cooling problem , see 14.7.

Altimeter E-07 mounted in missile S 13/3 , see 14.7.

Altimeter E-09 mounted (14/3).

16.8 Launching attempts I

18/3. Launcher upper front cover was not opened because of a leakage in the explosive actuator, and the firing sequence stopped. Launching of missile T cancelled, return to Tananger. It was decided to launch missile S the same day, see 14.8.

20/3. During count down (appr X - 90 min) one of the flares was set off. This was because the flare firing circuit was unsufficiently secured. The launcher and the missile were covered with CO_2. The expedition was cancelled.

16.9 Guidance/warhead section test II

16.9.1 Test at NDRE

The missile was taken to NDRE and demounted. Each sub-system was cleaned and tested separetely. The seeker IR-dome, the canard-fins and the wings were exchanged. Some abundant glue, which prevented the platform roll gimbal movement in a particular position, was removed from the platform cover. No faults were found.

The re-assembled missile T was tested. OK.

16.9.2 Vibration test at KV

8 - 9/4 - 1970.

4 runs lateral
8 runs axial

20 - 2000 - 20 Hz

1 octave/min

1 g peak

Platform Ro power amplifier defect. Platform E-09 exchanged with E-07.

16.10 Complete weapon system test at Haakonsvern and Tananger II

Missile T mounted onboard 17/4.

Launching and control system NDRE NOR 2 was to be used for launching of the missiles T, U and V on this expedition if it was operative in time. Because of hardware failures in both the NOR2 computer and the interface electronics, it was decided to use launching and control system Traustin on this expedition.

Arrival Tananger 22/4.

Seeker cooling hose exchanged in the afternoon 24/4. (Wrong type of cooling hose mounted at NDRE, too soft PVC).

Seeker breakdown in the morning 25/4 (Slip-ring defect). Seeker E-05 exchanged with E-07 (Taken from missile U).

Seeker E-05 slip-ring exchanged onboard by a KV engineer. Still seeker breakdown. Seeker E-05 was sent to KV in the night 25/4.

16.11 Launching attempts II

Launching planned 24/4 1300. Cancelled 24/4 1100 because of bad weather.

16.12 Launching

Date		25/4 - 1970 1352
Distance to target		5400 m
Direction to target		274.7°
Weather:	Sight	20 km
	Cloud cover	0/8
	Wind	8 m/s from S
	Temperature	5°C
	Sea state	2 - 3

The missile was to detect the target in the extremety of the seeker scanning area. This was done by an artificially generating of V_{yeo} (V_{yeo} = - 22 m/s).

17 MISSILE T, VALUATION

17.1 Data systems

17.1.1 Telemetry

Good data.

17.1.2 Cinetheodolites

T1: No data during 16.2-18 sec and 21.8 sec - else good data

T2: No data during 18.6 sec - else good data

T3: No data

T4: Good data

The resulting data are good 0 - 16 sec , not satisfactory 16 - 21.6 and bad for the rest of the trajectory (21.6 - 22.8 sec).

17.1.3 Photography

Escort boat 1 camera: The whole missile trajectory

Command tower camera: - " - " -

17.2 Equipment onboard KNM "Traust"

17.2.1 Launching and control system

OK. Total fire control accuracy can not be calculated because of the artifically generated V_{yeo} (V_{yeo} = - 22 m/s).

17.2.2 Launcher

OK.

17.3 Missile flight

See 17.5.5.

17.3.1 Boost phase

Normal. Missile velocity at the end of the boost phase was 256 m/s.

17.3.2 Mid-course phase

The platform Az was aligned against the target, but V_{yeo} (relative target velocity across target bearing) was artificially set to - 22 m/s. Because of this the missile trajectory was 5^{o} south of the line of sight.

The altitude when the first altitude sample was made, was only 64 m. The altimeter makes the missile climb, and the altitude is stabilized on 75 - 72 m after 2 altitude corrections. The missile rolled clockwise 0.51 Hz.

17.3.3 Terminal phase

Decision distance 1150 m and altitude at decision point 73 m. The target was detected 2^{o} from the right bound of the seeker scanning sector. The missile homed against and hit the target. The terminal phase lasted 5.2 sec, and the missile Az angle was approximately constant during the last 3 sec. Because of the great lateral manoever, the missile trajectory is steeper than usual the last 2.5 sec of the terminal phase.

17.4 Missile subsystem

17.4.1 Motor

See 17.5.3.

17.4.1.1 Booster motor

Burning time	2.55 sec
Velocity at burn out	256 m/s
Pressure	Normal, 80 kp/cm^2 max
Acceleration (start)	130 m/s^2

17.4.1.2 Sustainer motor

Sustainer motor pressure was approximately 70 kp/cm^2 from 4 sec to the missile hit the target. 70 kp/cm^2 gives a thrust of 97 kp (nom 120). The velocity during the mid-course phase was constant 252 m/s (nom 270 m/s). Because of the low sustainer motor pressure, the missile is not accelerated to nom velocity.

17.4.2 Platform

OK.

17.4.3 Altimeter

See 17.5.2 and 17.5.3.

6 altitude samples, 1 of these was a no return measurement. The 5 other measurements differ 2 - 4 m from the altitude calculated from the cinetheodolite data. Altitude command according to the altitude measurements.

17.4.4 Seeker

The target was detected at a range of 1150 m, 2^{o} from the right bound of the scanning sector. The seeker was OK during the whole terminal phase and the tracking command signals were according to the missile trajectory, ψ_{MP} and θ_{MP}.

17.4.5 Control loops

17.4.5.1 Azimuth control loops

See 17.5.1.

Mid-course guidance

V_{yeo} (Artificially generated)	- 22 m/s
Average ψ_{MP}	$- 6.8^{o}$
Lateral int 2	45 m
Oscillation	1.5^{o} pp 2.8 Hz
Lateral wind	8 m/s
Average missile velocity	252 m/s

Normal oscillation. ψ_{MP} is according to V_{yeo}, lateral wind and missile velocity.

17.4.5.2 Terminal guidance

Normal. ψ_{MP} according to tracking com Az.

17.4.5.2 Pitch control loops

See 17.5.2.

Mid-course guidance

Average θ_{MP} (11 - 17 sec)	1.25^{o}
Oscillation	2^{o} pp 2.8 Hz

Normal oscillation. Average θ_{MP} during the constant altitude periode was normal. θ_{MP} according to altitude command.

Terminal guidance

Normal, θ_{MP} according to tracking com Pi.

17.4.6 Gas servo

OK.

17.4.7 AC-power supply

OK.

17.4.8 Thermal batteries

OK.

Positive batteries: 30.3 V , constant during the flight

Negative battery : - 30.7 V - " -

17.5 Telemetry and missile trajectory recordings

Lateral control signals on 17.5.1.

Altitude control signals on 17.5.2.

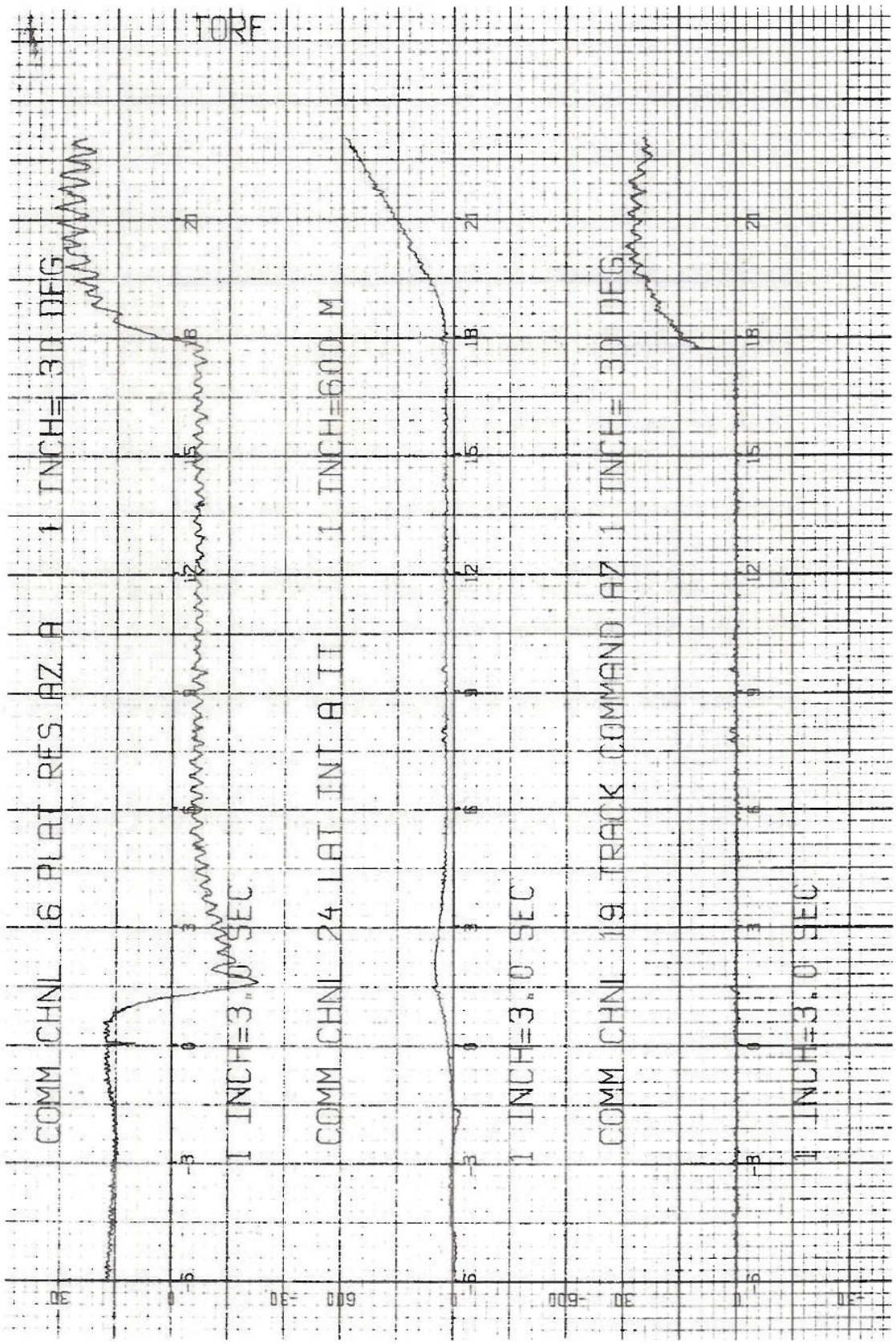
Motor pressures and altimeter ΔH on 17.5.3.

Seeker signals from 0.15 sec before to 0.15 sec after decision on 17.5.4.

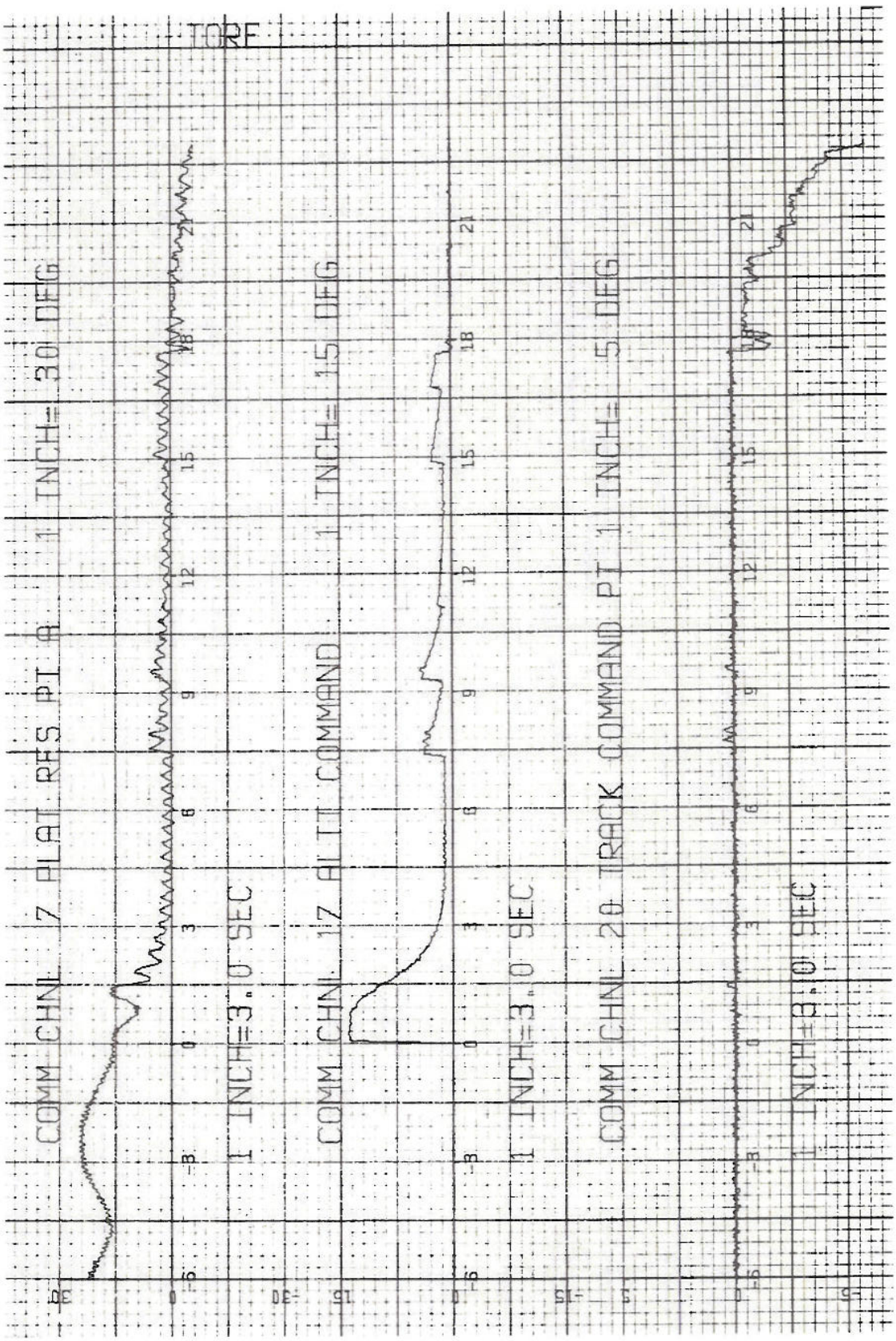
Vertical and horizontal projection of the missile trajectory on 17.5.5.

Time ref: T = 0 is take-off, except for 17.5.4 where T = is decision.

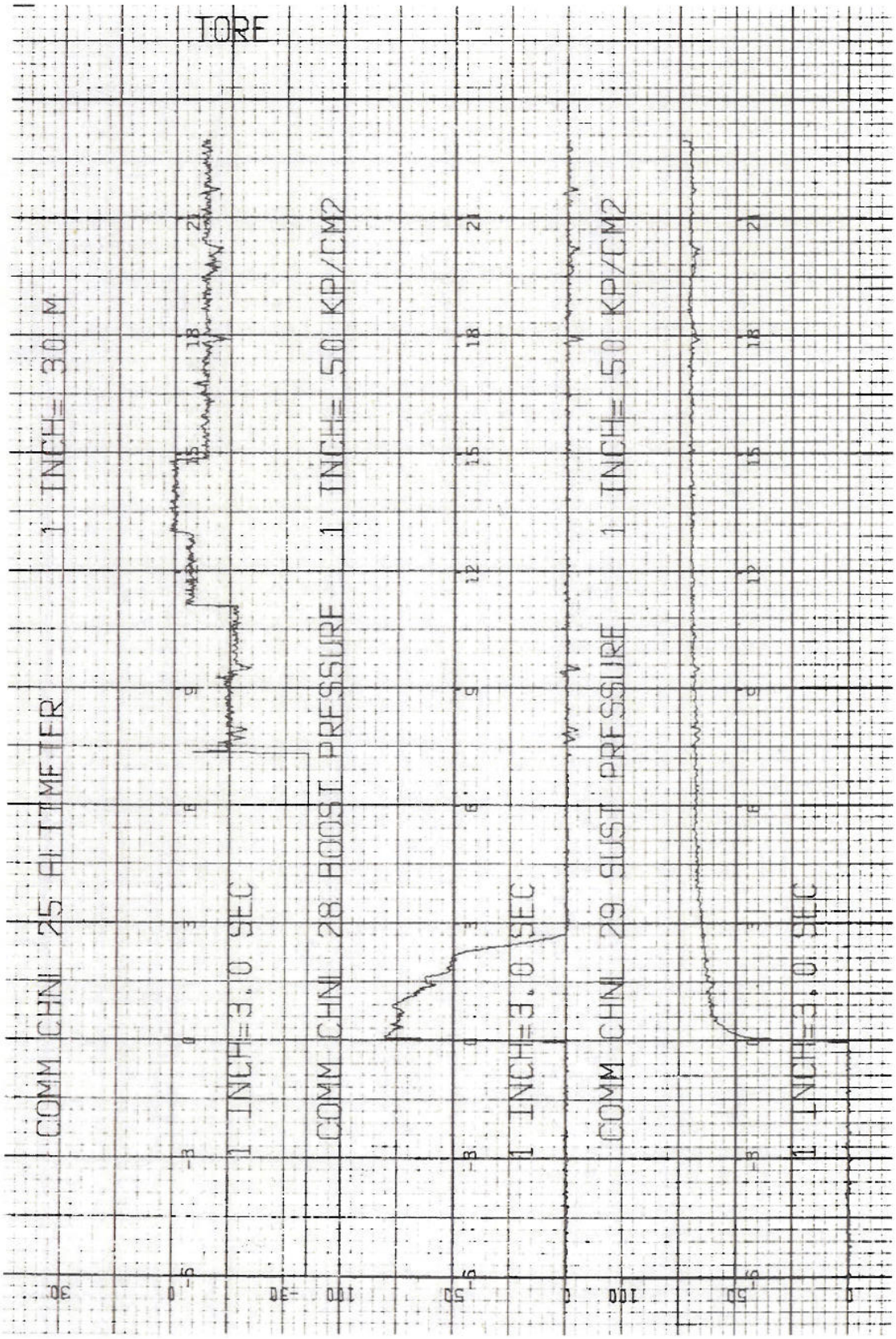
17.5.1 Lateral control signals



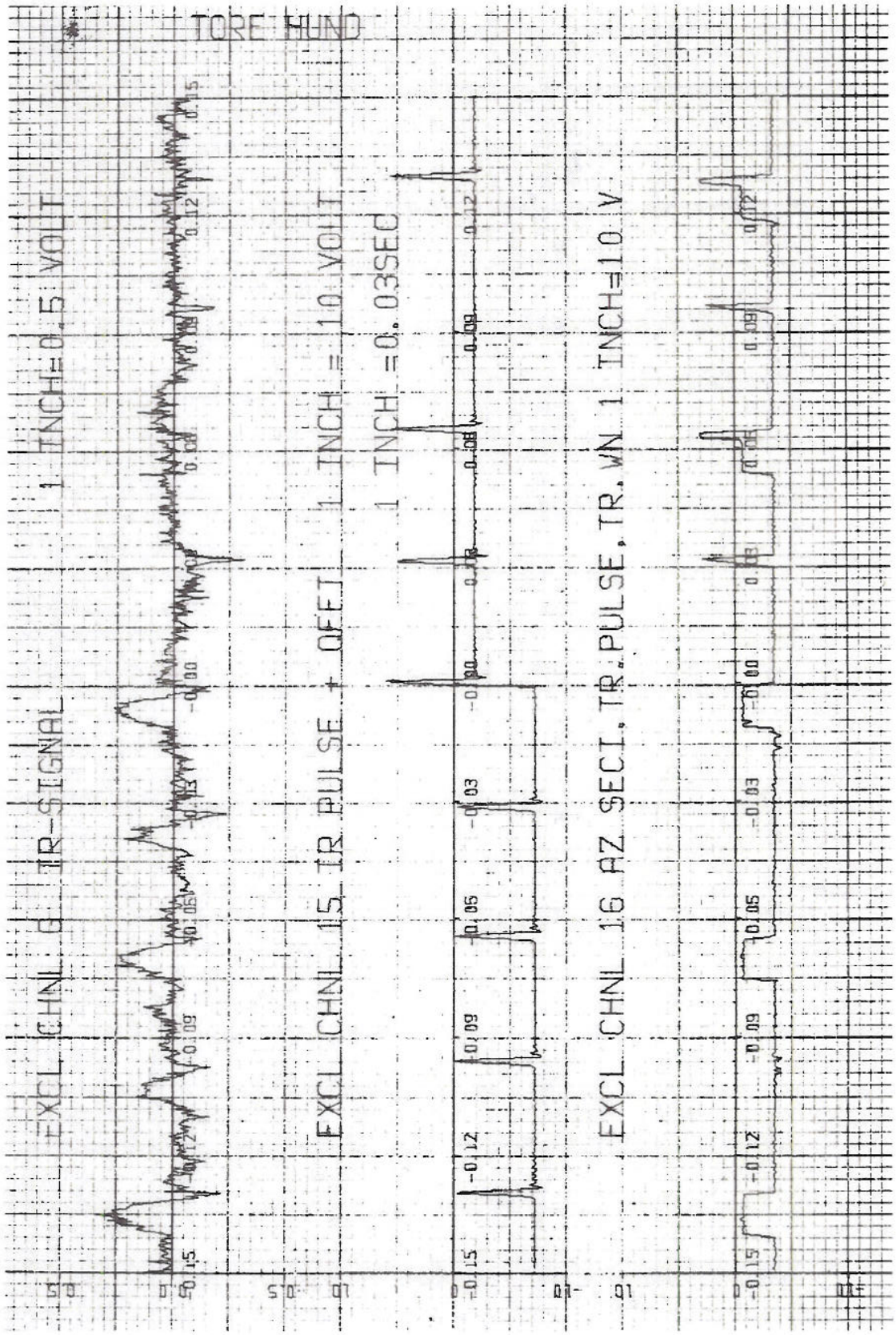
17.5.2 Altitude control signals



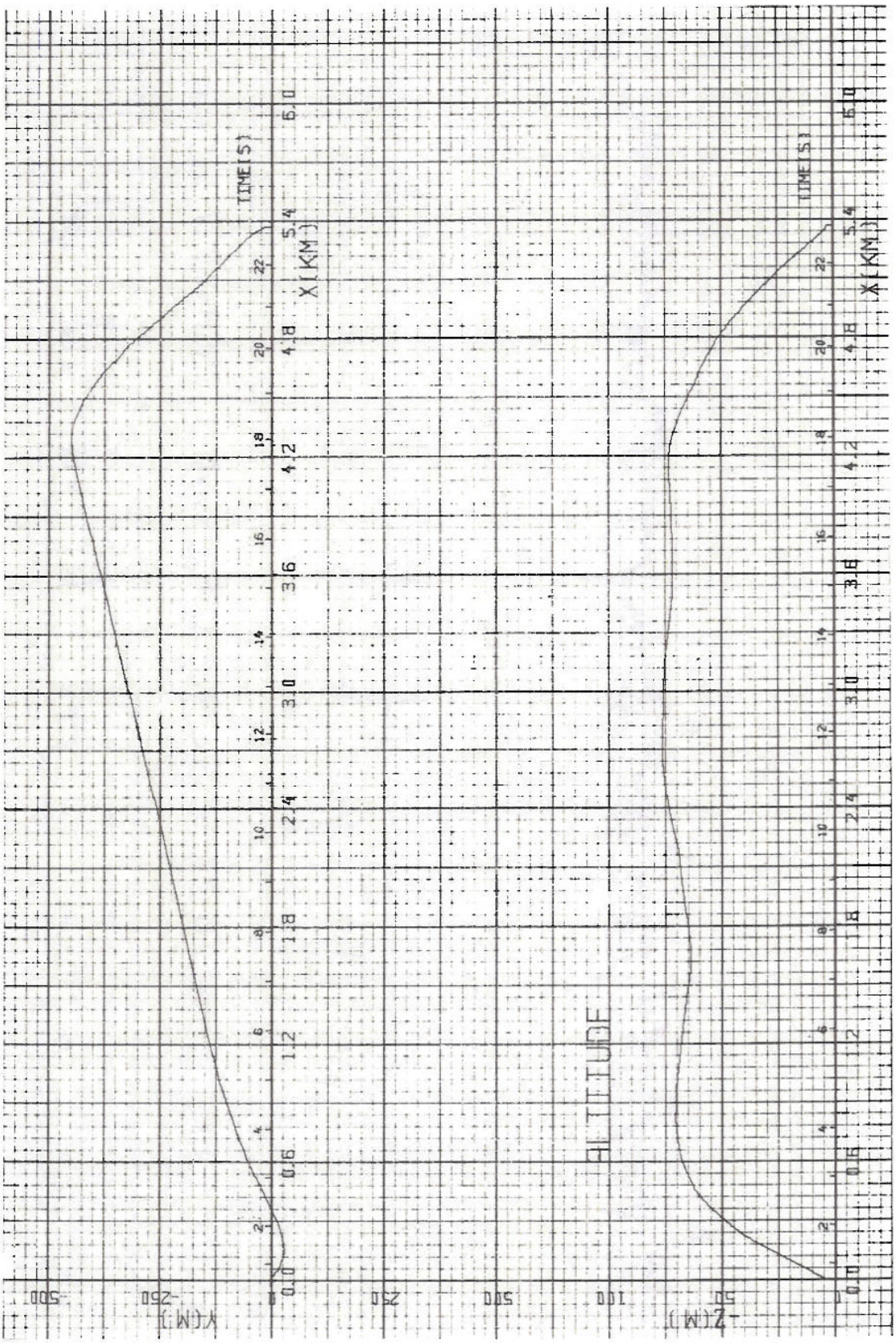
17.5.3 Motor pressures and altimeter ΔH



17.5.4 Seeker signals



17.5 Missile trajectory



17.6 Summary

Missile T was launched against ex KNM "Reinøysund" 25/4-1970 at a distance of 5400 m. The aim of this missile test firing was to home against a target which was detected at the bound of the seeker scanning sector. V_{yeo} was artificially set to - 22 m/s, and the resulting missile trajectory was 5^{o} south of the line of sight. The target was detected 2^{o} from the right bound of the seeker scanning sector. The missile homed against and hit the target. All the missile subsystems functioned satisfactorily.

18 MISSILE U, DESCRIPTION

18.1 Aim

To hit a realistic target whose bow points towards the launching ship. Medium range.

18.2 Technical description of the missile

18.2.1 Motor

18.2.1.1 Booster motor charge

Double base propellant, VU (British)	41.2	kg
Inhibitors	1.85	kg
Start thrust	4700	kp
Final thrust	2500	kp
Burning time	2.41	sec
Total impulse	8670	kps

18.2.1.2 Sustainer motor charge

Double base propellant, X-35 (Norwegian)	44.9	kg
Inhibitors	1.88	kg
Thrust	120	kp
Burning time	74	sec
Total impulse	8940	kps

18.2.2 Warhead

Inert warhead with fuse mounted.

18.2.3 Guidance section

E-03.

18.2.3.1 Seeker

E-06 (Electronics E-06, Optical unit E-06) Seeker E-07 originally mounted at KV.

Modifications at NDRE:

- New type of secondary mirrors mounted
- Telemetry electronics mounted
- Track threshold electronics modified
- Artificial IR-target modified.

18.2.3.2 Gas servo

E-09 (Electronics E-02, Gas generator E-08).

Modifications at NDRE:

- Firing circuit resistor changed from 5.6 Ω to 1 Ω.

18.2.3.3 Altimeter

E-10.

Laser effect 59 W.

18.2.3.4 Platform

E-06 (Platform E-03 originally mounted at KV).

18.2.3.5 AC-power supply

E-01.

18.2.3.6 Control unit

E-01.

18.2.3.7 Thermal batteries

35

37

95.

18.2.3.8 Control section

E-03.

Modifications at NDRE:

- Battery firing circuit resistors removed
- Fuse telemetry circuit mounted.

18.2.3.9 Control parameters

Main control loop Az	$6.02^{o}/o$
Lateral compensation	$0.145^{o}/m$
Tracking com Az	$K_{\psi_{\varepsilon n}} = 2.4^{o}/o$ $K\psi_{s_1} = 0.576^{o}/o$
Main control loop Pi	$5.98^{o}/o$
Altitude com	$0.185^{o}/m$ $\alpha_H = 1.3^{o}$ $\alpha_t = 0.95^{o}$
Tracking com Pi	$K_{\theta_{\varepsilon n}} = 2.3^{o}/o$ $K\theta_{s_1} = 0.46^{o}/o$
Href	82 m

18.2.4 Telemetry

Telemetry channels as listed in 6.3.1 except for ex ch 13 and ex ch 14 which were not used, and com ch 27 which was fuse arming signal.

18.2.5 Transponder

Transponder mounted.

18.3 Equipment onboard KNM "Traust"

18.3.1 Launching and control system

Traustin.

18.3.2 Launcher

Strømmen III

Port front position

Elevation 20°

Azimuth - 15°

18.3.3 Recording equipment

Recordings as listed in 12.3.3.

18.4 Target

ex KNM "Stavanger".

18.5 Photography

Camera on escort boat 1

2 Bolex cameras on the target.

18.6 Missile test at NDRE and KV

18.6.1 Acceptance test

3 - 4/3 - 1970 OK.

18.6.2 Subsystem test

18.6.2.1 Seeker

Seeker slip-ring fault. The slip-ring was exchanged.

18.6.2.2 Altimeter

OK.

18.6.3 Guidance/warhead section test

18.6.3.1 Test at NDRE

OK.

18.6.3.2 Vibration test at KV

13 - 14/4 - 1970.

3 runs lateral

5 runs axial

20 - 2000 - 20 Hz

1 octave/min

1 g peak

Platform Pi power amplifier defect. Platform E-03 exchanged with E-06.

18.7 Complete weapon system test at Haakonsvern and Tananger

Launcher with missile mounted onboard 19/4.

Arrival Tananger 22/4 , see 16.11.

Seeker E-07 mounted on missile T 25/4 , see 16.11. Seeker E-06 mounted 25/4 (Taken from missile V). Cooling hose exchanged. Cooling problems due to knocks on the seeker mounting cylinder and bad glueing of the solenoid walve. Seeker E-06 repaired onboard 26/4.

18.8 Launching attempts

None.

18.9 Launching

Date		27/4 - 1970 1251
Distance	to target	5500 m
Direction	to target	270.8°
Weather:	Sight	30 km
	Cloud cover	7/8
	Wind	12 m/s from NNW
	Temperature	6°C
	Sea state	1

19 MISSILE U, VALUATION

19.1 Data systems

19.1.1 Telemetry

Good data.

19.1.2 Transponder

Good data.

19.1.3 Cinetheodolites

T1: No data during 19 - 21.2 sec and 21.8 - 22.[illegible] sec, else good data

T2: Good data

T3: No data

T4: Good data

The resulting data are good during 0 - 19 sec, satisfactorily for the rest of the flight.

19.1.4 Photography

Escort boat 1 camera: The whole missile trajectory

Target camera 1 : The last part of the terminal phase and impact

Target camera 2 : The missile passed through the bow, this was filmed.

19.1.5 Recording equipment onboard KNM "Traust"

Good data.

19.2 Equipment onboard KNM "Traust"

19.2.1 Launching and control system

OK. Total fire control accuracy 0.40°.

19.2.2 Launcher

OK.

19.3 Missile flight

See 19.5.5.

19.3.1 Boost phase

Normal. Missile velocity at the end of the boost phase 263 m/s.

19.3.2 Mid-course phase

The missile lost altitude during the last part of the mid-course phase. This was due to an altimeter no return measurement and the low missile velocity (255 m/s).

The lateral guidance was OK. If the missile had not homed against the target, it would have passed 50 m to the left of the target center.

The missile rolled clockwise 0.36 Hz.

19.3.3 Terminal phase

Decision distance 1050 m and altitude at the decision point 65 m. The decision distance was shorter than usual because of the low altitude. The target was detected in the middle of the seeker scanning sector. The missile home against and hit the target. The missile passed through the bow of the missile.

19.4 Missile subsystems

19.4.1 Motor

See 19.5.3.

19.4.1.1 Booster motor

Burning time	2.55 sec
Velocity at burn out	263 m/s
Pressure	Normal, max 80 kp/cm^2
Acceleration (start)	128 m/s^2

19.4.1.2 Sustainer motor

The sustainer motor pressure was 70 kp/cm^2 (4 sec) and increased to 74 kp/cm^2 at the end of the missile flight. This gives an average thrust of 101 kp (120 kp nom). This thrust is too small to maintain constant velocity, and the missile velocity decreases from 260.4 m/s (4 sec) to 254.3 m/s (18 sec).

19.4.2 Platform

OK.

19.4.3 Altimeter

See 19.5.2 and 19.5.3.

4 altitude samples, 1 of these was a no return measurement. The other 3 measurements differed 1 - 4 m from the altitude calculated from the cinetheodolite data. Altitude command according to the altitude measurements.

19.4.4 Seeker

See 19.5.4.

The target was detected at a range of 1050 m in the middle of the seeker sector. The target bow pointed towards the missile. The seeker was OK during the whole terminal phase, and the tracking command signals were according to the missile trajectory, ψ_{MP} and θ_{MP}.

19.4.5 Control loops

19.4.5.1 Azimuth control loops

See 19.5.1.

Mid-course guidance

V_{yeo}	- 1 m/s
Average ψ_{MP}	2^{o}
Lateral int 2	- 18 m
Oscillation	1.5^{o} pp 2.9 Hz
Lateral wind	- 11 m/s
Average missile velocity	257 m/s

Normal oscillation. ψ_{MP} is according to V_{yeo}, lateral wind and missile velocity.

Terminal guidance

Normal, ψ_{MP} according to tracking com Az. The missile started to turn left even if the initial tracking com Az was 0. This is because of the lateral wind and V_{yeo}. When the tracking starts, the lateral compensation loop is disconnected. This was equivalent with 2^{o} left guidance command (ψ_{MP} average during the mid-course phase was 2^{o}).

19.4.5.2 Pi control loops

See 19.4.4.

Mid-course guidance

Average θ_{MP} (5 - 18 sec) 1.2^{o}

Oscillation 1.5^{o} pp 3 Hz

Normal oscillation, θ_{MP} according to altitude command.

Terminal guidance

Normal. θ_{MP} according to tracking com Pi.

19.4.6 Gas servo

OK.

19.4.7 AC-power supply

OK.

19.4.8 Thermal batteries

OK.

Positive batteris: 30.2 V , constant during the flight

Negative battery : - 30.6 V , - " -

19.4.9 Fuse

The fuse was armed 1.8 sec after take-off.

19.5 Telemetry and missile trajectory recordings

Lateral control signals on 19.5.1.

Altitude control signals on 19.5.2.

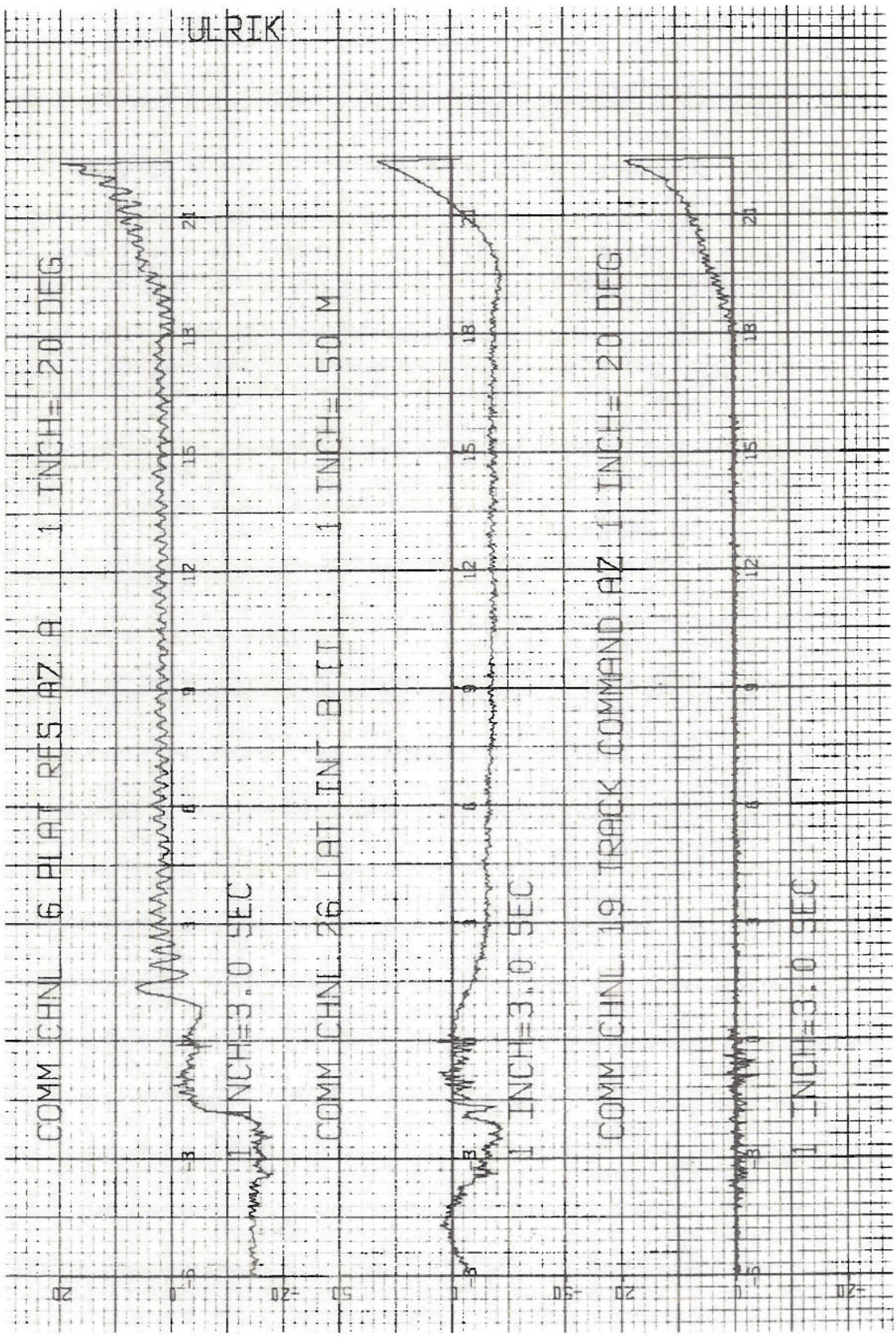
Motor pressures and altimeter on 19.5.3.

Seeker signals from 0.14 sec before to 0.21 sec after decision on 19.5.4.

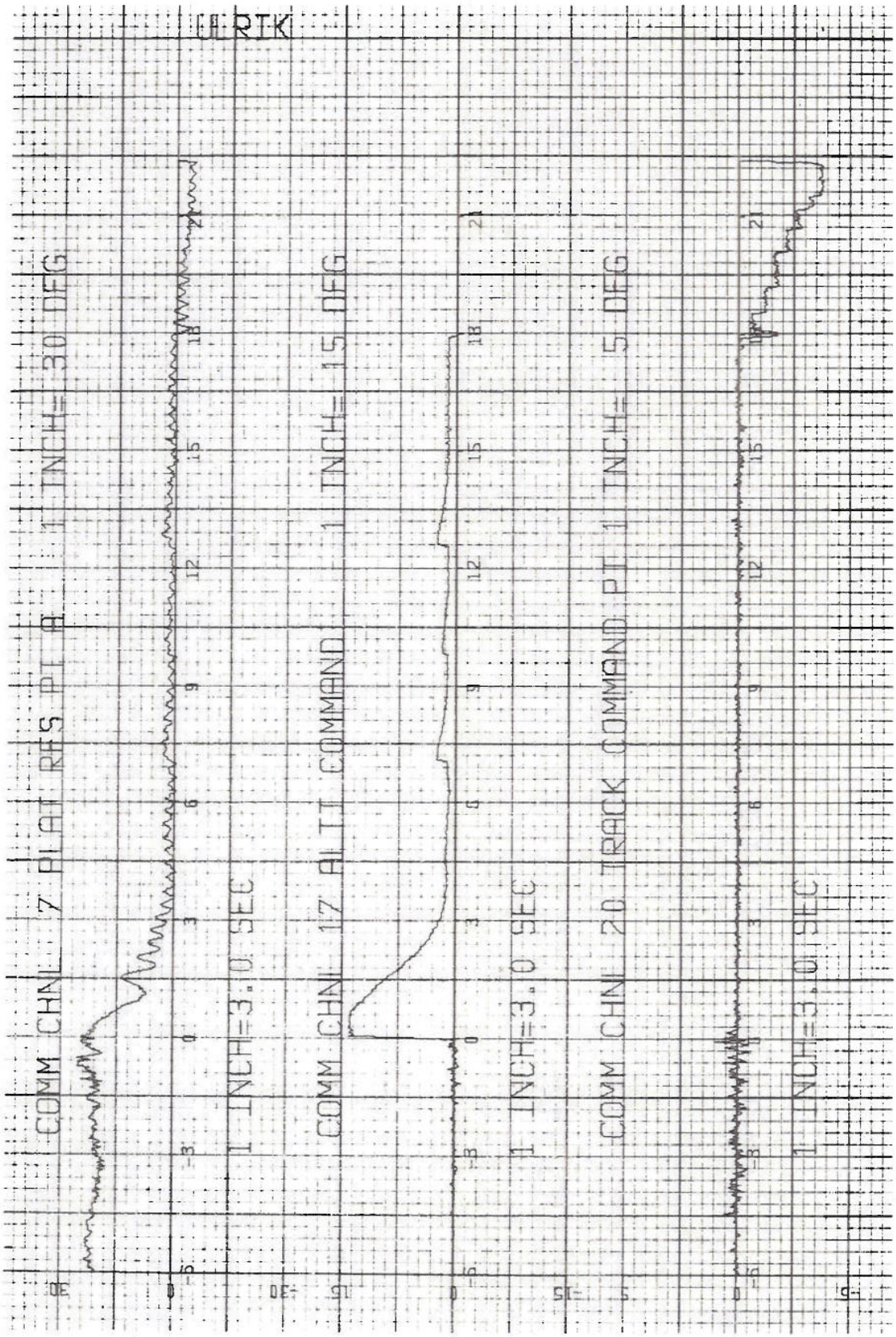
Vertical and horizontal projection of the missile trajectory on 19.5.5.

Time ref: T = 0 is take-off, except for 19.5.4 where T = 0 is decision.

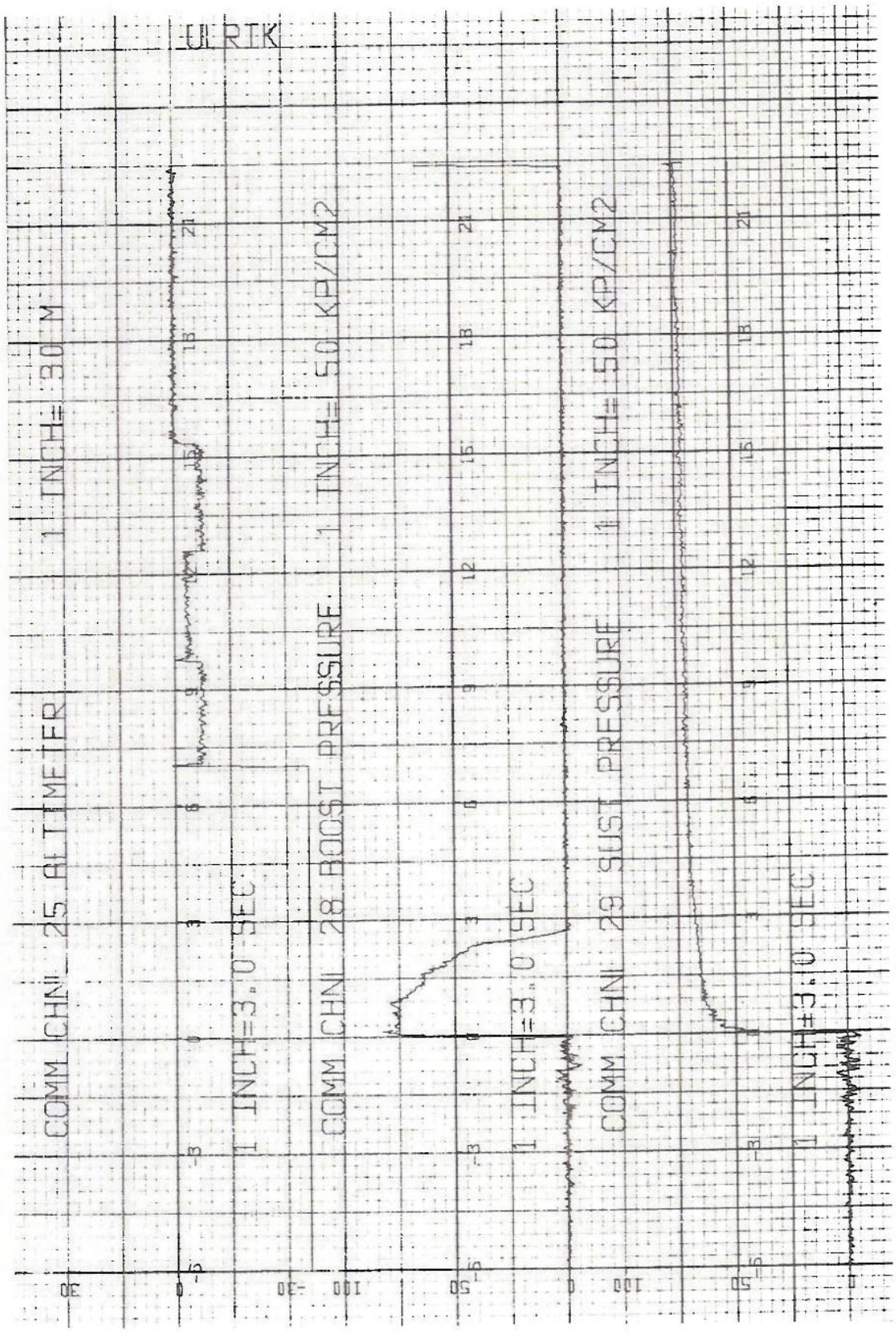
19.5.1 Lateral control signals



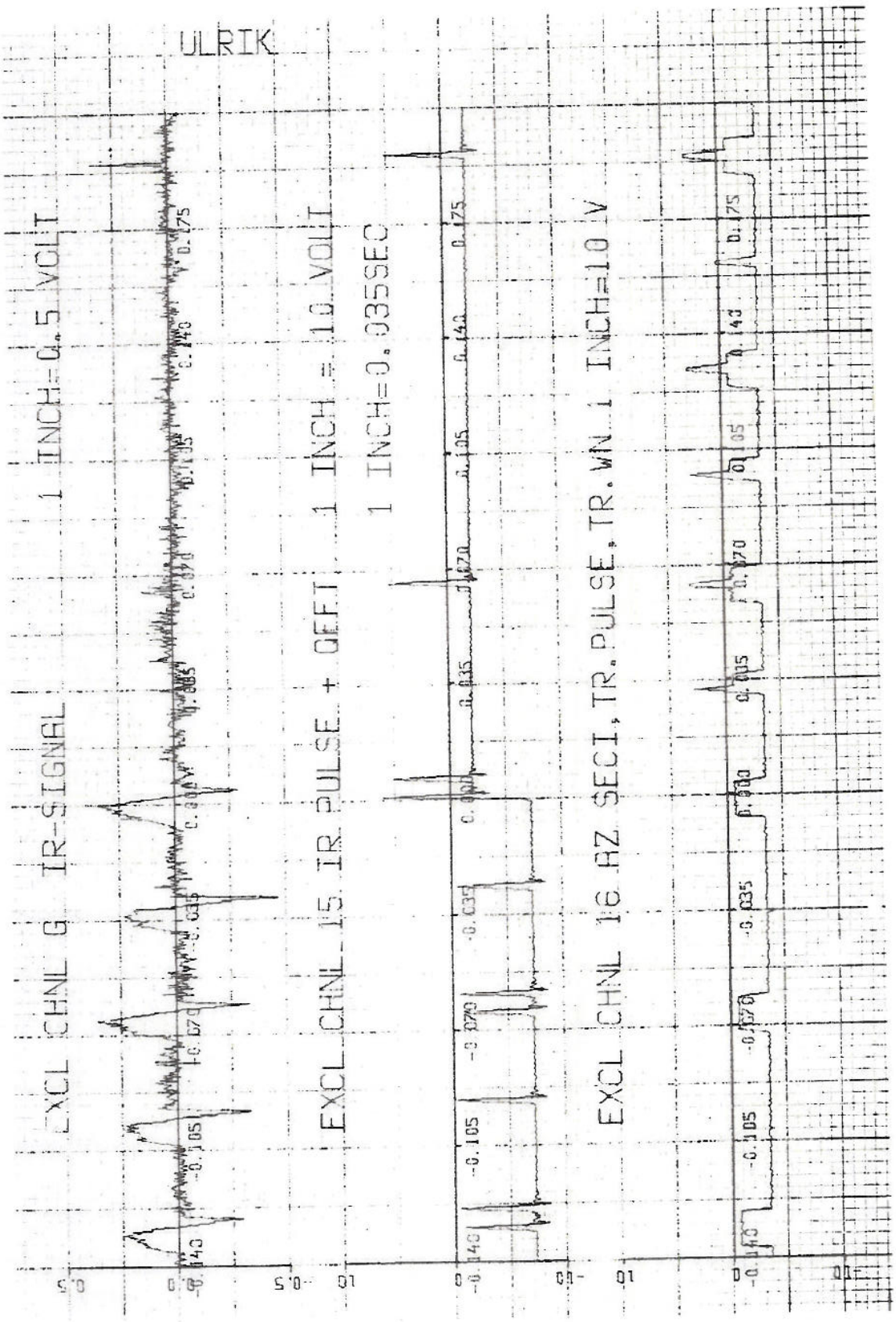
19.5.2 Altitude control signals



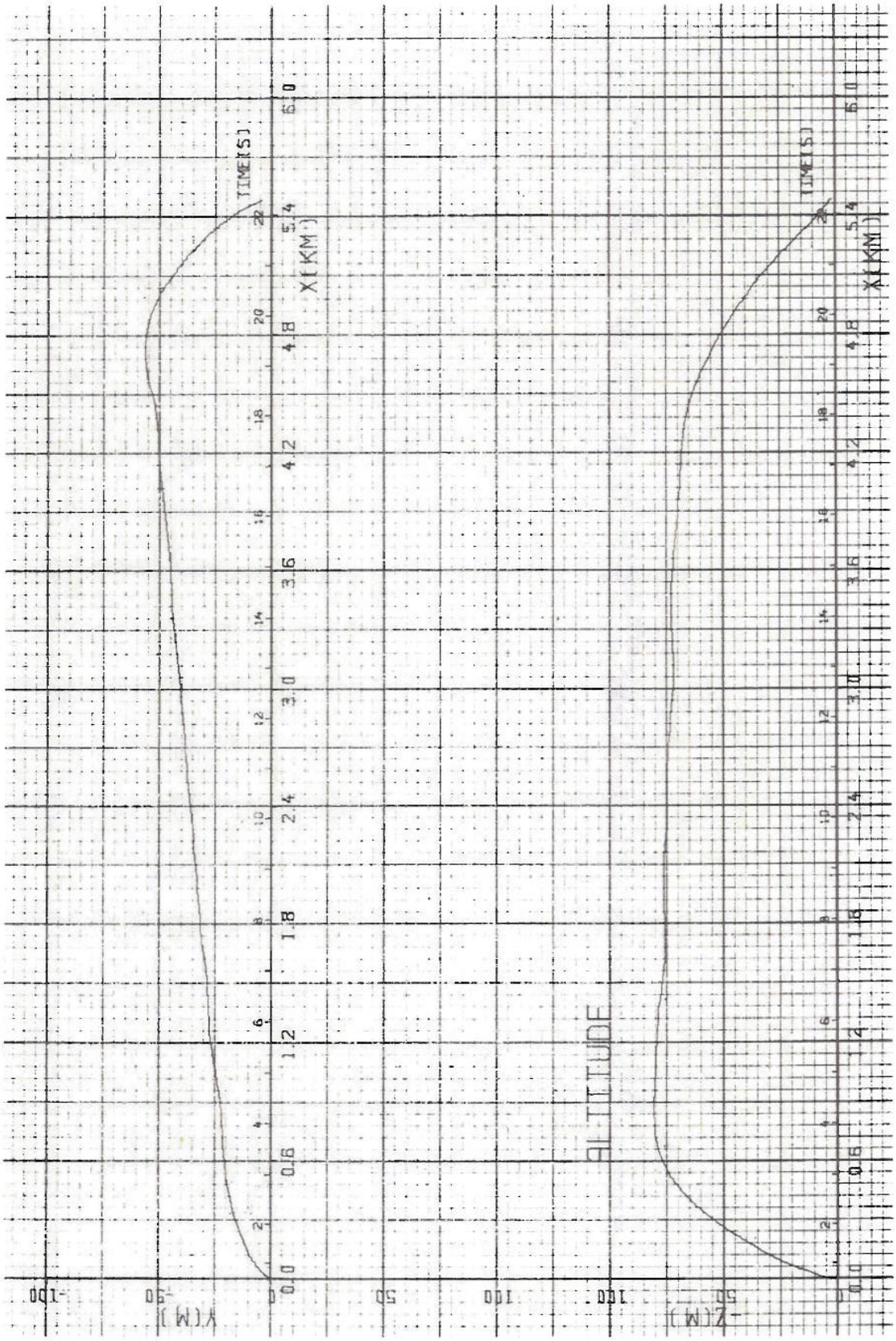
19.5.3 Motor pressures and altimeter ΔH



19.5.4 Seeker signals



19.5.5 Missile trajectory



19.6 Summary

Missile U was launched against ex-KNM "Stavanger" 27/4 - 1970 at a distance of 5500 m. The bow of the target pointed towards KNM "Traust" at take-off. The missile hit the target bow at the water line, and passed through the bow. All the missile subsystems functioned satisfactorily.

20 MISSILE V, DESCRIPTION

20.1 Aim

To hit a target at long range.

20.2 Technical description of the missile

20.2.1 Motor

20.2.1.1 Booster motor charge

Double base propellant, VU (British)	41.2 kg
Inhibitors	1.85 kg
Start thrust	4700 kp
Final thrust	2500 kp
Burning time	2.41 sec
Total impulse	8670 kps

20.2.1.2 Sustainer motor charge

Double base propellant, X-35 (Norwegian)	44.9 kg
Inhibitors	1.88 kg
Thrust	120 kp
Burning time	74 sec
Total impulse	8940 kps

20.2.2 Warhead

Inert warhead with fuse mounted.

20.2.3 Guidance section

E-05.

20.2.3.1 Seeker

E-05 (Electronics E-05, Optical unit E-05). Seeker E-06 originally mounted at KV.

Modifications at NDRE:

- Telemetry electronics mounted
- Down correction barring time 62.5 msec
- Depression angle adjusted to 4°
- Track threshold electronics modified.

20.2.3.2 Gas servo

E-07 (Electronics E-07, Gas generator E-06).

Modifications at NDRE:

- Firing circuit resistor changed from 5.6 Ω to 1 Ω.

20.2.3.3 Altimeter

E-06.

Laser effect 32 W.

20.2.3.4 Platform

E-05.

20.2.3.5 AC-power supply

E-02.

20.2.3.6 Control unit

E-03.

20.2.3.7 Thermal batteries

98

93

81.

20.2.3.8 Control section

E-06.

Modifications at NDRE:

- Battery firing circuit resistors removed
- Fuse telemetry circuit mounted
- 2 vibration accelerometers with telemetry amplifiers mounted.

20.2.3.9 Control parameters

Main control loop Az	6.42°/o
Lateral compensation	0.146°/m
Tracking com Az	$K_{\psi_{en}}$ = 2.41°/o $K_{\psi_{si}}$ = 0.58°/o
Main control loop Pi	6.33°/o
Altitude com	0.191°/m
Tracking com Pi	$K_{\theta_{en}}$ = 2.36°/o $K_{\theta_{si}}$ = 0.47°/o
Href	82 m

20.2.4 Telemetry

Telemetry channels as listed in 6.3.1, except for com ch 27 which was fuse arming signal.

20.2.5 Transponder

Transponder mounted.

20.3 Equipment onboard KNM "Traust"

20.3.1 Launching and control system

Traustin.

20.3.2 Launcher

Selco II

Starboard aft position

Elevation 20°

Azimuth 15°.

20.4 Target

ex-KNM "Stavanger".

20.5 Photography

Camera on escort boat 1

2 Bolex cameras on the target.

20.6 Missile test at NDRE and KV

20.6.1 Acceptance test

5/3 and 20/3 - 1970.

- Gas servo pick-off obliquely mounted
- Seeker breakdown due to slip-ring fault. The seeker was exchanged.

20.6.2 Subsystem test

20.6.2.1 Seeker

OK.

20.6.2.2 Altimeter

OK.

20.6.3 Guidance/warhead section test

20.6.3.1 Test at NDRE

OK.

20.6.3.2 Vibration test at KV

15/4 - 1970.

4 runs lateral

4 runs axial

20 - 2000 - 20 Hz

1 octave/min

1 g peak

OK.

20.7 Complete weapon system test at Haakonsvern and Tananger

Launcher with missile mounted onboard 25/4 - 1970 in Tananger.

Seeker E-06 mounted on missile U 25/4 , see 18.7.

Seeker E-05 (removed from missile T and sent to KV 25/4 for repair) arrived 27/4.

Seeker breakdown 28/4, seeker E-05 sent to KV 28/4 and returned Tananger 29/4. No faults detected during the tests 29 - 30/4.

20.8 Launching attempts

None.

20.9 Launching

Date	30/4 - 1970 1016
Distance to target	15 000 m
Direction to target	261.7°

Weather:	Sight	> 30 km
	Cloud cover	0/8
	Wind	6 - 12 m/s from N
	Temperature	5°C
	Sea state	2

21 MISSILE V, VALUATION

21.1 Data systems

21.1.1 Telemetry

Good data.

21.1.2 Transponder

Bad data, many drop-outs.

21.1.3 Cinetheodolites

T1: Lacked 73 photos, mainly during 27.4 - 33.4 sec and 52.2 - 70 sec

T2: Lacked 29 photos during 0 - 62 sec

T3: No data

T4: Good data

The resulting data are good during 0 - 62 sec and less good but satisfactorily for the rest of the flight.

21.1.4 Photography

Escort boat 1 camera: The whole missile trajectory

Target cameras : Nothing, the missile did not hit the target.

21.2 Equipment onboard KNM "Traust"

21.2.1 Launching and control system

OK. Total fire control accuracy 0.25°.

21.2.2 Launcher

OK.

21.3 Missile flight

See 21.5.4.

21.3.1 Boost phase

Normal. Missile velocity at the end of the boost phase 257 m/s.

21.3.3 Mid-course phase

The mid-course phase was very long (2.6 - 70 sec) because the seeker did not detect the target.

The variations in altitude during the flight were due to altimeter no return measurements (12 of 28 samples). The low altitude during the last part of the flight was because 6 of the 7 last altitude samples were no return measurements.

The horizontal projection of the trajectory was curved towards right. This is due to the Corrioli's acceleration (0.035 m/s^2) which will effect the trajectory on long range flights. Deviation due to the Corrioli's acceleration after 70 sec is 80 m which is according to the calculated missile trajectory. Compensation for the Corrioli's acceleration is built in to the platforms now delivered by KV. The missile passed 30 m to the left of the target center (the distance would have been 85 m without the Corrioli's acceleration).

The missile rolled clockwise 0.45 Hz.

21.3.3 Terminal phase

The seeker did not take decision on the target. After a flight of 18 km , the missile homed against the internal artificial IR-target of the seeker. This is done if no target is detected till 25 sec after the seeker is "armed". The missile hit the sea surface after a flight of 18 900 m.

21.4 Missile subsystems

21.4.1 Motor

See 21.5.3.

21.4.1.1 Booster motor

Burning time	2.50 sec
Velocity at burn out	263 m/s
Pressure	Normal, max 85 kp/cm^2
Acceleration (start)	118 m/s^2

21.4.1.2 Sustainer motor

The sustainer motor pressure was normal till 41 sec , but started then to increase rapidly from 80 kp/cm^2 to 140 kp/cm^2 (47 sec). The pressure was approximately 140 kp/cm^2 till 53 sec and was > 140 kp/cm^2 (max pressure of the pressure transducer) till the normal pressure decreasing before burn out (63 sec). The pressure increasing might have caused a motor burst if it had started before. The high pressure caused a shorter burning time and greater thrust than usual. The missile was accelerated from 250 m/s (41 sec) to 290 m/s (63 sec) because of the great thrust.

21.4.2 Platform

OK.

21.4.3 Altimeter

See 21.5.2 and 21.5.3.

28 altitude samples, 12 of these were no return measurements. 6 of the 7 last samples were no return samples. The reason of the no return measurements was probably low laser effect. This altimeter had the lowest laser effect of the altimeters used during the evaluation program, and was further reduced because of heat from the servo gas generator during the long flight.

The missile lost altitude during the "no return measurements periode". This is because α_H is approximately 0.2° too small to keep constant altitude. The missiles R, S, T, U and V have lost altitude between each altitude sample. This is because α_t was too low. α_t was increased from 0.95° to 1.15° on the succeeding missiles and is 1.15° on the altimeters now delivered by KV.

The altitude samples differ 1 - 5 m from the altitude calculated from the cinetheodolite data. Altitude command according to the altitude measurements.

21.4.4 Seeker

The missile did not home against the target, due to the following seeker faults:

IR-signal

0 - 1.15 sec	Normal
1.15 - 1.35 sec	- 3.5 V DC-shift, unnormal signal in and outside sector II
1.35 - 2.5 sec	Normal
2.5 - 9 sec	- 3.5 V DC-shift, unnormal signal in and outside sector II. The signal in sector II decreased slowly, and disappeared at 9 sec
9 sec	- 3.5 V DC-shift, normal signal in sector I and no signal in sector II.

The reason of this was probably a short circuit of Az sector II on module 1706 to ground. The faults during the missile flight was exactly the same as were detected onboard KNM "Traust" 28/4. The seeker was repaired at KV the same day. A 2-layer insulating sheet was glued under module 1706 to prevent short circuit to ground, but a short circuit was probably generated during the boost phase.

The target generated IR-pulse in sector I, but the seeker did not take decision because Az sector II is a part of the decision circuit. No target was detected, and consequently the missile homed against the internal seeker IR-target 25 sec after the seeker was armed.

21.4.5 Control loops

21.4.5.1 Az control loops

See 21.5.1.

Mid-course guidance

V_{yeo}	0 m/s
ψ_{MP}	1.5 to 3°
Lateral int 2	- 10 to - 20 m
Oscillation	2° pp 2.8 Hz
Lateral wind	- 6 to - 14 m/s
Missile velocity	250 to 290 m/s

Normal oscillation. ψ_{MP} was according to V_{yeo}, lateral wind and missile velocity. ψ_{MP} increased during the flight because the lateral wind increased with increasing distance from the shore.

Terminal guidance

ψ_{MP} according to the constant tracking com Az.

21.4.5.2 Pi control loops

See 21.5.2.

Mid-course guidance

Average θ_{MP} (5 - 50 sec)	1.4°
Average θ_{MP} (50 - 70 sec)	1.0°
Oscillation	2° pp 3 Hz

Normal oscillation. To keep approximately constant altitude during 5-50 sec, θ_{MP} was 1.4^{o} because the low missile velocity. During 50 - 70 sec (the "no return measurement" period) was $\theta_{MP} = 1.0^{o}$, but the velocity was higher and the missile trajectory slope was only $- 0.2^{o}$.

Terminal guidance

θ_{MP} according to the constant tracking com Pi.

21.4.6 Gas servo

OK.

21.4.7 AC-ower supply

OK.

21.4.8 Thermal batteries

OK.

Positive batteries:	30.5 V at take-off, decreasing to 30 V at the end of the flight
Negative battery :	- 30.5 V , constant during the flight.

21.4.9 Fuse

The fuse was armed 1.8 sec after take-off.

21.5 Telemetry and missile trajectory recordings

Lateral control signals on 21.5.1.

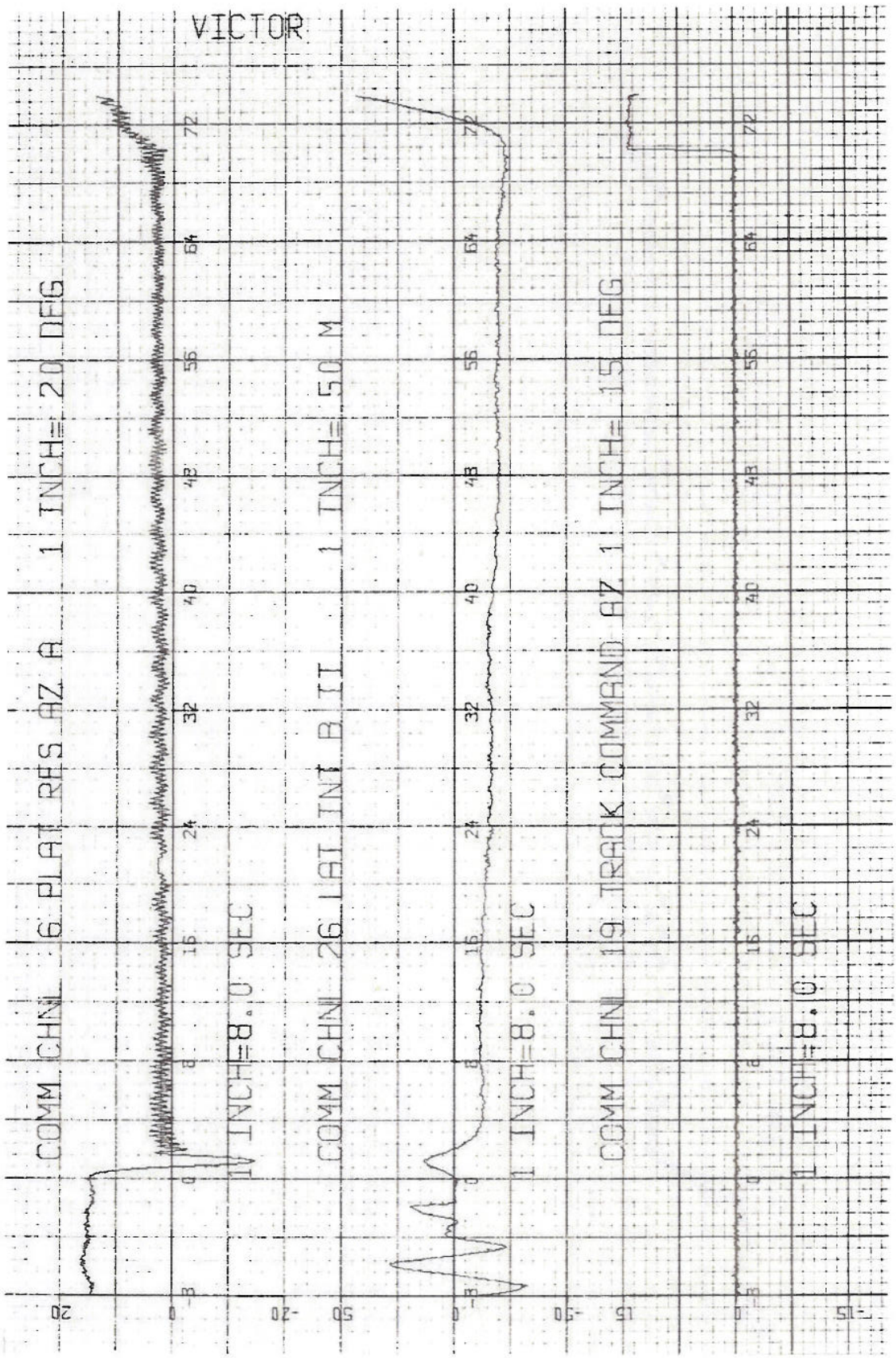
Altitude control signals on 21.5.2.

Motor pressures and altimeter ΔH on 21.5.3.

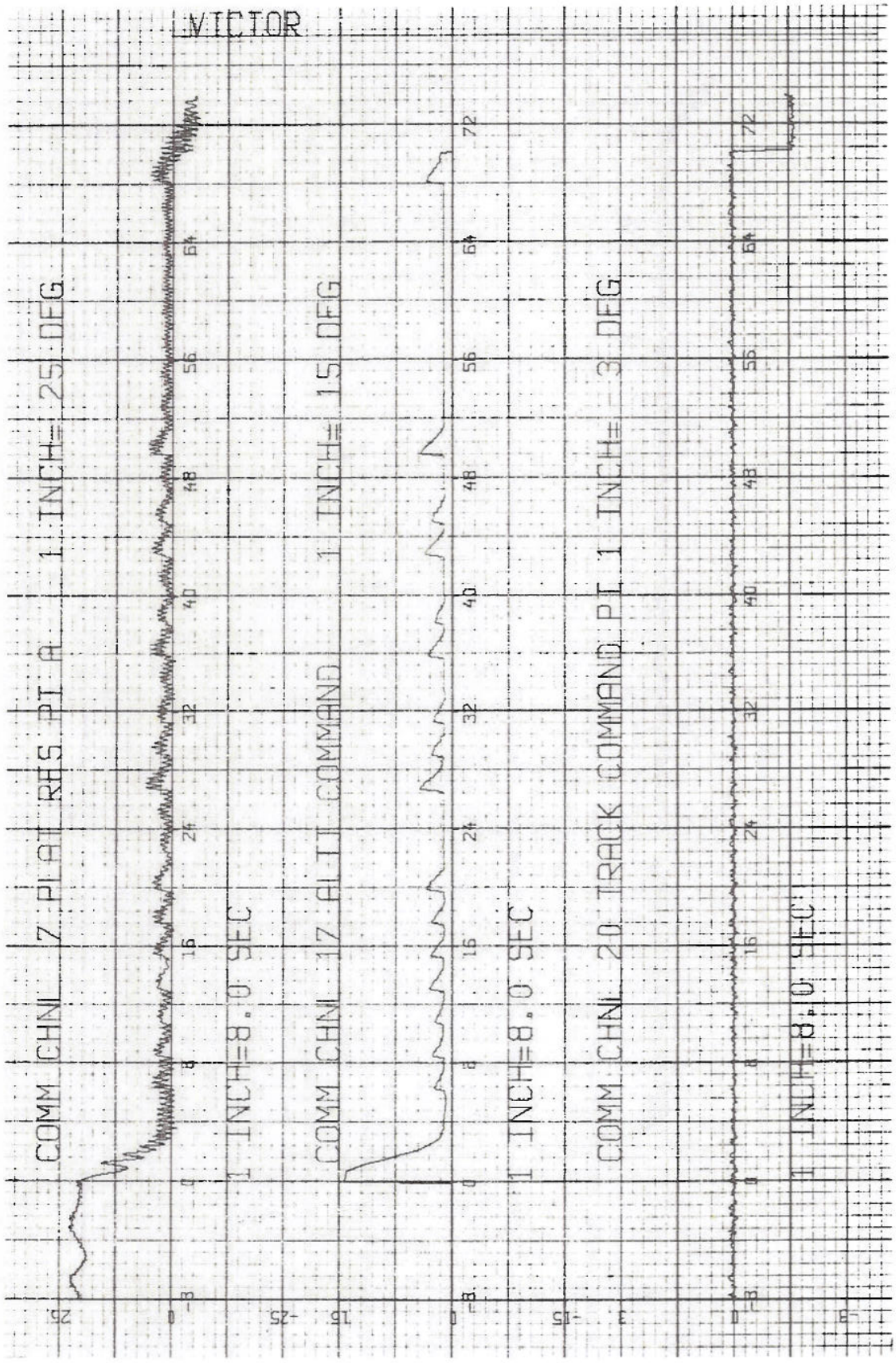
Vertical and horizontal projection of the missile trajectory on 21.5.4.

Time ref: T = 0 is take-off.

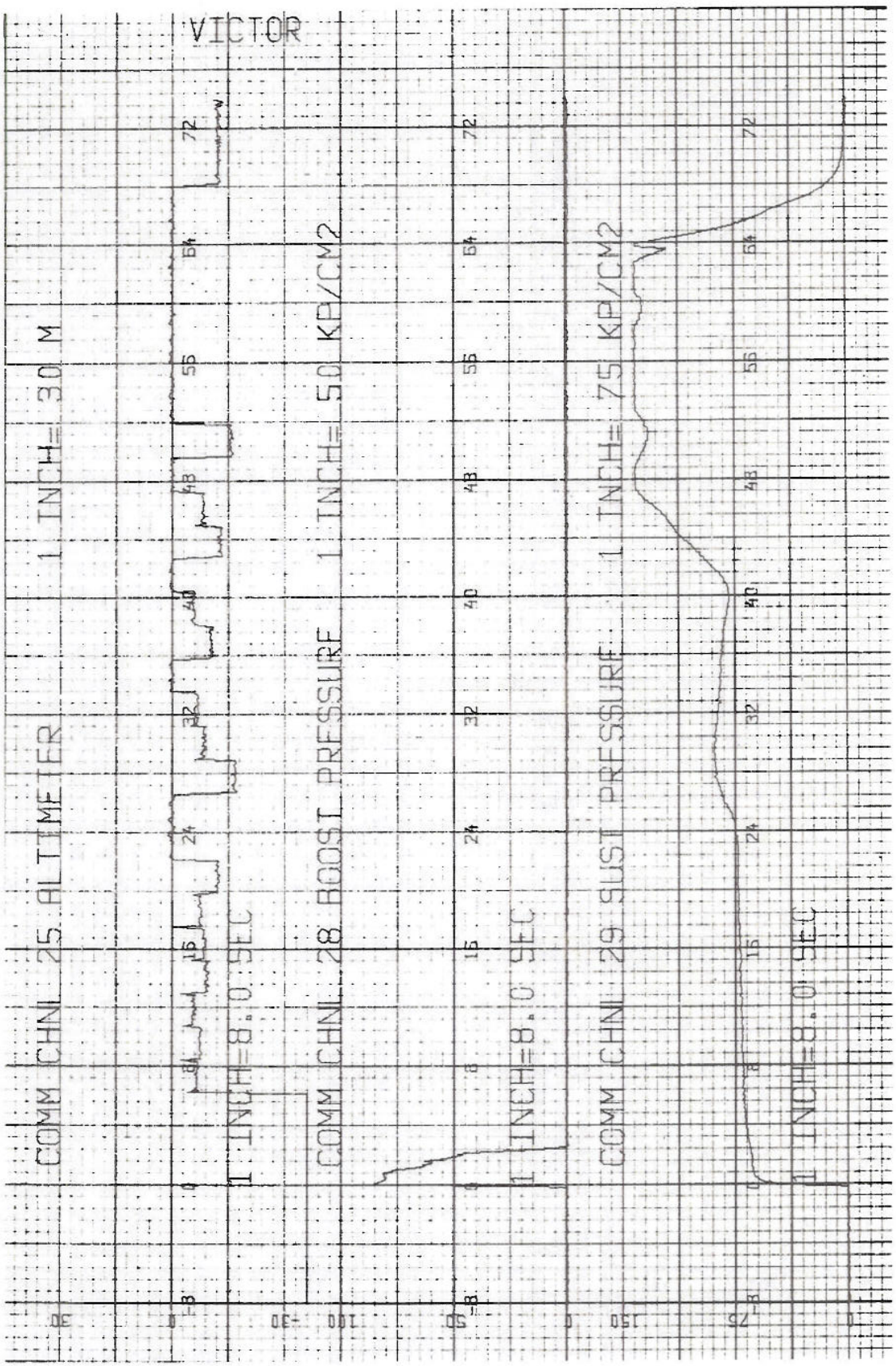
21.5.1 Lateral control signals



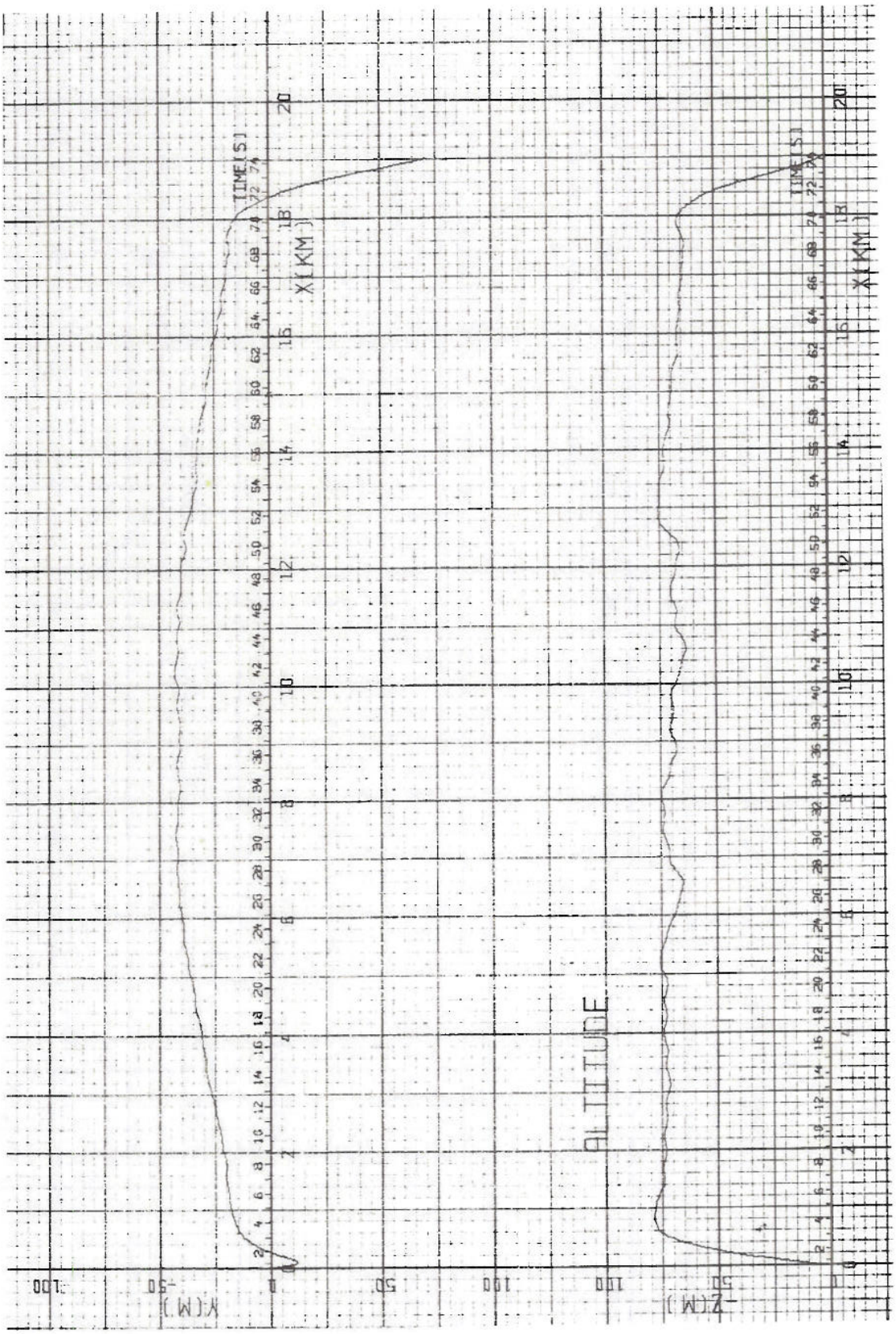
21.5.2 Altitude control signals



21.5.3 Motor pressures and altimeter ΔH



21.5.4 Missile trajectory



21.6 Summary

Missile V was launched against ex-KNM "Stavanger" 30/4 -1970 at a distance of 15 000 m. Due to seeker errors the missile did not home against the target. The lateral guidance was accurate and the missile passed 30 m to the left of the target center.

The sustainer motor pressure started to increase 41 sec after take-off, and was $\geq$ 140 kp/cm^2 during 52 - 63 sec. If the pressure increasing had started before, it might have caused a motor burst.

12 of 28 altitude samples were no return measurements. This was because of low laser effect and rough sea.

22 MISSILE W, DESCRIPTION

22.1 Aim

To hit a target at long range.

22.2 Technical description of the missile

22.2.1 Motor

22.2.1.1 Booster motor charge

Double base propellant, R3 X (Norwegian)	41.8 kg
Inhibitors	1.65 kg
Start thrust	3950 kp
Final thrust	3600 kp
Burning time	3.32 sec
Total impulse	8740 kps

22.2.1.2 Sustainer motor charge

Double base propellant, R4 X (Norwegian)	44.4	kg
Inhibitors	1.88	kg
Thrust	130	kp
Burning time	69	sec
Total impulse	8940	kps

22.2.2 Warhead

Inert warhead.

22.2.3 Guidance section

E-10.

Protection bag mounted at NDRE, removed onboard KNM "Traust".

22.2.3.1 Seeker

E-04.

Modifications at NDRE:

- Telemetry electronics mounted
- New type of secondary mirrors mounted.

22.2.3.2 Gas servo

E-02 (Electronics E-05, Gas generator E-03).

Modifications at NDRE:

- Firing circuit resistor changed from 5,6 Ω to 1 Ω.

22.2.3.3 Altimeter

E-05.

Laser effect 58 W.

Modifications at NDRE:

- α_t changed from 0.95° to 1.15°.

22.2.3.4 Platform

E-10.

22.2.3.5 AC-power supply

E-07.

22.2.3.6 Control unit

E-05.

22.2.3.7 Thermal batteries

82

86

92.

22.2.3.8 Control section

E-10

Modifications at NDRE:

- Battery firing circuit resistors removed.

22.2.3.9 Control parameters

Main control loop Az	$6.18^{\circ}/o$
Lateral compensation	$0.14^{\circ}/m$
Tracking com Az	$K_{\psi_{\varepsilon n}} = 2.42^{\circ}/o$ $K_{\psi_{s1}} = 0.58^{\circ}/o$
Main control loop Pi	$6.23^{\circ}/o$
Altitude com	$0.195^{\circ}/m$ $\alpha_H = 1.3^{\circ}$ $\alpha_t = 1.15^{\circ}$
Tracking com Pi	$K_{\theta_{\varepsilon n}} = 2.42^{\circ}/o$ $K_{\theta_{s1}} = 0.48^{\circ}/o$
Href	82 m

22.2.4 Telemetry

Telemetry channels as listed in 6.3.1, except for ex ch 13 which was not used, and IR + track flip-flop which were on ex ch 14 instead of ex ch 15.

22.3 Equipment onboard KNM "Traust"

22.3.1 Launching and control system

NDRE NOR2.

22.3.2 Launcher

Strømmen III

Starboard middle position

Elevation 21.5°

Azimuth 15°

22.4 Target

ex-KNM "Reinøysund".

22.5 Photography

Camera on escort boat 1

High-speed camera on KNM "Traust"

35 mm Artiflex camera on KNM "Traust".

22.6 Missile test at NDRE and KV

22.6.1 Acceptance test

14 - 15/4 - 1970 OK.

22.6.2 Subsystem test

22.6.2.1 Seeker

- Primary mirror was spotted, exchanged
- Glue on the contact surface of the 1701 heat-sink
- IR-detector socket was deformed.

22.6.2.2 Altimeter

OK.

22.6.3 Guidance/warhead section test I

22.6.3.1 Test at NDRE

OK.

22.6.3.2 Vibration test at KV

26/5 - 1970.

4 runs lateral

4 runs axial

20 - 2000 - 20 Hz

1 octave/min

1 g peak

OK.

22.7 Special environmental test onboard KNM "Steil"

The missiles W and X were planned to be launched primo June 1970. Launching and control system NDRE NOR 2 was to be used. NDRE NOR 2 was also planned to be used for launching of the missiles S, T, U and V, see 14.7 and 16.11, but was not operative in time. NDRE NOR 2 was further delayed because of hardware failures of the digital computer. It was decided to delay the launching of W and X till the new launching and control system was operative. In the meantime missile W was to be used for a long time enviromental test onboard KNM "Steil", and missile X was to be used for testing of NDRE NOR 2 at NDRE.

Protection bag was mounted on the guidances section, and launcher with missile W was mounted on KNM "Steil" 3/6. The missile was onboard to 24/7 and was then taken to NDRE for inspection and test.

22.8 Guidance/warhead section test II

22.8.1 Test at NDRE

OK.

22.8.2 Vibration test at KV

5/8 - 1970

3 runs lateral

3 runs axial

20 - 2000 - 20 Hz

1 octave/min

1 g peak

OK.

22.9 Complete weapon system test at Haakonsvern and Tananger

The missiles W and X were mounted onboard KNM "Traust" 11/8.

Altimeter breakdown (12/8) because of a defect FET-switch on module 1813.

Seeker breakdown (12/8) because of a short circuit on module 1701. Seeker and altimeter sent to KV for repair (13/8).

Arrival Tananger 18/8.

Seeker and altimeter returned from KV 19/8. Robin wire in the control section was short circuited when the guidance section was mounted on the rest of the missile. Missile W was OK 20/8.

Launching and control system NDRE NOR 2 was to be used for launching of missile W and X, and was very carefully tested.

22.10 Launching attempts

None.

22.11 Launching

Date		21/8 - 1970 1202
Distance	to target	15 100 m
Direction	to target	266.3°
Weather:	Sight	20 - 30 km
	Cloud cover	8/8
	Wind	10 m/s from ENE
	Temperature	15°C
	Sea state	0 - 1

23 MISSILE W, VALUATION

23.1 Data systems

23.1.1 Telemetry

Good data.

23.1.2 Cinetheodolites

T1: Lacked 58 photos, mainly during 46.4 - 56.4 sec

T2: Good data

T3: Good data

T4: Good data

The resulting data were good.

23.1.3 Photography

Escort boat 1 camera: The whole missile trajectory

High speed camera onboard KNM "Traust": Take-off

Aritiflex camera - " - : Launcher opening.

23.2 Equipment onboard KNM "Traust"

23.2.1 Launching and control system

It was a platform Az misalignment in the period - 6.5 to - 3.5 sec. See 23.5.1. It is impossible to say if the fault was in the analog slave electronics (which was of the same type as used in Traustin) or in the digital part of the system. If this fault had been generated 3 - 6.5 sec later, the missile trajectory would have been 10 - 15° north of the direction to the target. Else OK.

Total fire control accuracy 0.3°.

23.2.2 Launcher

OK.

23.3 Missile flight

See 23.5.6.

23.3.1 Boost phase

Normal. Missile velocity at the end of the boost phase was 282 m/s.

23.3.2 Mid-course phase

The altitude was high before the first altitude sample (3 - 7 sec) , but was close to Href for the rest of the flight.

The lateral guidance was accurate. The missile passed 120 m to the right of the target senter. If the Corriole's acceleration had been compensated, see 21.3.2, the missile would have passed 75 m to the right of the target center.

The missile rolled clockwise 0.56 Hz.

23.3.3 Terminal phase

The seeker did not take decision on the target. After a flight of 15.8 km the missile homed against a false internal IR-target. The missile hit the sea surface after a flight of 17 km.

23.4 Missile subsystems

23.4.1 Motor

See 23.5.3.

23.4.1.1 Booster motor

Burning time	2.65 sec
Velocity at burn out	282 m/s
Pressure	Normal, max 93 kp/cm^2
Acceleration (start)	129 m/s^2

23.4.1.2 Sustainer motor

The sustainer motor pressure increased from 70 kp/cm^2 (3 sec) to 82 kp/cm^2 (32 sec), and was appr 84 kp/cm^2 during the rest of the flight. This gives a thrust of 134 kp , and the missile was accelerated during flight to a velocity at the end of the mid-course phase of 300 m/s.

23.4.2 Platform

OK.

23.4.3 Altimeter

See 23.5.2 and 23.5.3.

27 altitude samples, 4 of these were probably no return measurements. The altimeter functioned very well during the flight, and the altitude was so near Href that it is difficult to say if the 4 no return measurements really are no return measurements or if H = Href. The missiles R, S, T, U and V lost altitude between the altitude samples, this missile did not. This was because α_t was changed from 0.95° to 1.15° and the missile velocity was high.

23.4.4 Seeker

The missile did not home against the target. This was due to 2 seeker faults, each of them would have caused the missile to miss the target:

- The seeker timer was set to arm the seeker 44 sec after take-off, but the seeker was armed 56.2 sec after take-off, and the missile then had passed the target. Probably a seeker timer component fault.

- During most of the flight IR-pulses were generated at the left bound of the seeker sectors. This was due to an incoupling transient of the seeker IR-preamplifier, which was removed on the succeeding seekers. The missile would have homed against the false IR-target even if the seeker timer had been OK, it would have taken decision on the false IR-target before the real target would have been detected.

The seeker detection of the real target is shown on 23.5.4 and decision on the false IR-target is shown on 23.5.5.

23.4.5 Control loops

23.4.5.1 Az control loops

See 23.5.1.

Mid-course guidance

V_{yeo}	1 m/s
ψ_{MP}	0.6 to 1°
Lateral int 2	- 5 to - 8 m
Oscillation	1° on 3 Hz
Lateral wind	- 2 to - 4 m/s
Missile velocity	280 - 300 m/s

Normal oscillation. ψ_{MP} was according to V_{yeo}, lateral wind and missile velocity. ψ_{MP} increased during the flight because the lateral wind increased with increasing distance from the shore.

Terminal guidance

ψ_{MP} according to tracking com Az.

23.4.5.2 Pi control loops

See 23.5.2.

Mid-course guidance

Average θ_{IP} 1.3°

Oscillation 1.2° pp 3.2 Hz

Normal oscillation. θ_{IP} according to altitude com.

Terminal guidance

θ_{IP} according to tracking com Pi.

23.4.6 Gas servo

OK.

23.4.7 AC-power supply

OK.

23.4.8 Thermal batteries

OK.

Positive batteries: 31 V at take-off, decreasing to 30.7 V at the end of the flight

Negative batteries : - 30.7 V , constant during the flight.

23.5 Telemetry and missile trajectory recordings

Lateral control signals on 23.5.1.

Altitude control signals on 23.5.2.

Motor pressures and altimeter ΔH on 23.5.3.

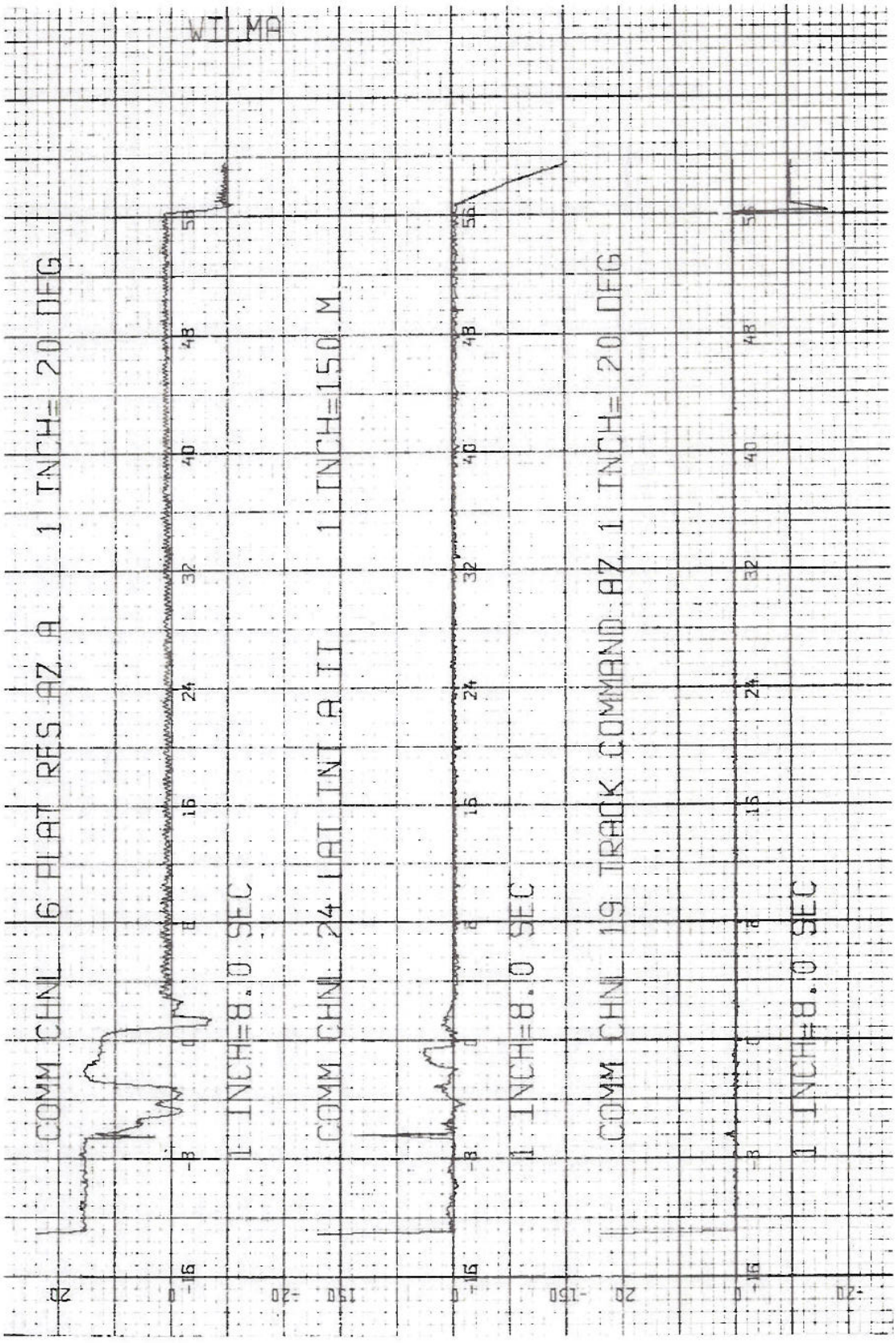
Seeker signals (detecting of the target) on 23.5.4.

Seeker signals (decision on the false IR-target) on 23.5.5.

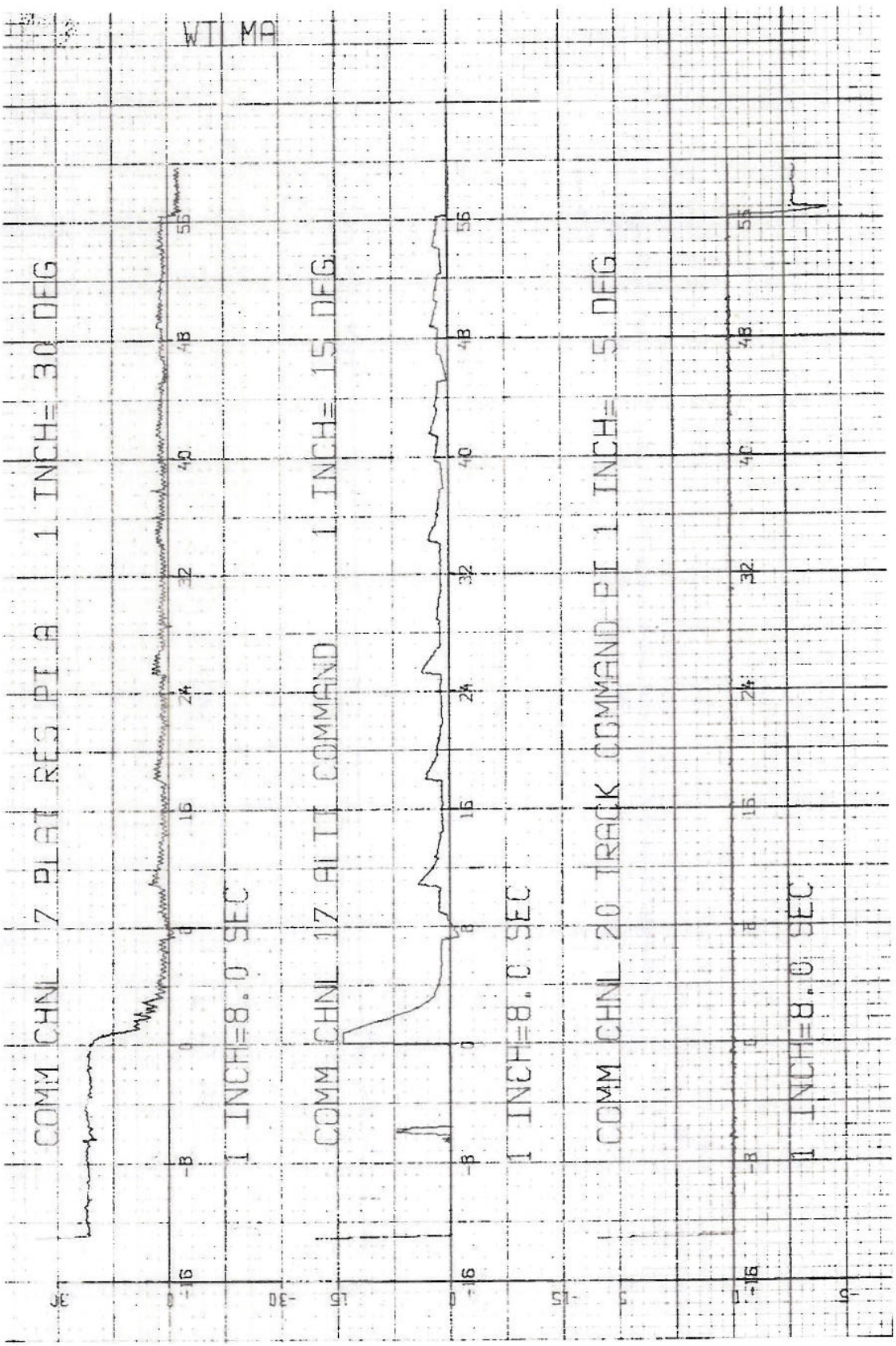
Vertical and horizontal projection of the missile trajectory on 23.5.6.

Time ref: T = 0 is take-off, except for 23.5.5 where T = 0 is decision.

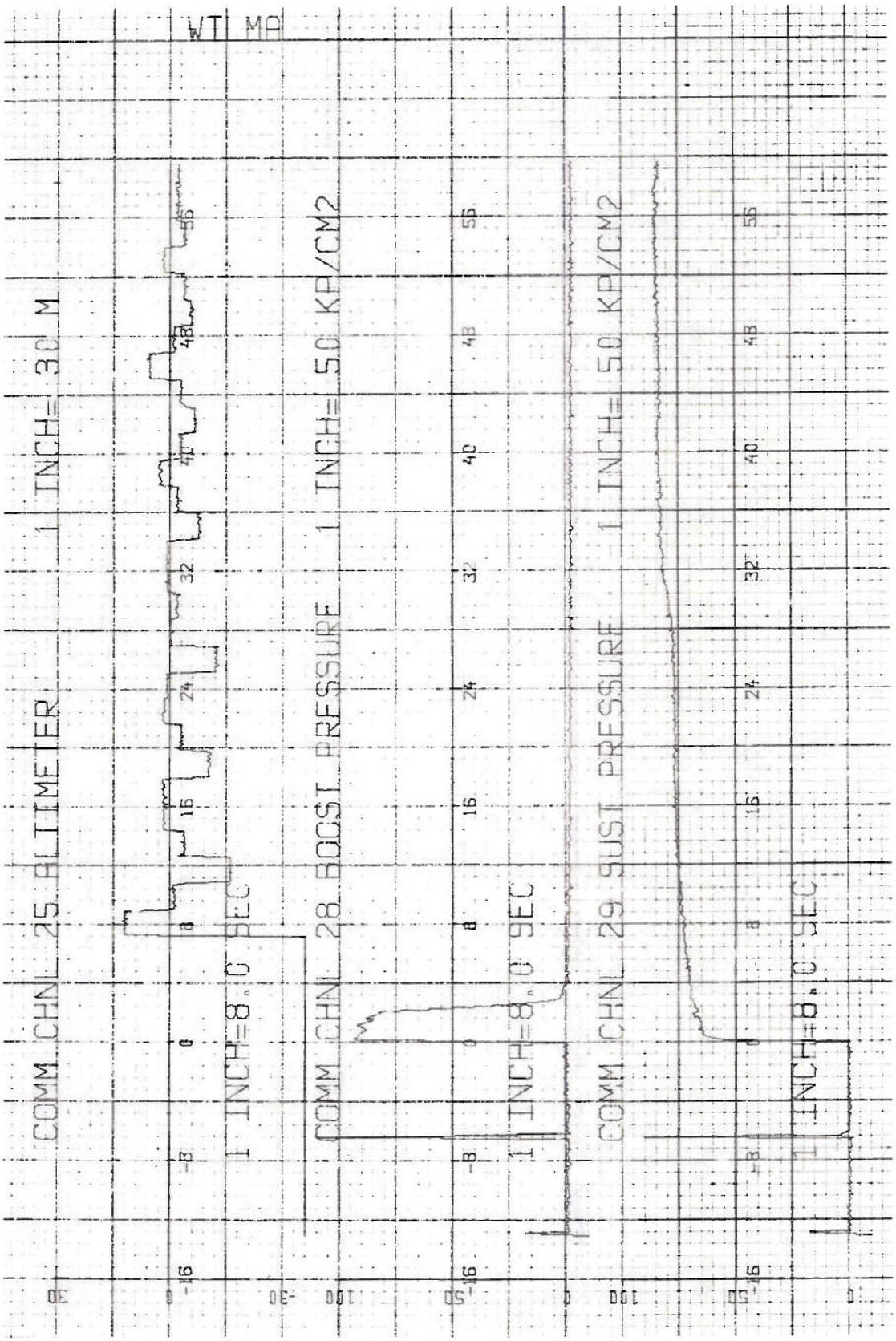
23.5.1 Lateral control signals



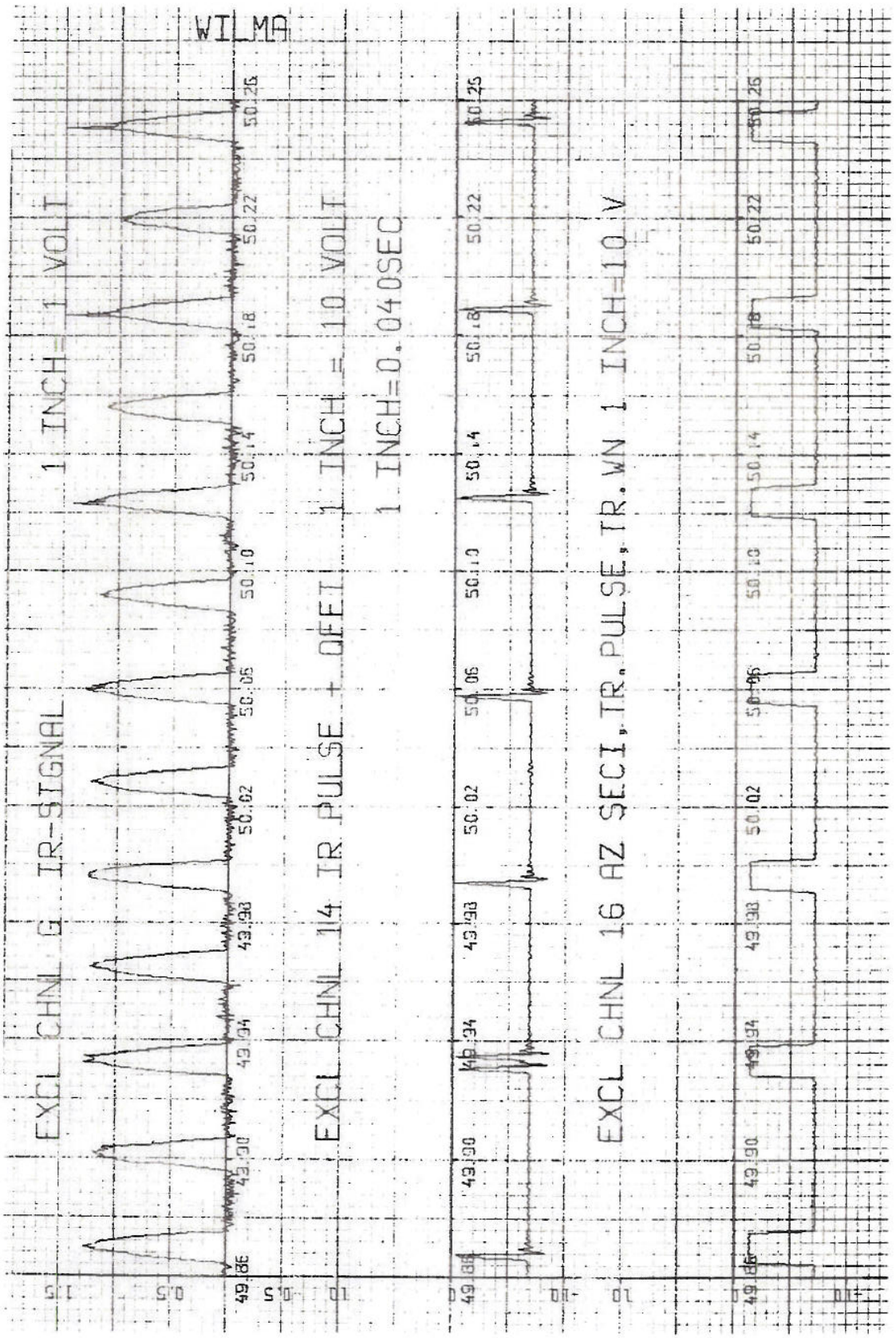
23.5.2 Altitude control signals



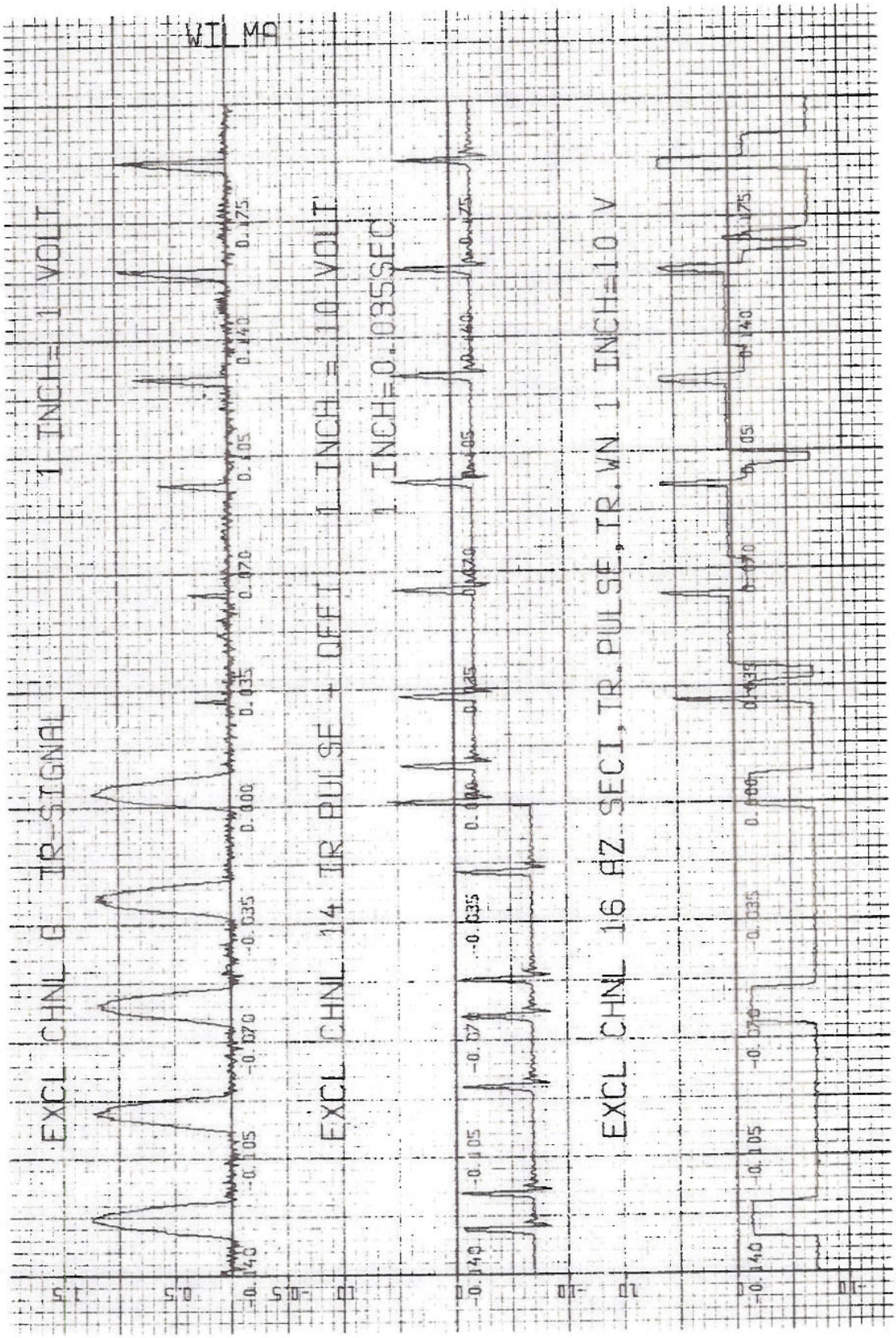
23.5.3 Motor pressures and altimeter ΔH



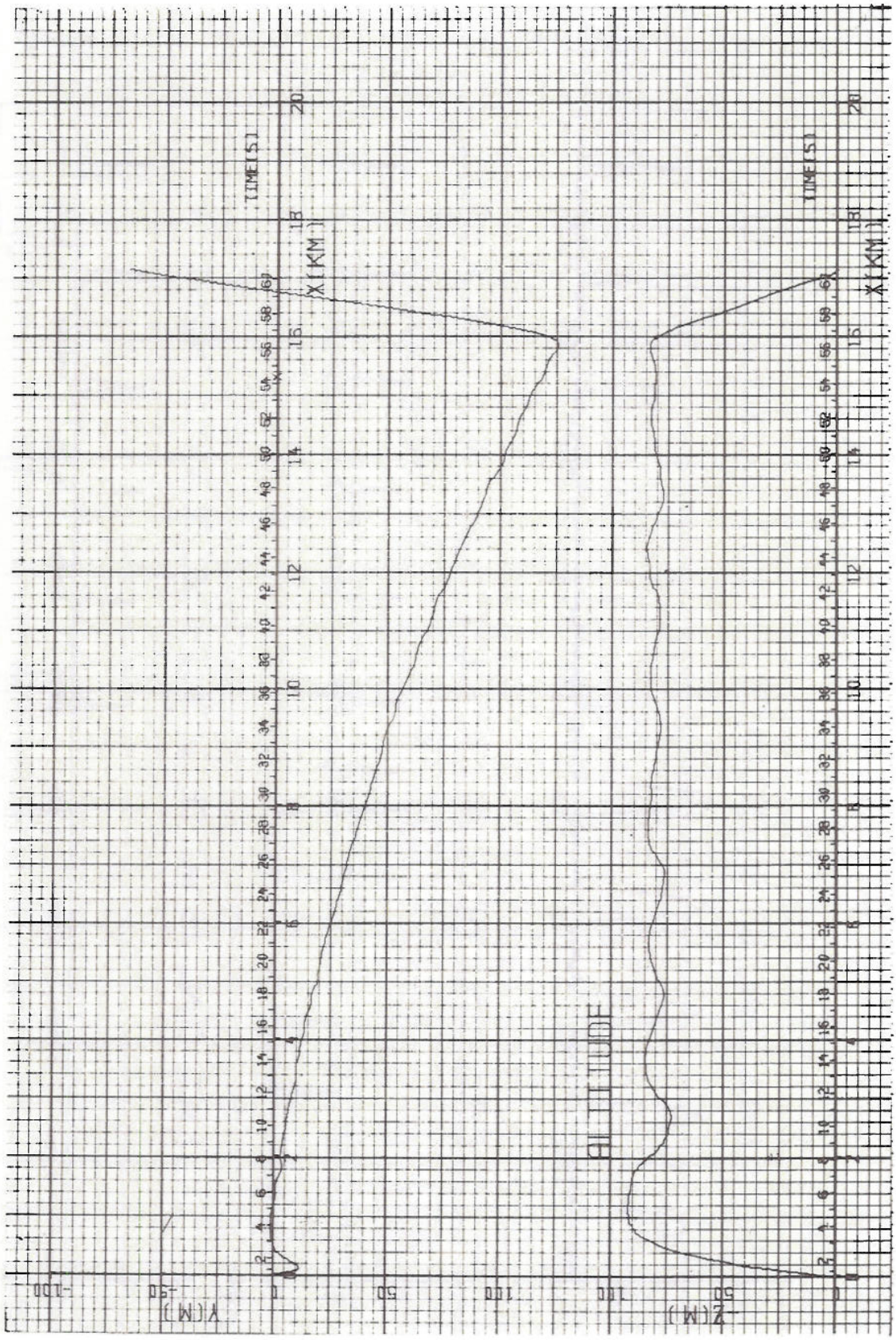
23.5.4 Seeker signals. Detecting of the target



23.5.5 Seeker signals. Decision on the false IR-target



23.5.6 Missile trajectory



23.6 Summary

Missile W was launched against ex-KNM "Reinøysund" 21/8-1970 at a distance of 15 100 m. Due to 2 seeker errors the missile did not home against the target. The lateral guidance was accurate, and the missile passed 120 m to the right of the target center.

The launching and control system NDRE NOR 2 was used for the first time, and functioned satisfactorily.

24 MISSILE X, DESCRIPTION

24.1 Aim

To hit a target at long range.

24.2 Technical description of the missile

24.2.1 Motor

24.2.1.1 Booster motor

Double base propellant, R3 X (Norwegian)	41.8 kg
Inhibitors	1.65 kg
Start thrust	3950 kp
Final thrust	3600 kp
Burning time	2.32 sec
Total impulse	8740 kps

24.2.1.2 Sustainer motor

Double base propellant, R4 X (Norwegian)	44.9	kg
Inhibitors	1.88	kg
Thrust	130	kp
Burning time	69	sec
Total impulse	8940	kps

24.2.2 Warhead

Inert warhead.

24.2.3 Guidance section

E-07.

Protection bag mounted at NDRE, removed onboard KNM "Traust".

24.2.3.1 Seeker

E-03.

Modifications at NDRE:

- Telemetry electronics mounted
- New type of secondary mirrors mounted.

24.2.3.2 Gas servo

E-01 (Electronics E-01, Gas generator E-05).

Modifications at NDRE:

- Firing circuit resistor changed from 5.6 Ω to 1 Ω.

24.2.3.3 Altimeter

E-08.

Laser effect 63 W.

Modifications at NDRE:

- α_t changed from 0.95° to 1.15°.

24.2.3.4 Platform

E-09.

24.2.3.5 AC-power supply

E-08.

24.2.3.6 Control unit

E-07.

24.2.3.7 Thermal batteries

Unknown. 83, 84 and 85 originally mounted at KV.

24.2.3.8 Control section

E-07.

Modifications at NDRE:

- Battery firing circuit resistors removed
- 2 vibration accelerometers with telemetry amplifiers mounted.

24.2.3.9 Control parameters

Main control loop Az	$6.3^{o}/o$
Lateral compensation	$0.14^{o}/m$
Tracking com Az	$K_{\psi_{\varepsilon n}} = 2.41^{o}/o$ $K_{\psi_{s1}} = 0.58^{o}/o$
Main control loop Pi	$6.0^{o}/o$
Altitude com	$0.19^{o}/m$ $\alpha_H = 1.3^{o}$ $\alpha_t = 1.15^{o}$
Tracking com Pi	$K_{\theta_{\varepsilon n}} = 2.31^{o}/o$ $K_{\theta_{s1}} = 0.46^{o}/o$
Href	82 m

24.2.4 Telemetry

Telemetry channels as listed in 6.3.1.

24.3 Equipment onboard KNM "Traust"

24.3.1 Launching and control system

NDRE NOR 2.

24.3.2 Launcher

Strømmen II

Port front position

Elevation 21.5^{o}

Azimuth -15^{o}

24.4 Target

ex-KNM "Reinøysund".

24.5 Photography

Camera on escort boat 1

High speed camera onboard KNM "Traust"

35 mm Artiflex camera - " -

2 Bolex cameras on the target.

24.6 Missile test at NDRE and KV

24.6.1 Acceptance test

11 - 12/5 - 1970 OK.

24.6.2 Subsystem test

24.6.2.1 Seeker

OK.

24.6.2.2 Altimeter

OK.

24.6.3 Guidance/warhead section test I

24.6.3.1 Test at NDRE

OK.

24.6.3.2 Vibration test at KV

27/5 - 1970.

4 runs lateral

4 runs axial

20 - 2000 - 20 Hz

1 octave/min

1 g peak

OK.

24.7 Guidance/warhead section test II

24.7.1 Test with NDRE NOR 2 at NDRE

Missile X was to be used for testing of NDRE NOR 2 at NDRE, See 22.7. Missile X was connected to NDRE NOR 2 17/6. The thermal batteries were fired because of a short circuit of the thermal battery squibs in NDRE NOR 2 (The short circuit was ment as an extra protection, but resulted in current through the battery squibs). The batteries were exchanged.

Missile X was used for testing till NDRE NOR 2 was mounted onboard KNM "Traust" for further testing.

24.7.2 Vibration test at KV

5 - 6/8 - 1970.

3 runs lateral

3 runs axial

20 - 2000 - 20 Hz

1 octave/min

1 g peak

OK.

24.8 Complete weapon system test at Haakonsvern and Tananger

Launcher with missile mcunted onboard KNM "Traust" 11/8.

Carefully testing of NDRE NOR 2 (12 - 18/8).

Arrival Tananger 18/8.

Seeker breakdown 18/8. Seeker sent to KV, where the slip-ring and the IR-preamplifier were exchanged. Returned 21/8.

24.9 Launching attempts

22/8 - 1970 1100.

Cancelled on X-6 minutes. The seeker IR-signal was weak, this could be due to cooling problems. Return Tananger for filling of liquid N_2 and check of the cooling system. The cooling system was OK, the weak IR-signal was due to smooth temperature distribution over the launcher. (An artificial IR-target was mounted in the launchers of the succeeding missiles).

24.10 Launching

Date		22/8 - 1970 1258
Distance	to target	15 400 m
Direction	to target	273.2°
Weather:	Sight	30 km
	Cloud cover	8/8
	Wind	7 m/s from E
	Temperature	15°C
	Sea state	1

25 MISSILE X, VALUATION

25.1 Data systems

25.1.1 Telemetry

Good data.

25.1.2 Cinetheodolites

T1: Good data

T2: Good data

T3: Good data

T4: Good data.

25.1.3 Photography

Escort boat 1 camera: The whole missile trajectory

High-speed camera on KNM "Traust": Take-off

Artiflex camera - " - : Launcher opening.

25.2 Equipment onboard KNM "Traust"

25.2.1 Launching and control system

OK.

The missile flight was too short to calculate fire control accuracy.

25.2.2 Launcher

OK.

25.3 Missile flight

See 25.5.4.

25.3.1 Boost phase

The boost phase was normal, except that the altitude was lower than usual. This was because of a platform Pi misalignment of -2.8°, see 25.4.2. The missile velocity at the end of the boost phase was 278 m/s.

25.3.2 Mid-course phase

Because of the -2.8° platform Pi misalignment, the missile hit the sea surface after a flight of 1800 m. The first altitude sample was at 7.1 sec when the altitude was 7 m. Min range of the altimeter (H_{min}) is 40 m, but it would have been too late to avoid the splash down even if $H_{min} = 0$ m.

The lateral guidance was OK.

The missile rolled clockwise, 0.48 Hz.

25.3.3 Terminal phase

No terminal phase.

25.4 Missile subsystems

25.4.1 Motor

See 25.5.3.

25.4.1.1 Booster motor

Burning time	2.60 sec
Velocity at burn out	278 m/s
Pressure	Normal, max 105 kp/cm^2
Acceleration (start)	125 m/s^2

25.4.1.2 Sustainer motor

Normal during the short flight.

25.4.2 Platform

Pitch misalignment of - 2.8° , probably because of high frequency noise during the alignment period. See 13.4.2.

25.4.3 Altimeter

See 25.5.2 and 25.5.3.

The altimeter made 1 altitude sample, but the altitude was only 7 m and accordingly below min range. Altitude com was OK.

25.4.4 Seeker

Normal (only boost and mid-course phase).

25.4.5 Control loops

25.4.5.1 Az control loops

See 25.5.1.

Mid-course guidance

V_{yeo}	1 m/s
ψ_{MP} (7.5 sec)	≈ 0^{o}
Lateral int 2 (7.5 sec)	3 m
Oscillation	2.0^{o} pp 3 Hz
Lateral wind	≈ 0 m/s
Missile velocity	278 m/s

Normal oscillation. The flight was too short for ψ_{MP} and lat int 2 to get their "static" values, but ψ_{MP} seemed to would have stabilized on approximately 0^{o} according to V_{yeo}, lateral wind and missile velocity.

Terminal guidance

None.

25.4.5.2 Pi control loops

See 25.5.2.

Mid-course guidance

Average θ_{MP}	1.2^{o}
Oscillation	1.5^{o} pp 2.8 Hz

Normal oscillation. θ_{MP} according to altitude com.

Terminal guidance

None.

25.4.6 Gas servo

OK.

25.4.7 AC-power supply

OK.

25.4.8 Thermal batteries

OK.

Positive batteries: 30.3 V , constant during the flight

Negative battery : - 31 V , - " -

25.5 Telemetry and missile trajectory recordings

Lateral control signals on 25.5.1.

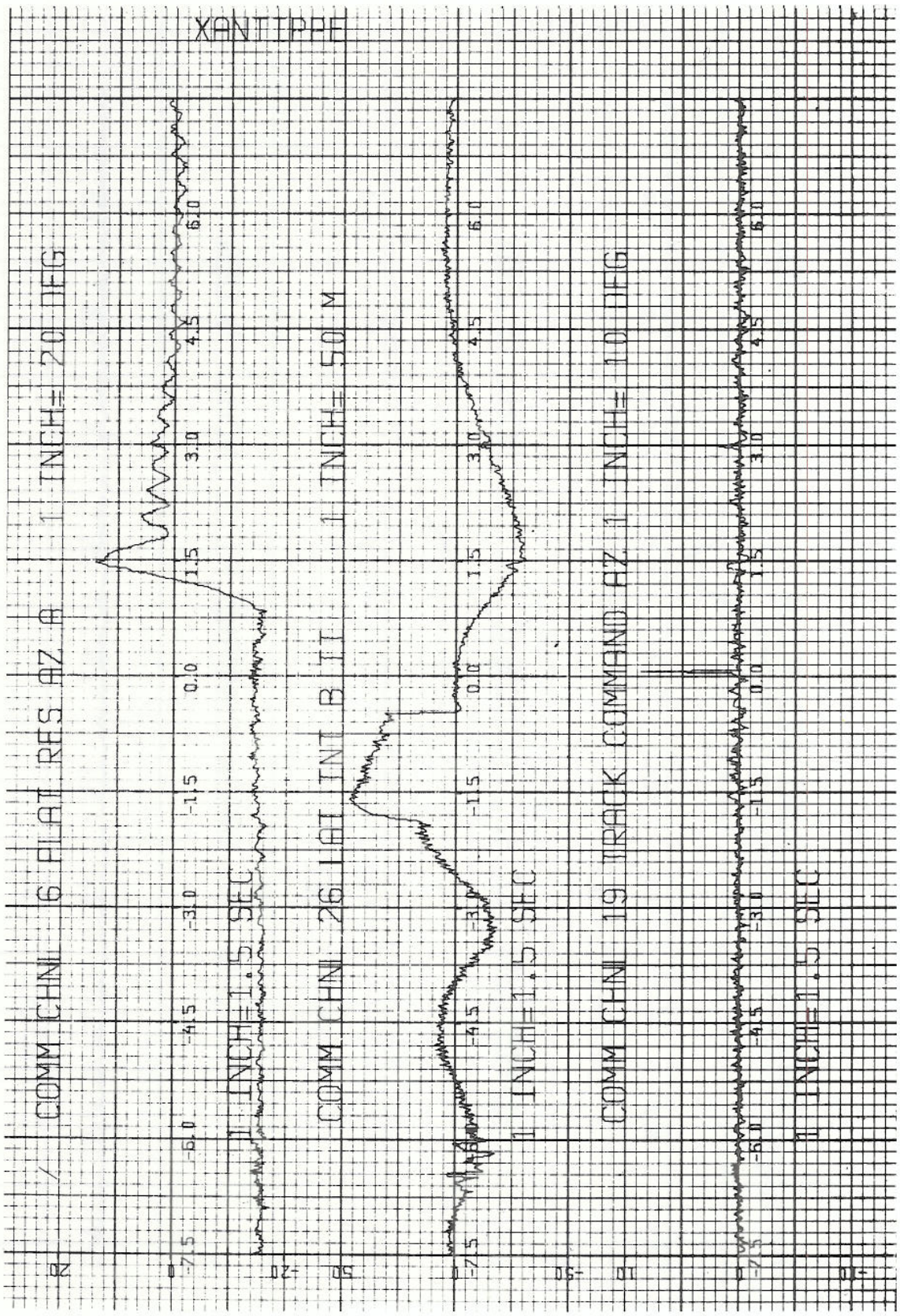
Altitude control signals on 25.5.2.

Motor pressures and altimeter ΔH on 25.5.3.

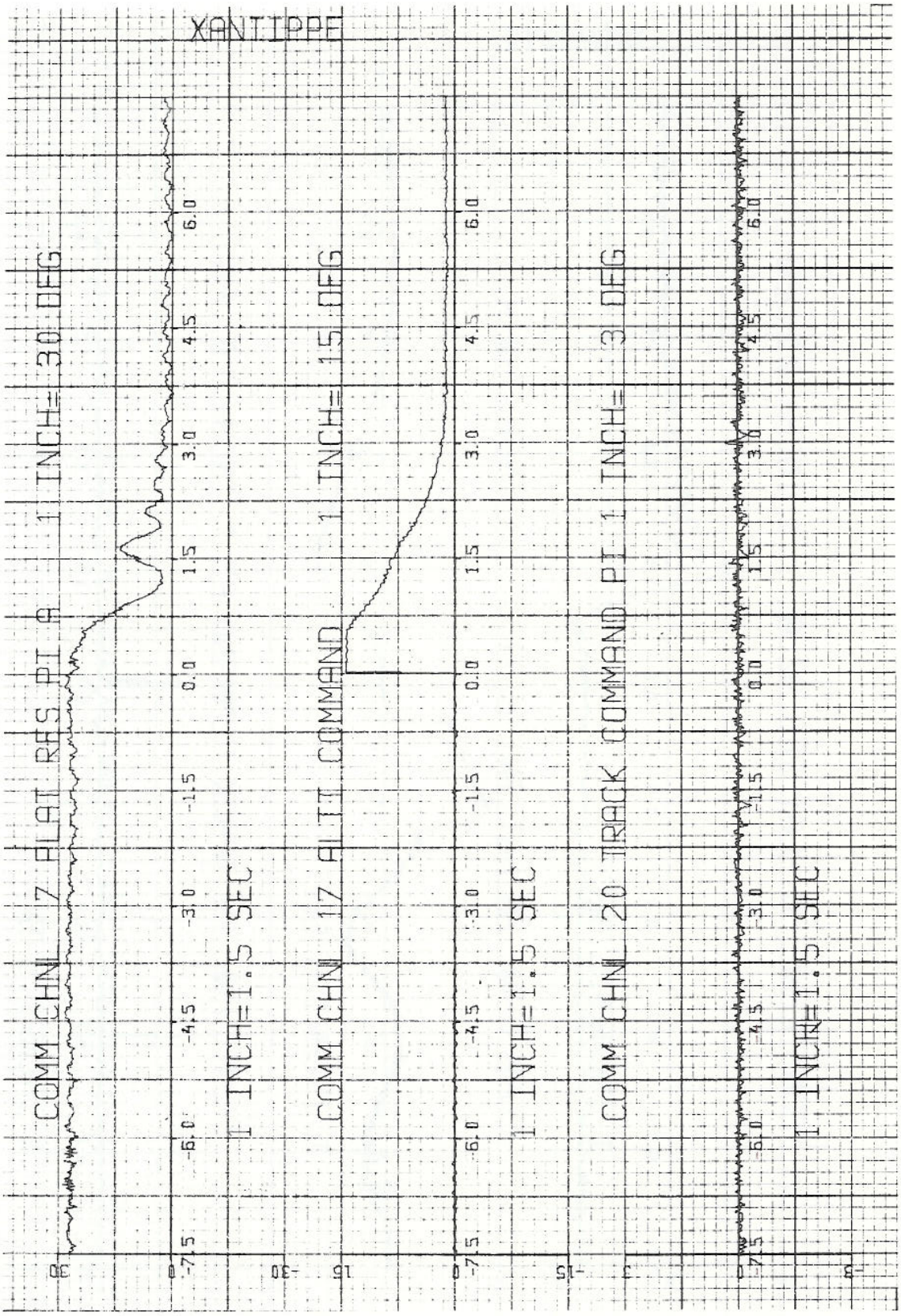
Vertical and horizontal projection of the missile trajectory on 25.5.4.

Time ref: T = 0 is take-off.

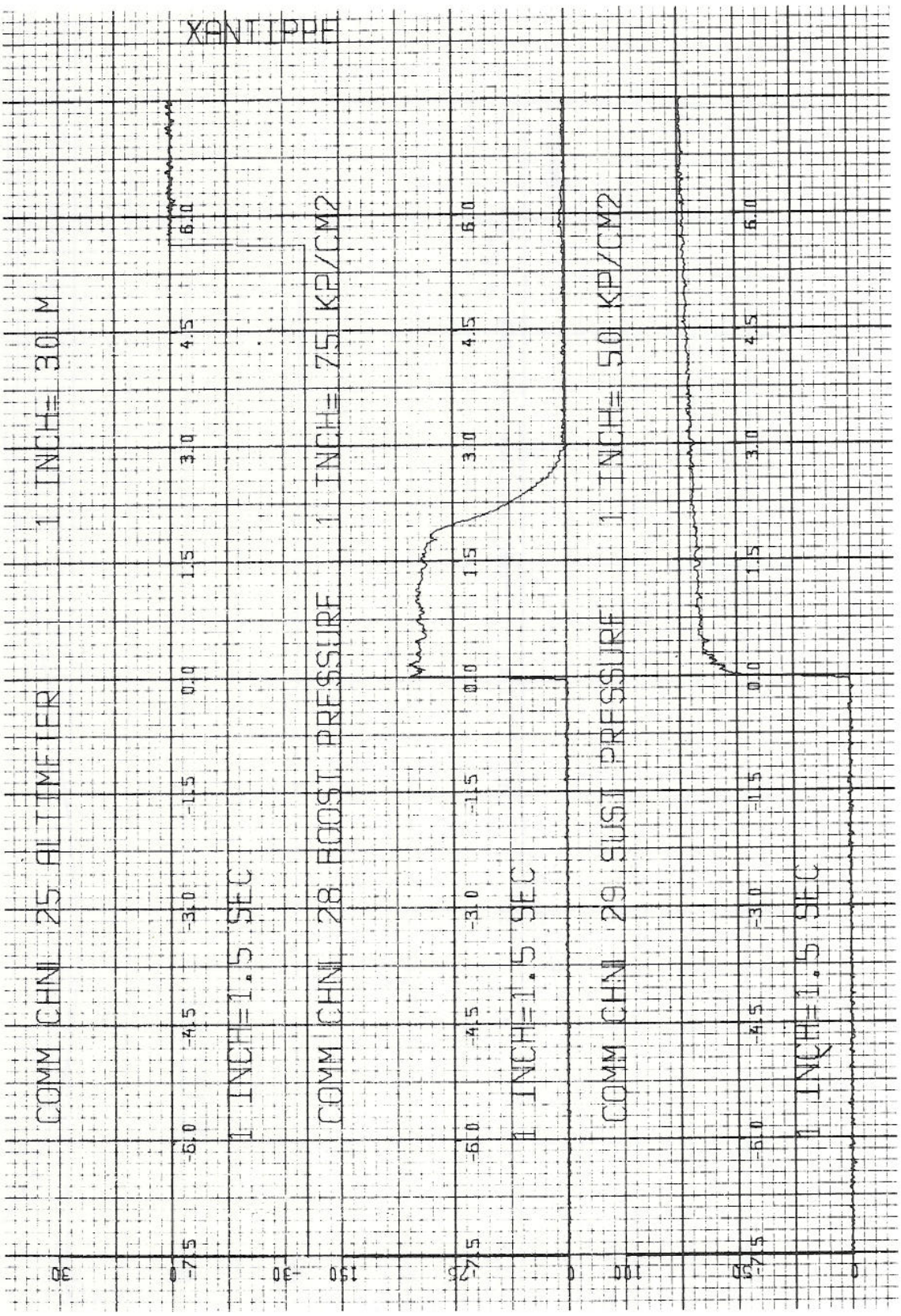
25.5.1 Lateral control signals



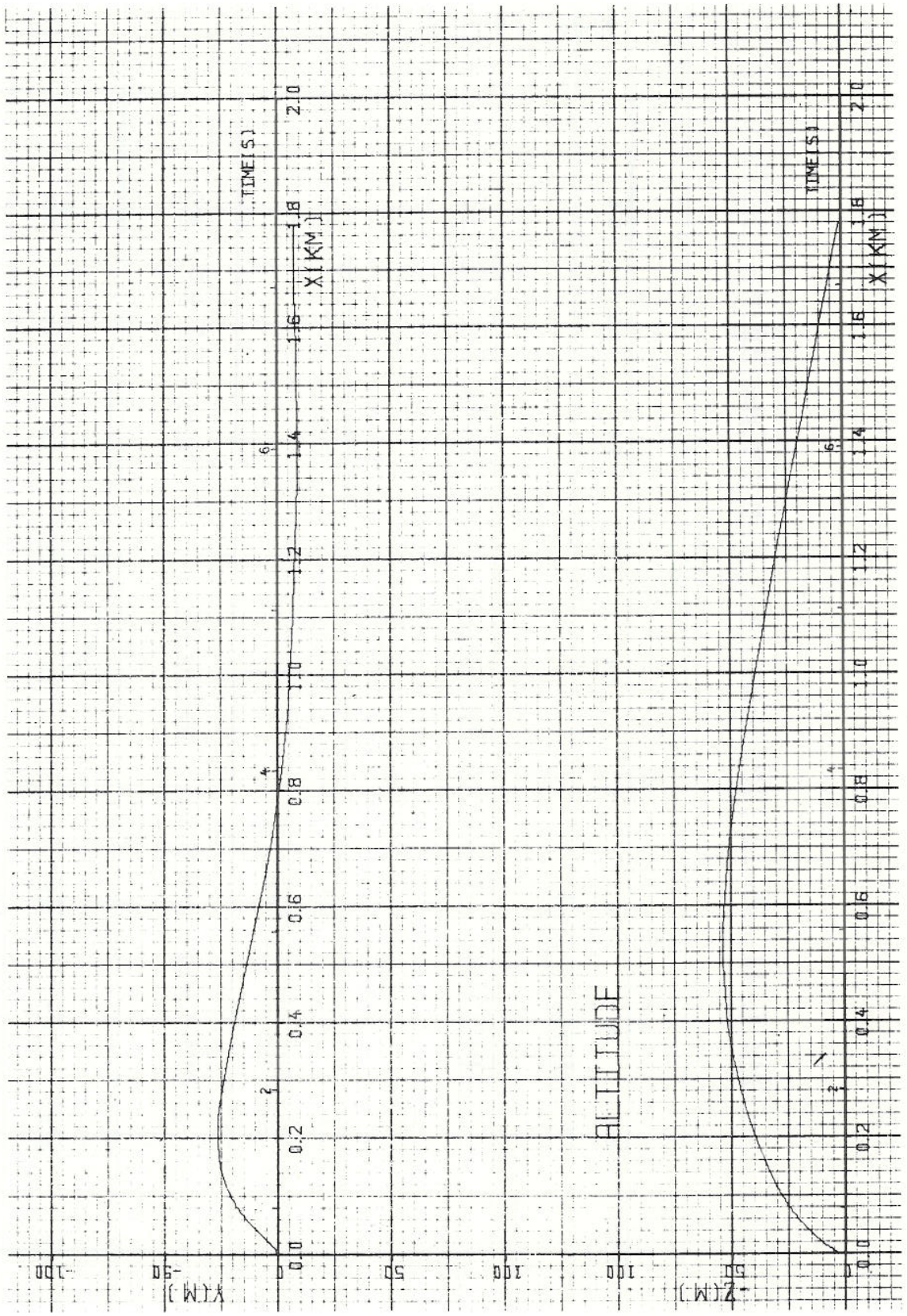
25.5.2 Altitude control signals



25.5.3 Motor pressures and altimeter ΔH



25.5.4 Missile trajectory



25.6 Summary

Missile X was launched against ex-KNM "Reinøysund" 22/8 - 1970 at a distance of 15 400 m. Due to a - 2.8° platform Pi misalignment, the missile hit the sea surface after a flight of 1800 m. The platform Pi misalignment was probably due to high frequency noise during the alignment period.

The rest of the system functioned satisfactorily.

26 MISSILE Q, DESCRIPTION

26.1 Aim

To hit a target at long range.

26.2 Technical description of the missile

26.2.1 Motor

26.2.1.1 Booster motor charge

Double base propellant, VU (British)	41.5	kg
Inhibitors	1.85	kg
Start thrust	4700	kp
Final thrust	2500	kp
Burning time	2.41	sec
Total impulse	8670	kps

26.2.1.2 Sustainer motor charge

Double base propellant, X-35 (Norwegian)	44.8	kg
Inhibitors	1.88	kg
Thrust	120	kp
Burning time	74	sec
Total impulse	8940	kps

26.2.2 Warhead

Inert warhead.

26.2.3 Guidance section

E-01.

26.2.3.1 Seeker

E-01 (Electronics E-01, Optical unit E-01).

Modifications at NDRE:

- Telemetry electronics mounted
- New type of secondary mirrors mounted.

26.2.3.2 Gas servo

E-03 (Electronics E-10, Gas generator E-01).

Modifications at NDRE:

- Firing circuit resistor changed from 5.6 Ω to 1 Ω.

26.2.3.3 Altimeter

E-01.

Laser effect 72 W.

Modifications at NDRE:

- α_t changed from 0.95° to 1.15°.

26.2.3.4 Platform

E-01.

26.2.3.5 AC-power supply

E-05.

26.2.3.6 Control unit

E-06.

26.2.3.7 Thermal batteries

Unknown. 28, 24 and 39 originally mounted at KV.

26.2.3.8 Control section

E-01.

Modifications at NDRE:

- Battery firing circuit resistors removed.

26.2.3.9 Control parameters

Main control loop Az	6.65°/o
Lateral compensation	0.134°/m
Tracking com Az	$K_{\psi_{\varepsilon n}}$ = 2.35°/o $K_{\psi_{s1}}$ = 0.56°/o
Main control loop Pi	6.35°/o
Altitude com	0.189°/m α_H = 1.3° α_t = 1.15°
Tracking com Pi	$K_{\theta_{\varepsilon n}}$ = 2.36°/o $K_{\theta_{s1}}$ = 0.47°/o
Href	82 m

26.2.4 Telemetry

Telemetry channels as listed in 6.3.1 except for ex ch 13 and ex ch 14 which were not used.

26.3 Equipment onboard KNM "Traust"

26.3.1 Launching and control system

KV MK1 MOD 1.

26.3.2 Launcher

Strømmen II

Starboard middle position

Evaluation 21.5°

Azimuth 15°

26.4 Target

ex-KNM "Reinøysund".

26.5 Photography

Camera on escort boat 1

High-speed camera onboard KNM "Traust".

26.6 Missile test at NDRE and KV

26.6.1 Acceptance test

9 - 10/9 - 1970 OK.

26.6.2 Subsystem test

26.6.2.1 Seeker

Mounting cylinder was not gas tight.

26.6.2.2 Altimeter

OK.

26.6.3 Guidance/warhead section test

26.6.3.1 Test at NDRE

- Altimeter fault. Module 1802 exchanged
- Platform fault. The capasitors over the gyroloop relay contacts short circuited. 50 V type exchanged with 100 V type.

26.6.3.2 Vibration test at KV

30/9 - 2/10 1970.

9 runs lateral

5 runs axial

20 - 2000 - 20 Hz

1 octave/min

1 g peak

Platform fault. The gyros did not start because of a bad connection on FEP II.

Altimeter fault because of bad soldering. The altimeter was re-soldered.

26.7 Complete weapon system test at Haakonsvern and Tananger I

Launcher with missile mounted onboard 7/10.

Control and launching system KV MK1 MOD 1 was to be used for launching of missile Q. Building and testing of the prototype model to be used started at NDRE ultimo April, and the testing onboard started 5/10. The testing was very time consuming because of the following reasons:

- The start sequence was modified
- The autotest was modified
- Autotest and slave electronics breakdowns
- The interface electronics between HSA and the digital computer SM4 was modified to make it more capable of noise resistance.
- The memory control of SM4 was modified because the contents of some memory cells were destroyed when HSA was connected to the system.

- Software modifications

The system was OK 28/10.

Arrival Tananger 29/10.

The platform was slaved over Az end stop because of uncorrect HSA data 3/12. The platform was repaired onboard.

The expedition was cancelled 6/11 because of HSA faults. The HSA system had to be re-wired, and this would take 2 - 3 weeks including testing. KNM "Traust" returned Haakonsvern. Launcher and missile stayed onboard.

26.8 Complete weapon system test at Haakonsvern and Tananger II

Test started 24/11. Some autotest and sequence electronics break downs.

Arrival Tananger 2/12.

26.9 Launching attempts

3/12 1250. The launcher was opened and the thermal batteries fired, but the firing sequence stopped. This was due to a fault in the firing sequence electronics of the launching and control system. R13 on firing sequence card 2 was 100 kΩ instead of 100 Ω . This circuit operated OK if the power supply voltage was < 30 V , but the voltage of the thermal batteries was 31 V , and the sequence stopped.

New batteries were sent from KV and mounted the same night. The guidance section was mounted on the missile 4/12. Test of complete missile.

5 - 7/12. Launching cancelled because of bad weather.

26.10 Launching

Date		8/12 - 1970 1028
Distance	to target	16800 m
Direction	to target	≈ 259°
Weather:	Sight	20 km
	Cloud cover	8/8
	Wind	10 m/s from NW
	Temperature	6°
	Sea state	2 - 3

27 MISSILE Q, VALUATION

27.1 Data systems

27.1.1 Telemetry

Good data.

27.1.2 Cinetheodolites

T1: Lacked 38 photos, mainly during 16.6 - 24.8 sec

T2: No data

T3: Bad data

T4: Good data

The resulting data were bad, because of weather conditions, synchronizing and lack of photos.

27.1.3 Photography

Escort boat 1 camera: The whole missile trajectory

High speed camera onboard KNM "Traust": Nothing, the camera was started too early.

27.2 Equipment onboard KNM "Traust"

27.2.1 Launching and control system

OK.

The fire control accuracy can not be calculated because the exact position of the target is unknown.

27.2.2 Launcher

OK.

27.3 Missile flight

See 27.5.4.

27.3.1 Boost phase

Normal. Missile velocity at the end of the boost phase was 261 m/s.

27.3.2 Mid-course phase

Normal till 25 sec. The missile then started to climb because of an altimeter fault, and the altitude was 300 m at 33.1 sec when the motor bursted because of too high sustainer motor pressure. The high sustainer motor pressure was independent of the missile trajectory.

The missile rolled clockwise 0.55 Hz.

27.3.3 Terminal phase

No terminal phase.

27.4 Missile subsystems

27.4.1 Motor

See 27.5.3.

27.4.1.1 Booster motor

Burning time	2.55 sec
Velocity at burn out	261 m/s
Pressure	Normal, max 86 kp/cm^2
Acceleration (start)	132 m/s^2

27.4.1.2 Sustainer motor

The pressure was normal till 18 sec. The pressure then increased from 75 kp/cm^2 to 135 kp/cm^2 (31 sec), which is max pressure for the pressure transducer. The pressure increased further, and was probably appr 160 kp/cm^2 at motor burst (33.1 sec). See 13.4.1.2 and 23.4.1.2.

The pressure in the normal period (4 - 18 sec) was 71 - 75 kp/cm^2, which gives a thrust of 101 kp. This was too little to maintain the velocity, and the missile retardered from 261 m/s at booster burn out to 247 m/s (18 sec).

27.4.2 Platform

OK.

27.4.3 Altimeter

See 27.5.2 and 27.5.3.

Normal till 25 sec. 10 altitude samples, none of these was a no return measurement. It is difficult to calculate the accuracy of the altimeter measurements because of the bad cinetheodolite data. Altitude com according to the altitude measurements.

At 25 sec the altimeter gave max up order, and did so at each altitude sample during the rest of the flight. The explanation is probably as follows:

It was connection between A,i and Buffer 1809, but the connection between A,i and Control 1813 had disappeared after the last time the missile was tested on shore (2/10 - 1970). Probably this have happened during the flight, but if it happened before, it could not be detected during testing onboard. At 25 sec the altimeter made a no return measurement. Because of the fault described above, this resulted in a max up order and the missile started to climb. Because of the great altitude (120 m) and missile Pi angle ($\theta_{MP} = 6^{\circ}$), the next altitude measurement also was a no return measurement, and caused a max up order. When the next altitude measurement was made, the altitude was 190 m , which is above altimeter max range, and the altimeter made a no return measurement, and so forth.

27.4.4 Seeker

Normal (only boost and mid-course phase).

27.4.5 Control loops

27.4.5.1 Az control loops

See 27.5.1.

Mid course guidance

V_{yeo}	0 m/s
ψ_{MP}	1.5^{o}
Lateral int 2	- 10 m
Oscillation	1.5^{o} pp 3 Hz
Lateral wind	- 7 m/s
Missile velocity	255 m/s

Normal oscillation. ψ_{MP} was according to V_{yeo}, lateral wind and missile velocity.

Terminal guidance

None.

27.4.5.2 Pi control loops

See 27.5.2.

Mid-course guidance

Average θ_{MP} (5 - 18 sec)	1.3^{o}
Oscillation	1.5^{o} pp 3.1 Hz

Normal oscillation. θ_{MP} according to altitude com.

Terminal guidance

None.

27.4.6 Gas servo

OK.

27.4.7 AC-power supply

OK.

27.4.8 Thermal batteries

OK.

Positive batteries: 29.7 V , constant during the flight

Negative battery : - 30.7 V , constant during the flight.

27.5 Telemetry and missile trajectory recordings

Lateral control signals on 27.5.1

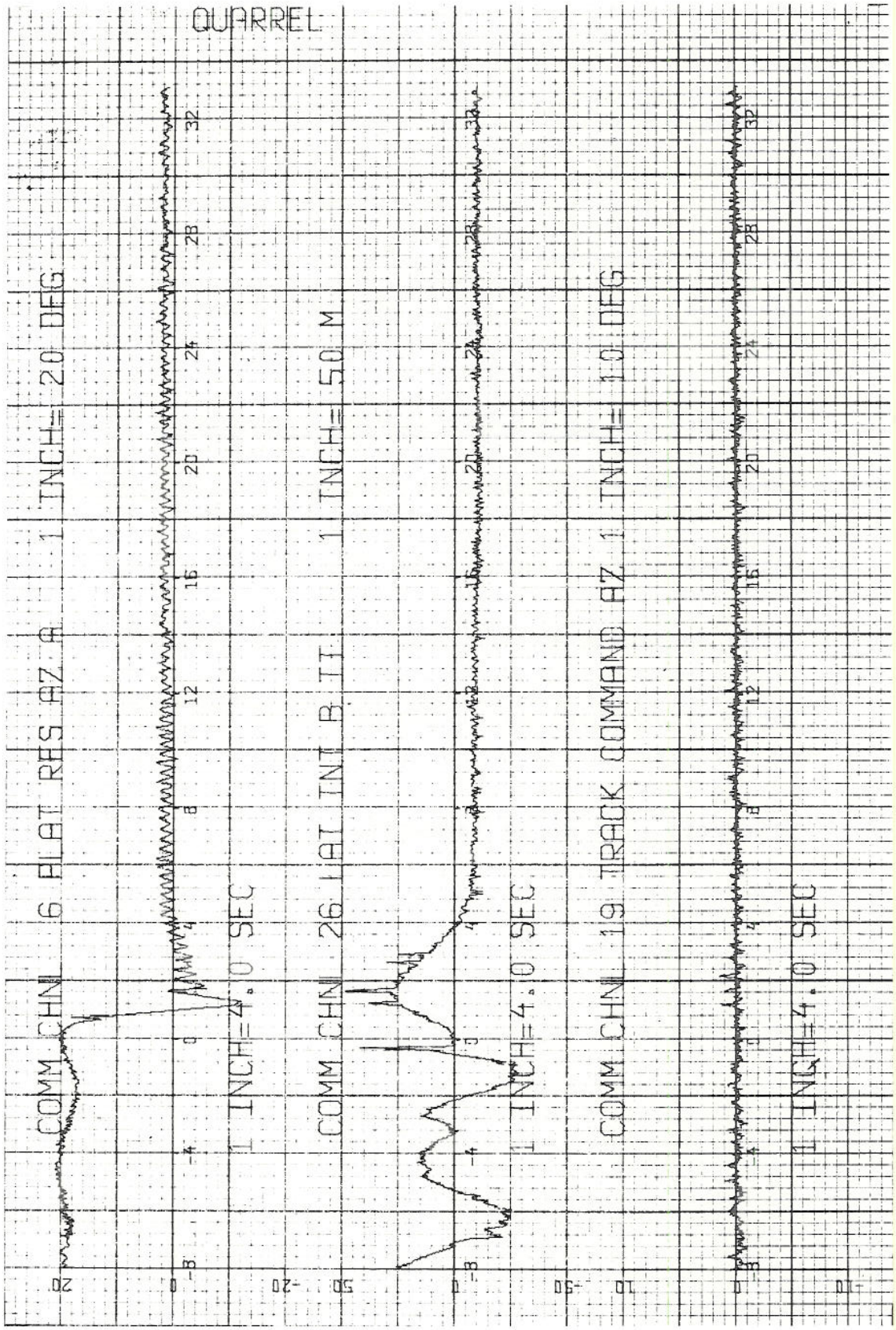
Altitude control signals on 27. 5.2

Motor pressures and altimeter ΔH on 27.5.3

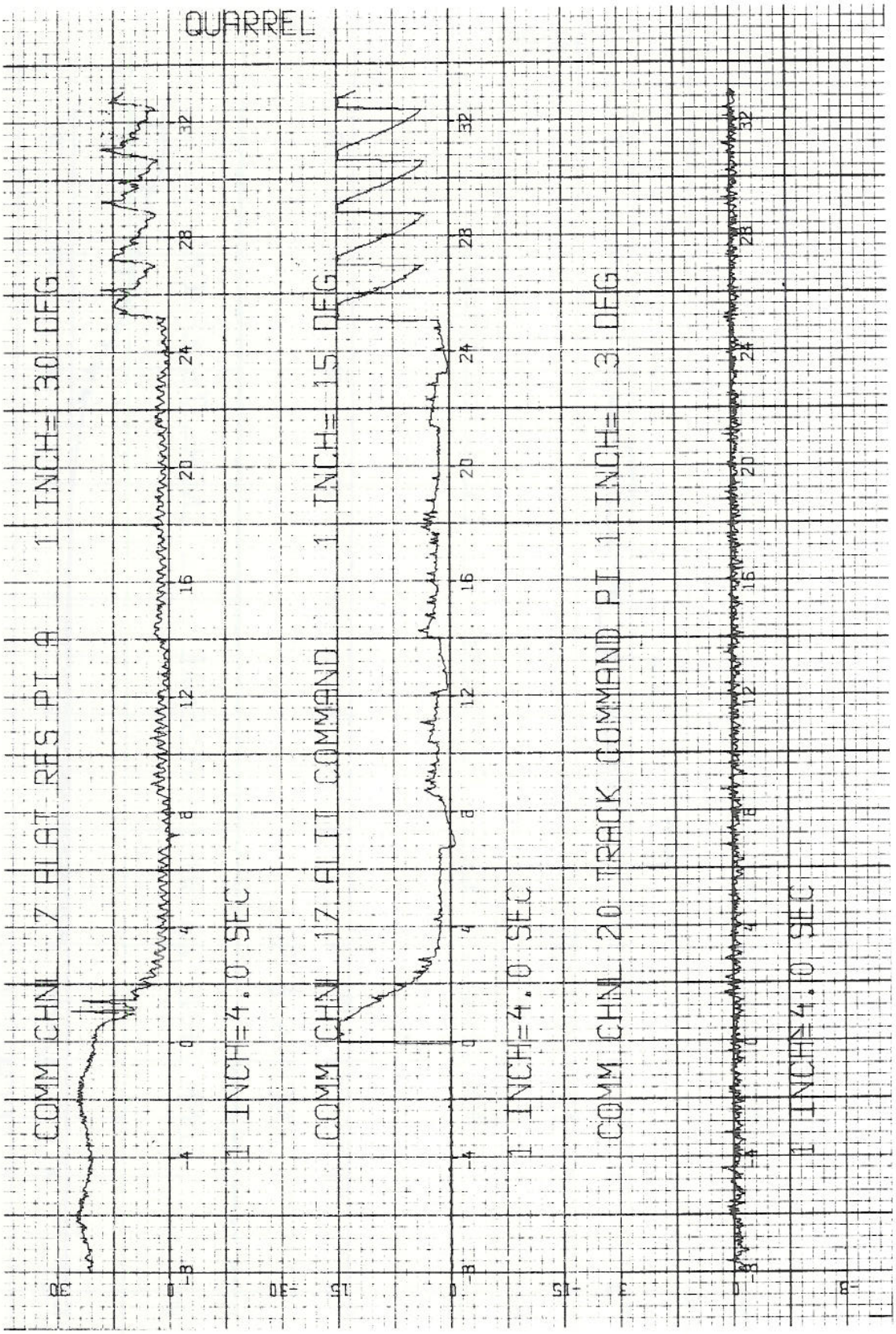
Vertical and horizontal projection of the missile trajectory on 27.5.4.

Time ref: T = 0 is take-off.

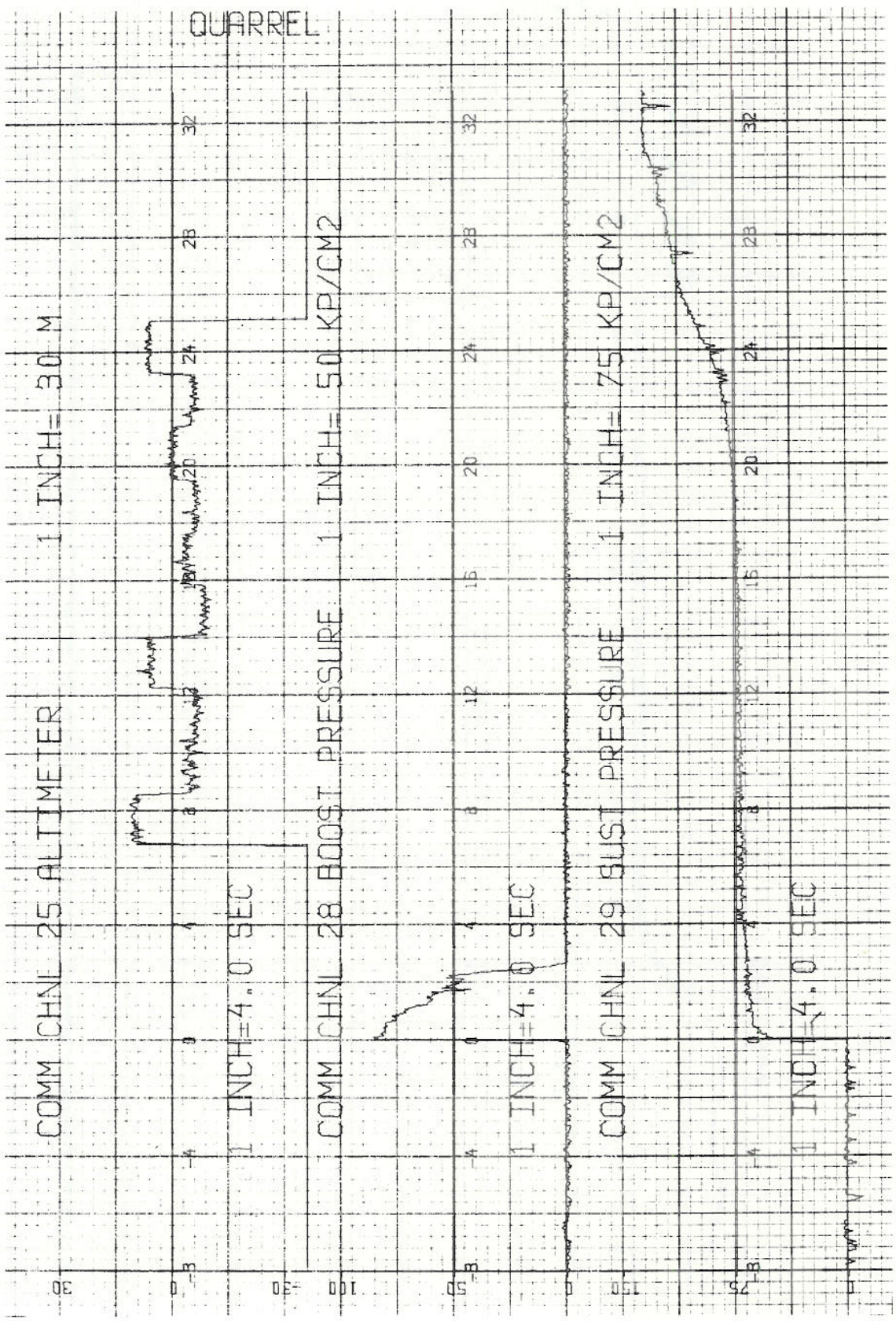
27.5.1 Lateral control signals



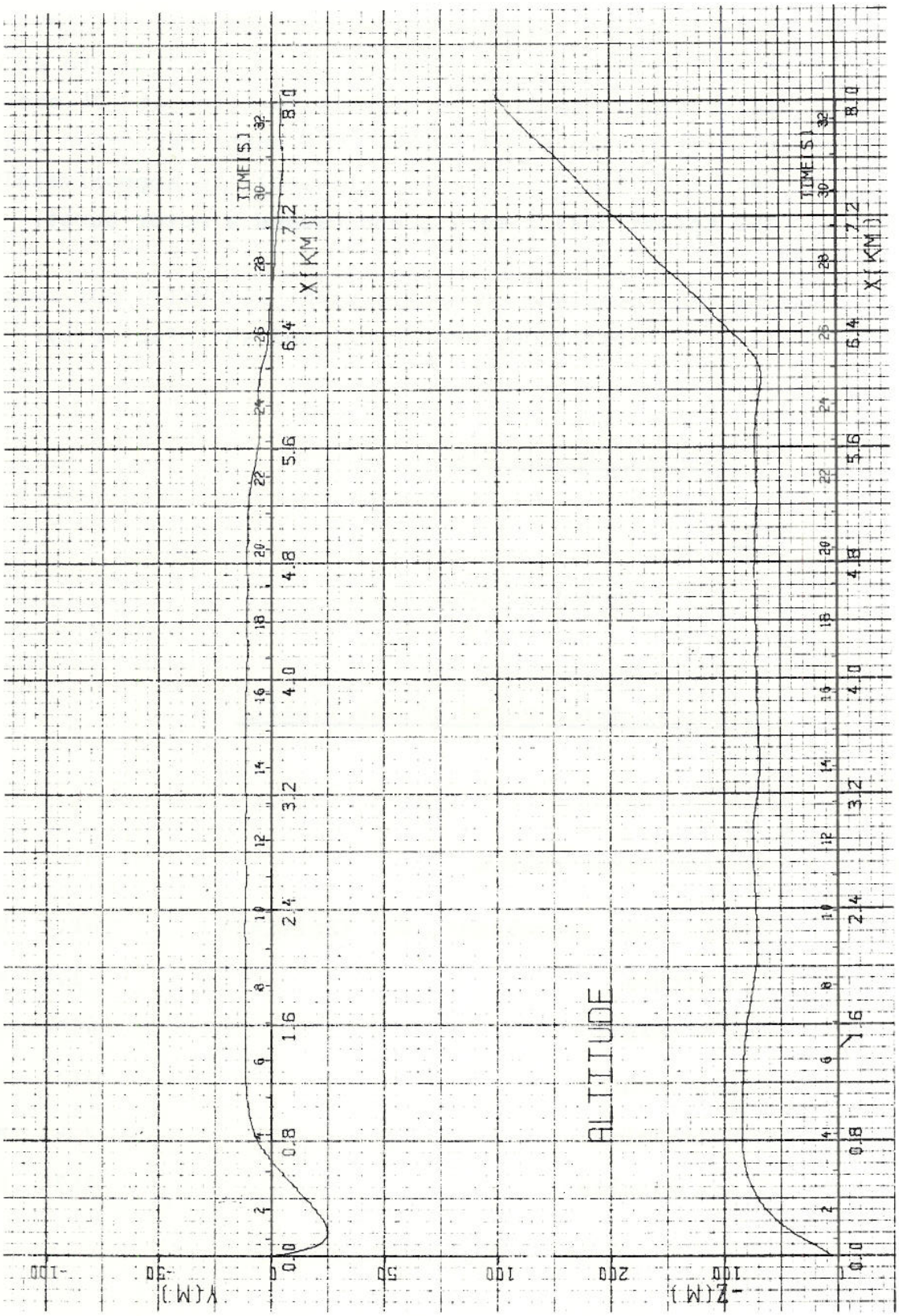
27.5.2 Altitude control signals



27.5.3 Motor pressures and altimeter ΔH



27.5.4 Missile trajectory



27.6 Summary

Missile Q was launched against ex-KNM "Reinøysund" 8/12 - 1970 at a distance of 16 800 m. Due to an altimeter fault the missile started to climb at 25 sec. The trajectory slope was 7.6°. The sustainer motor pressure increased from 80 kp/cm² (18 sec) to approximately 160 kp/cm² (33.1 sec), and caused a motor burst.

The launching and control system KV MK1 MOD1 was used for the first time, and functioned satisfactorily.

28 MISSILE Y, DESCRIPTION

28.1 Aim

To hit a target at long range.

28.2 Technical description of the missile

28.2.1 Motor

28.2.1.1 Booster motor charge

Double base propellant, VU (British)	41.4	kg
Inhibitors	1.85	kg
Start thrust	4700	kp
Final thrust	2500	kp
Burning time	2.41	sec
Total impulse	8670	kps

28.2.1.2 Sustainer motor charge

Double base propellant, IMI-OTO/10 (British)	43.0	kg
Inhibitors	3.47	kg
Thrust	110	kp
Burning time	77	sec
Total impulse	8390	kps

Modifications at NDRE:

- Rubber ring between the charge and the motor cover. This was done to lock the charge pneumaticly to the motor cover.

28.2.2 Warhead

Inert warhead.

28.2.3 Guidance section

E-09.

28.2.3.1 Seeker

E-10 (Electronics E-10, Optical unit E-10).

Modifications at NDRE:

- Telemetry electronics mounted
- New type of secondary mirrors mounted
- New type of IR-pre-amplifier (1710B) mounted
- RF-EMI filter on Az motor wires and the pre-amplifier power supply.

28.2.3.2 Gas servo

E-10 (Electronics E-08, Gas generator E-10)

Modifications at NDRE:

- Firing circuit resistor changed from 5.6 Ω to 1 Ω.

28.2.3.3 Altimeter

E-03.

Laser effect 67 W.

Modifications at NDRE:

- α_t changed from 0.95° to 1.15°.

28.2.3.4 Platform

E-04 (E-03 originally mounted at KV).

28.2.3.5 AC-power supply

E-03 (E-10 originally mounted at KV).

28.2.3.6 Control unit

E-09.

28.2.3.7 Thermal batteries

90

89

99.

28.2.3.8 Control section

E-09.

Modifications at NDRE:

- 2 vibration accelerometers with telemetry amplifiers mounted
- Battery firing circuit resistors removed.

28.2.3.9 Control parameters

Main control loop Az	6.13°/o
Lateral compensation	0.136°/m
Tracking com Az	$K_{\psi_{\varepsilon n}}$ = 2.37°/o $K_{\psi_{sl}}$ = 0.57°/o
Main control loop Pi	6.76°/o
Altitude com	0.19°/m α_H = 1.3° α_t = 1.15°
Tracking com Pi	$K_{\theta_{\varepsilon n}}$ = 2.32°/o $K_{\theta_{sl}}$ = 0.46°/o
Href	82 m

28.2.4 Telemetry

Telemetry channels as listed in 6.3.1.

28.3 Equipment onboard KNM "Traust"

28.3.1 Launching and control system

KV MK1 MOD 1.

28.3.2 Launcher

Strømmen III

Port front position

Elevation 21.5°

Azimuth - 15°

28.4 Target

ex-KNM "Reinøysund".

28.5 Photography

Camera on escort boat 1

High speed camera onboard KNM "Traust".

28.6 Missile test at NDRE and KV

28.6.1 Acceptance test

26 - 27/5 - 1970 OK.

28.6.2 Subsystem test

28.6.2.1 Seeker

- Mounting cylinder was not gas tight
- Seek threshold incorrectly adjusted.

28.6.2.2 Altimeter

OK.

28.6.3 Guidance/warhead section test I

28.6.3.1 Test at NDRE

- Platform fault. The capasitors over the gyroloop relay contacts short circuited. Platform E-03 exchanged with E-04 (taken from missile Z. E-04 had the same capasitor fault, but was repaired at this moment. See 30.6.3.1).

- AC-power supply fault. Defect 3200 Hz supply. AC-power supply E-10 exchanged with E-03 (taken from missile Z).

28.6.3.2 Vibration test at KV

28/9 - 1/10 - 1970.

6 runs lateral

6 runs axial

20 - 2000 - 20 Hz

1 octave/min

1 g peak

Seeker fault. IR-signal abnormal during vibrations. Seeker E-10 exchanged with E-01 (taken from missile Z). Missile Y with seeker E-01 was vibrated. Seeker E-01 also had abnormal IR-signal during vibrations. Missile Y returned to NDRE.

28.7 Guidance/warhead section test II

28.7.1 Test at NDRE

Seeker E-10 and E-01 were modified: RF-EMI filters were mounted in the Az motor wire and on the IR-pre-amplifier power supply.

Seeker E-10 re-mounted on missile Y. Test OK.

28.7.2 Vibration test at KV

18 - 23/11 - 1970.

5 runs lateral

5 runs axial

20 - 2000 - 20 Hz

1 octave/min

1 g peak

Seeker fault. The encoder disk was scratched. New encoder disk mounted at KV.

28.8 Complete weapon system test at Haakonsvern and Tananger I

Launcher with missile mounted onboard 26/11.

Seeker fault 27/11. The seeker did not always take decision during autotests, and was sent to KV for repair.

Arrival Tananger 2/12.

Seeker returned from KV and mounted on the missile 4/12.

Missile Y was taken on shore 4/12, but was re-mounted onboard 5/12 when it was clear that the fault was not in the missile but in the launching and control system. The fault was as follows:

If it was a short overload of the negative missile power supply, this power supply was disconnected while the positive missile power supply was not disconnected. The disconnecting was not indicated any place, and the whole launching and control system had to be switch off to reset the negative power supply. The power supply design is now changed.

Seeker fault 11/12. Seeker timer defect, sent to KV for repair.

Telemetry transmitter defect 11/12. New transmitter mounted.

Seeker returned from KV and mounted on the missile 12/12.

The platform was slaved to Az end stop because of a capacitor short circuit in the slave electronics 12/12. Platform Az sin wire loosened. The expedition was cancelled.

28.9 Launching attempts I

Cancelled because of bad weather 10/12.

28.10 Guidance/warhead section test III

The platform was repaired at KV, and was mounted in the guidance section 4/1 - 1971. Test OK.

28.11 Complete weapon system test at Haakonsvern and Tananger II

Missile with launcher mounted onboard 6/1 - 1971.

Az slave electronics changed to give lower max slave velocity. This was done to prevent the platform from being destroyed if there was a slave electronics fault, see 28.8.

28.12 Launching attempts II

None.

28.13 Launching

Date		12/1 - 1971 1105
Distance	to target	16 800 m
Direction	to target	267.8°
Weather:	Sight	> 40 km
	Cloud cover	0/8
	Wind	5 m/s from SE
	Temperature	6°C
	Sea state	0

29 MISSILE Y, VALUATION

29.1 Data systems

29.1.1 Telemetry

Good data.

29.1.2 Cinetheodolites

T1: Good data

T2: Good data

T3: Lacked 17 of total 38 photos

T4: Good data

The resulting data were good.

29.1.3 Photography

Escort boat 1 camera: The whole missile trajectory

High speed camera onboard KNM "Traust": Nothing, the camera was started too early.

29.2 Equipment onboard KNM "Traust"

29.2.1 Launching and control system

OK. The flight was to short to calculate the fire control accuracy.

29.2.2 Launcher

OK.

29.3 Missile flight

See 29.5.4.

29.3.1 Boost phase

Because of the high start pressure of the booster motor, see 29.4.1.1, the start acceleration was 210 m/s^2. The altitude during the boost phase was lower than usual. This was because of a platform Pi misalignment of - 3.4°, see 29.4.2. The velocity at the end of the boost phase was 271 m/s.

29.3.2 Mid-course phase

Because of the - 3.4° platform Pi misalignment, the missile hit the sea after a flight of 1750 m. The flight lasted only 7.5 sec , and the altimeter made no altitude samples.

The lateral guidance was OK.

The missile rolled clockwise 0.3 Hz.

29.3.3 Terminal phase

No terminal phase.

29.4. Missile subsystems

29.4.1 Motor

See 29.5.3.

29.4.1.1 Booster motor

Burning time	2.45 sec
Velocity at burn out	271 m/s
Pressure	Start pressure 138 kp/cm^2 , else normal
Acceleration (start)	210 m/s^2

The start pressure (0 - 0.1 sec) was high with a max pressure of 138 kp/cm^2 (normal 90 kp/cm^2). This high pressure caused a start acceleration of 210 m/s^2 (normal 130 m/s^2). The cause of this high start pressure is too narrow gas discharge, which causes errodating burning and a strongly increased gas generation. This effect disappears when the gas discharge is extended (some of the propellant has burnt).

29.4.1.2 Sustainer motor

Normal during the short flight.

29.4.2 Platform

Pitch misalignment of - 3.4° , probably because of high frequency noise during the alignment period. See 25.4.2 and 13.4.2.

29.4.3 Altimeter

See 29.5.2 and 25.5.3.

The altimeter did not manage to make any altitude samples because of the short flight (7.5 sec). The first altitude sample would have been made at 8.8 sec. Altitude com was normal.

29.4.4 Seeker

Normal (only boost and mid-course phase).

29.4.5 Control loops

29.4.5.1 Az control loops

See 29.5.1.

Mid-course guidance

V_{yeo}	1.8 m/s
ψ_{MP} (7.5 sec)	- 0.8°
Lateral int 2 (7.5 sec)	12 m
Oscillation	1.5° on 2.8 Hz
Lateral wind	3 m/s
Missile velocity	270 m/s

Normal oscillation. The flight was too short for ψ_{MP} and lateral int 2 to get their "static" values, but ψ_{MP} seemed to would have stabilized on appr 0° according to V_{yeo} and lateral wind.

Terminal guidance

None.

29.4.5.2 Pi control loops

See 29.5.2.

Mid-course guidance

Average θ_{MP}	1.3^{o}
Oscillation	2^{o} pp 2.9 Hz

Normal oscillation. θ_{MP} according to altitude com.

Terminal guidance

None.

29.4.6 Gas servo

OK.

29.4.7 AC-power supply

OK.

29.4.8 Thermal batteries

OK.

Positive batteries: 30.7 V , constant during the flight

Negative battery : - 30.3 V , constant during the flight.

29.5 Telemetry and missile trajectory recordings

Lateral control signals on 29.5.1

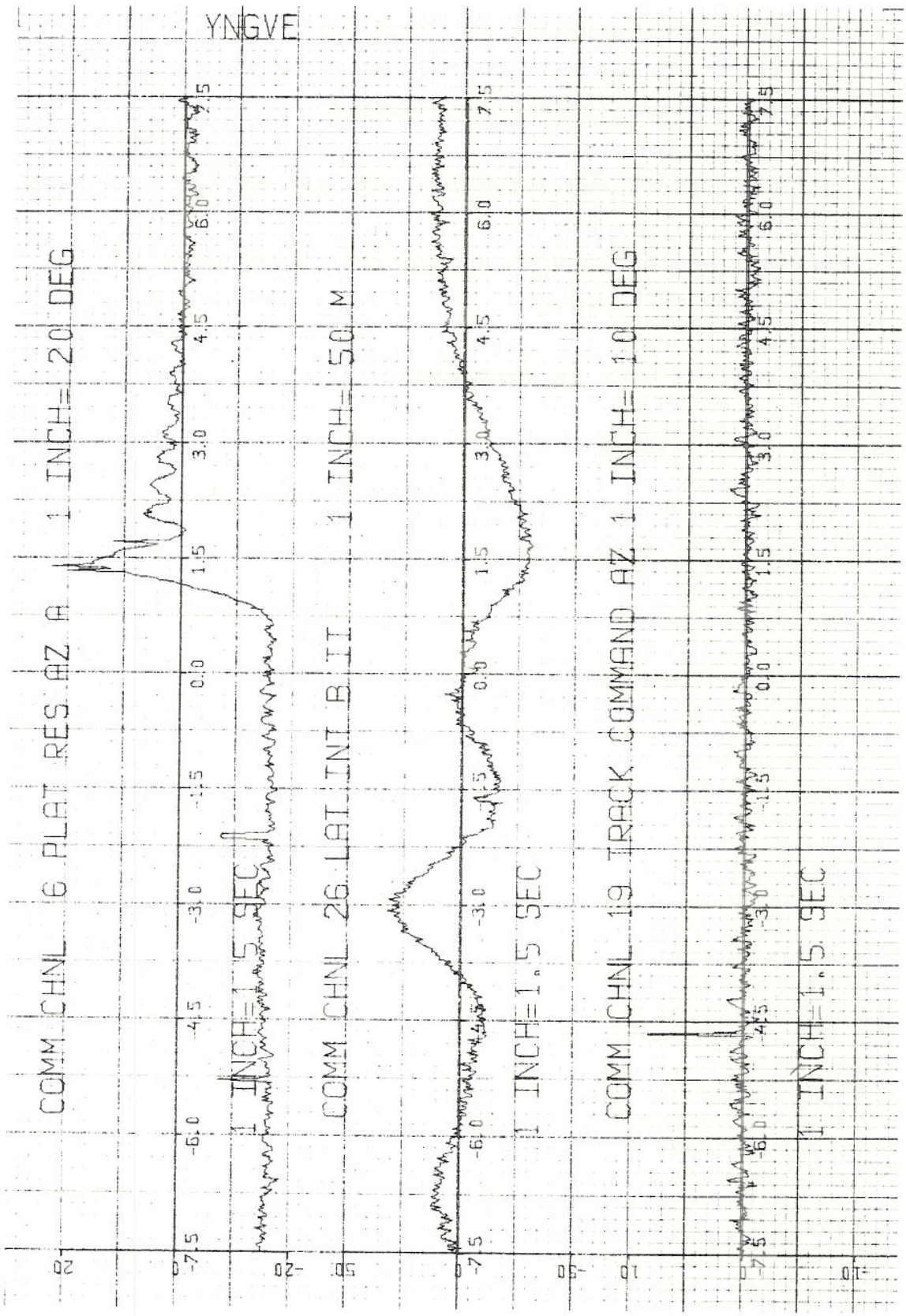
Altitude control signals on 29.5.2

Motor pressures and altimeter ΔH on 29.5.3

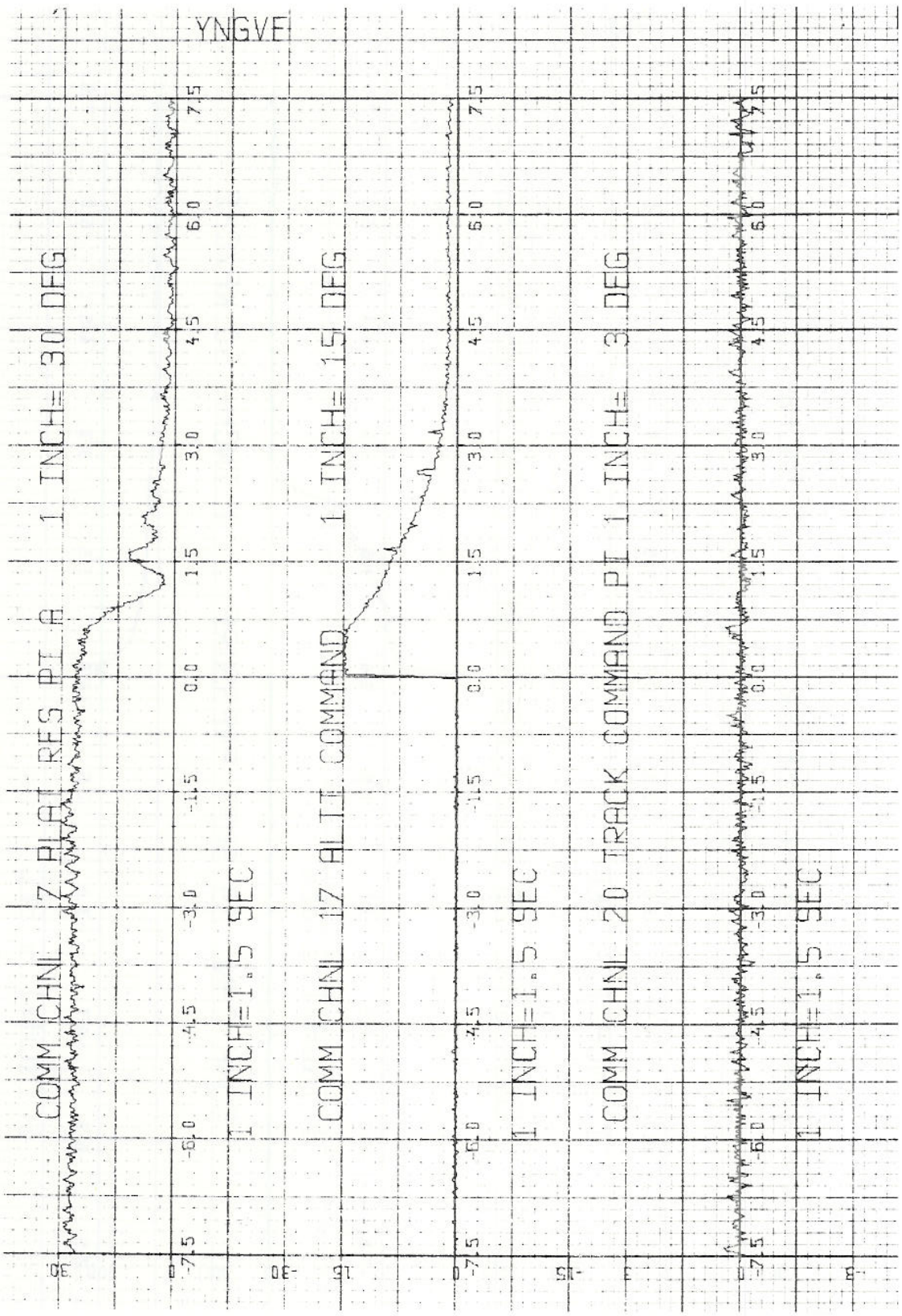
Vertical and horizontal projection of the missile trajectory on 29.5.4.

Time ref: T = 0 is take-off.

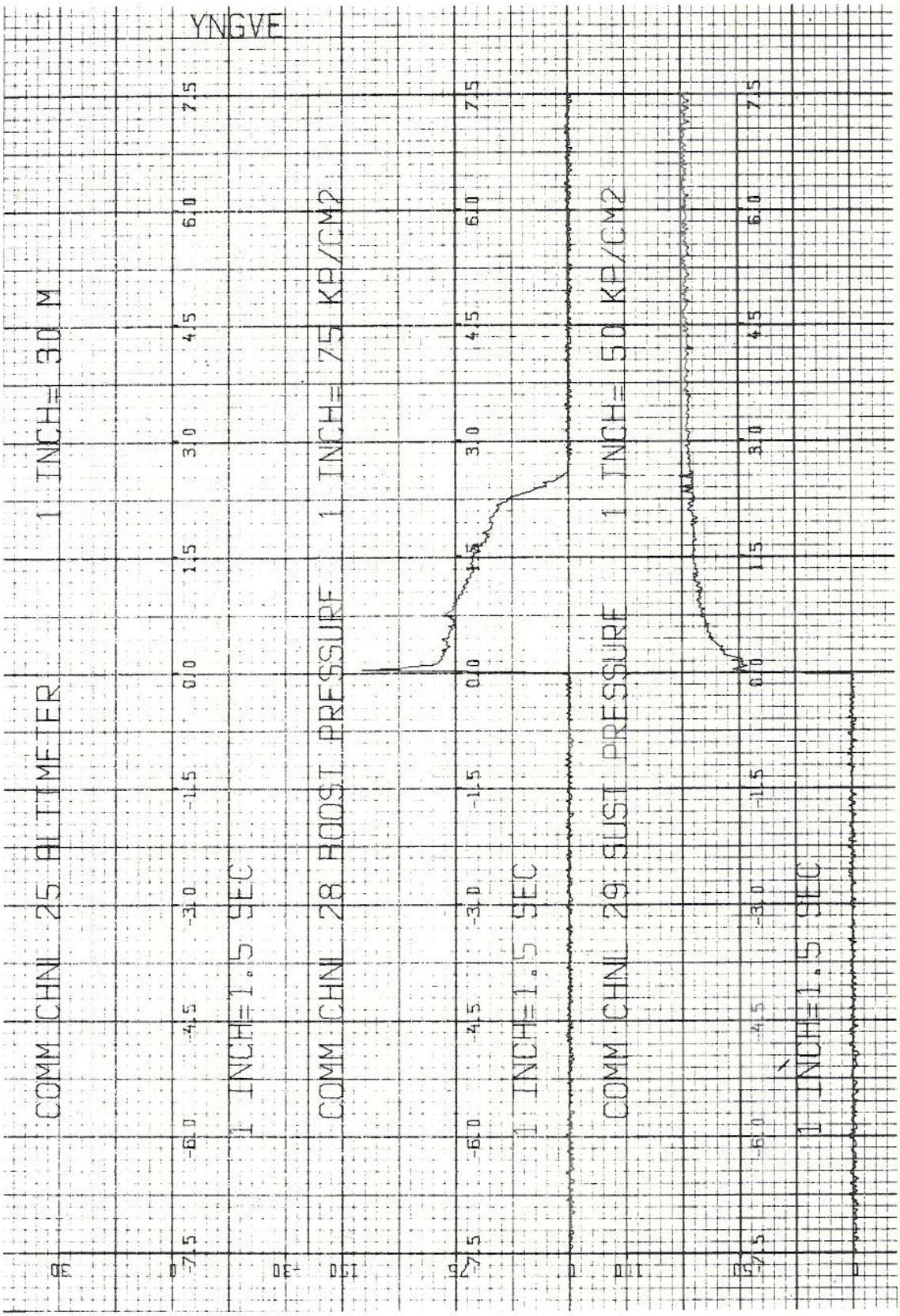
29.5.1 Lateral control signals



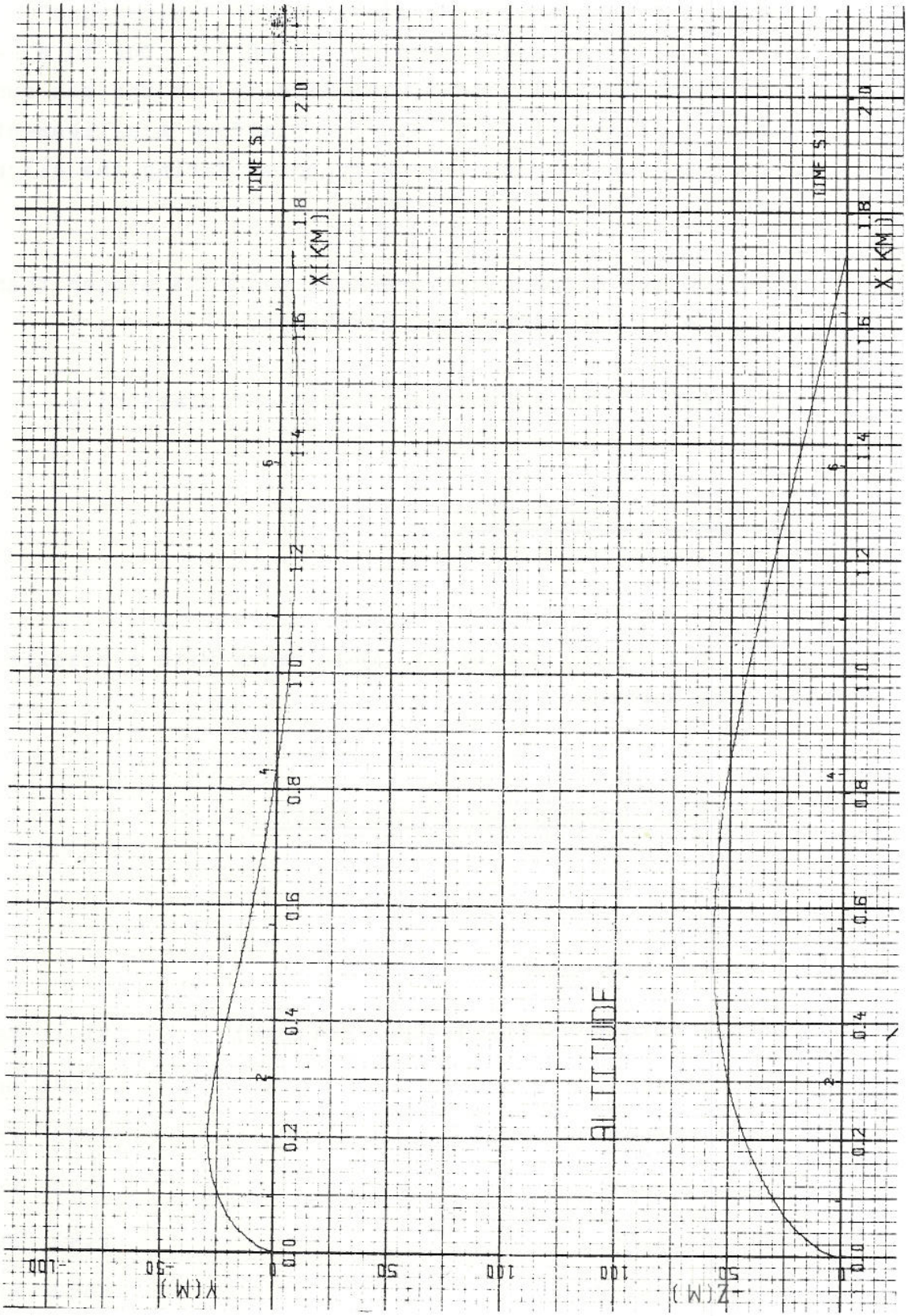
29.5.2 Altitude control signals



29.5.3 Motor pressures and altimeter ΔH



29.5.4 Missile trajectory



29.6 Summary

Missile Y was launched against ex-KNM "Reinøysund" 12/1 - 1971 at a distance of 16 800 m. Due to a - 3.4° platform Pi misalignment, the missile hit the sea surface after a flight of 1750 m. The platform misalignment was probably due to high frequency noise during the alignment period.

The booster motor start pressure was > 50% higher than usual because of too narrow gas discharge.

The rest of the system functioned satisfactorily.

30 MISSILE Z, DESCRIPTION

30.1 Aim

To hit a moving target at med. range with a missile with a live warhead.

30.2 Technical description of the missile

30.2.1 Motor

30.2.1.1 Booster motor charge

Double base propellant, VU (British)	41.1	kg
Inhibitors	1.85	kg
Start thrust	4700	kp
Final thrust	2500	kp
Burning time	2.41	sec
Total impulse	8670	kps

30.2.1.2 Sustainer motor charge

Double base propellant, IMI-0T0/10 (British)	15.75	kg
Inhibitors	2.01	kg
Thrust	110	kp
Burning time	28	sec
Total impulse	3050	kps

Modifications at NDRE:

- Rubber ring between the charge and the motor cover to lock the charge pneumaticly to the motor cover
- The charge was reduced (burning time 28 sec , normal 77 sec).

This was done of safety reasons, to prevent the missile with live warhead to reach the shore if there was a fault in the guidance system.

30.2.2 Warhead

Live warhead. 46 kg explosives. Penetration and delay.

30.2.3 Guidance section

E-08.

30.2.3.1 Seeker

E-08 (Electronics E-09, Optical unit E-08).

Modifications at NDRE:

- Telemetry electronics mounted
- New type of secondary mirrors mounted

- New type of IR-pre-amplifier
- RF-EMI filter on Az motor wires and the pre-amplifier power supply.

30.2.3.2 Gas servo

E-04 (Electronics E-04, Gas generator E-04).

Modifications at NDRE:

- Firing circuit resistor changed from 5.6 Ω to 1 Ω.

30.2.3.3 Altimeter

E-02.

Laser effect 109 W.

Modifications at NDRE:

- α_t changed from 0.95° to 1.15°.

30.2.3.4 Platform

E-03 (E-04 originally mounted at KV).

30.2.3.5 AC-power supply

E-10 (E-03 originally mounted at KV).

30.2.3.6 Control unit

E-08.

30.2.3.7 Thermal batteries

88

89

99.

30.2.3.8 Control section

E-08.

Modifications at NDRE:

- 2 vibration accelerometers with telemetry amplifiers mounted.
- Battery firing circuit resistors removed.

30.2.3.9 Control parameters

Main control loop Az	$6.1^{o}/o$
Lateral compensation	$0.14^{o}/m$
Tracking com Az	$K_{\psi_{\varepsilon n}} = 2.42^{o}/o$ $K_{\psi_{s1}} = 0.58^{o}/o$
Main control loop Pi	$5.83^{o}/o$
Altitude com	$0.20^{o}/m$ $\alpha_H = 1.3^{o}$ $\alpha_t = 1.15^{o}$
Tracking com Pi	$K_{\theta_{\varepsilon n}} = 2.44^{o}/o$ $K_{\theta_{s1}} = 0.49^{o}/o$
Href	82 m

30.2.4 Telemetry

Because of want of space, due to the live warhead, the telemetry equipment was reduced, and the telemetry channels were as listed below:

Ex ch 7 Lateral integrator 2

" 8 Az sin (ψ_{MP})

" 9 Pi sin (θ_{MP})

" 10 Tracking com Az

" 11 Tracking com Pi

" 12 Altitude com

" 13 Altimeter ΔH

" 14 Body vibration accelerometer axial

" 15 Track pulse + QFFT

" 16 Az sector I + Az track pulse + track window

" E Body vibration accelerometer lateral

" G Seeker IR-signal

30.3 Equipment onboard KNM "Traust"

30.3.1 Launching and control system

KV MK1 MOD 1.

30.3.2 Launcher

Selco III

Port front position

Elevation 21.5°

Azimuth - 15°

30.4 Target

ex-KNM "Reinøysund" with 2 artificial IR-targets (propan stoves) on the bow. Moving in a circle using own engines.

30.5 Photography

Camera on escort boat 1

High speed camera onboard KNM "Traust".

30.6 Missile test at NDRE and KV

30.6.1 Acceptance test

15 - 16/5 - 1970 OK.

30.6.2 Subsystem test

30.6.2.1 Seeker

- Mounting cylinder was not gas tight
- Seek threshold incorrectly adjusted.

30.6.2.2 Altimeter

OK.

30.6.3 Guidance/warhead section test

30.6.3.1 Test at NDRE I:

- Platform fault (E-04). The capacitors over the gyro loop relay contacts short circuited. When platform E-04 was repaired, it was mounted in missile Y, see 28.6.3.1. When platform E-03 was repaired, it was mounted in missile Z.
- AC-power supply E-03 mounted in missile Y, see 28.6.3.1. E-10 was mounted in missile Z when it was repaired.

30.6.3.2 Test at NDRE II

Seeker E-01 was vibrated on missile Y, see 28.6.3.2. Because of the faults detected, the seeker was modified: RF-EMI filters were mounted in the Az motor wire and on the IR-pre-amplifier power supply. Guidance/warhead section tested after the modifications. OK.

30.6.3.3 Vibration test at KV

18 - 23/11 - 1970.

5 runs lateral

5 runs axial

20 - 2000 - 20 Hz

1 octave/min

1 g peak

- Seeker fault. IR-signal abnormal during vibrations. IR-pre-amplifier exchanged at NDRE
- Platform fault. Pi power amplifier defect, exchanged at KV
- Servo fault. Short circuit on SEP because of tin solder. Servo repaired at KV.

30.7 Complete weapon system test at Åmøy

Missile Z was assembled at Åmøy near Stavanger, and launcher with missile was taken onboard there 13/1 - 1970. This was done because of safety reasons due to the live warhead.

Because of the platform Pi misalignment of missile Y, probably due to high frequency noise, the platform and the launching and control system sensitivity of high frequency

noise was investigated: When the radio transmitter onboard KNM "Traust" was used, there were platform Pi misalignments of 6 - 8°, and the digital computer of the launching and control system was unfit for use. Own ship's radar, escort ship's radar and radio transmitter had no effect. The radio transmitter onboard KNM "Traust" was not used during launching of missile Y.

It was decided to have radio silence during launching of missile Z.

30.8 Launching attempts

14/1. Cancelled because of platform Pi misalignment due to computer soft-ware fault: The axial compensation was wrongly calculated if there were discontinuities in own ship's velocity data.

15/1. Cancelled because of bad weather.

30.9 Launching

Date		16/1 - 1971
Distance	to target	4500 m
Direction	to target	287.1°
Weather:	Sight	> 30 km
	Cloud cover	6/8
	Wind	3 m/s from NNW
	Temperature	4°C
	Sea state	1

31 MISSILE Z, VALUATION

31.1 Data systems

31.1.1 Telemetry

Good data.

31.1.2 Cinetheodolites

T1: Good data

T2: Good data

T3: No data

T4: Lacked 32 photos during 12.6 sec -

The resulting data were satisfactorily.

31.1.3 Photography

Escort boat 1 camera: The whole missile trajectory

High speed camera onboard KNM "Traust": Nothing, the camera was started too early.

31.2 Equipment onboard KNM "Traust"

31.2.1 Launching and control system

OK. Total fire control accuracy was good, but can not be exactly calculated because the movement of the target as a function of time is not known.

31.2.2 Launcher

Opening time was 11 sec (normal 5 sec). This can partly be explained by a long seeker cooling hose, which have to be torn off by the launcher upper cover. The explosive actuator design is no changed to give a faster launcher opening (2 sec).

31.3 Missile flight

See 31.5.4.

31.3.1 Boost phase

Normal. Velocity at the end of the boost phase was 257 m/s.

31.3.2 Mid-course phase

The altitude was approximately constant 75 m during the mid-course phase.

Lateral guidance was normal. If the missile had not homed against the target, it would have passed over the target ship.

The missile rolled clockwise, 0.46 Hz.

31.3.3 Terminal phase

Decision distance 1050 m and altitude at decision point 70 m. The target was detected in the middle of the seeker scanning sector. The missile homed against the target, and hit the bow of the target ship, half way between the 2 artificial IR-targets. The warhead detonated as planned. The terminal phase lasted 4.3 sec. At decision the whole target

ship was looked at as target, but 1.5 sec before impact, the seeker switched over to the artificial IR-targets on the bow of the target ship, and the warhead detonated half way between these 2 artificial IR-targets.

31.4 Missile subsystems

31.4.1 Motor

Because of the live warhead, there were only 12 telemetry channels, and the booster and sustainer motor pressures were not telemetered. The motors seemed to have functioned normally. The velocity at booster motor burn out was 257 m/s, and the missile velocity at the end of the flight was 250 m/s.

31.4.2 Platform

OK.

31.4.3 Altimeter

See 31.5.2 and 31.5.3.

4 altitude samples, none of these was no return measurements. The measurements differed 1 - 6 m from the altitude calculated from the cinetheodolite data.

Altitude command according to the measurements.

31.4.4 Seeker

The target was detected at a range of 1050 m. The seeker was normal during the whole missile flight. The seeker

switched over from the whole target ship to the artificial IR-target 1.5 sec before impact.

31.4.5 Control loops

31.4.5.1 Az control loop

See 31.5.1.

Mid-course guidance

V_{yeo}	Not telemetered
ψ_{MP}	≈ 0°
Lateral int 2	≈ 0 m
Oscillation	1.2° 2.7 Hz
Lateral wind	- 2 m/s
Missile velocity	254 m/s

Normal oscillation. V_{yeo} is unknown, but the lateral guidance has been normal.

Terminal guidance

Normal, ψ_{MP} according to tracking com Az.

31.4.5.2 Pi control loops

See 31.5.2.

Mid-course guidance

θ_{MP}	≈ 1.2°
Oscillation	2° pp 2.8 Hz

Normal oscillation. θ_{MP} according to altitude com.

Terminal guidance

θ_{MP} according to tracking com Pi.

31.4.6 Gas servo

OK.

31.4.7 AC-power supply

OK.

31.4.8 Thermal batteries

The battery voltages were not telemetered, but must have been OK.

31.4.9 Warhead

The missile penetrated the bow of the target ship, which was a landing craft, and the warhead detonated in free air appr 0.5 m over the main gate. The detonation blew a hole with diamter 1 m in the gate, and the gate was detached. The forward sides of the ship were pressed out 1.5 m on each side, and there were great splint destructions forward. There also were splint destructions astern, and here it was a minor fire. The effect of the detonation was according to the results of previous free air detonation trials.

The artificial IR-targets were placed in the bow of the target ship, to make the warhead detonate here, and prevent the target ship from sinking. This was attained.

31.5 Telemetry and missile trajectory recordings

Lateral control signals on 31.5.1

Altitude control signals on 31.5.2

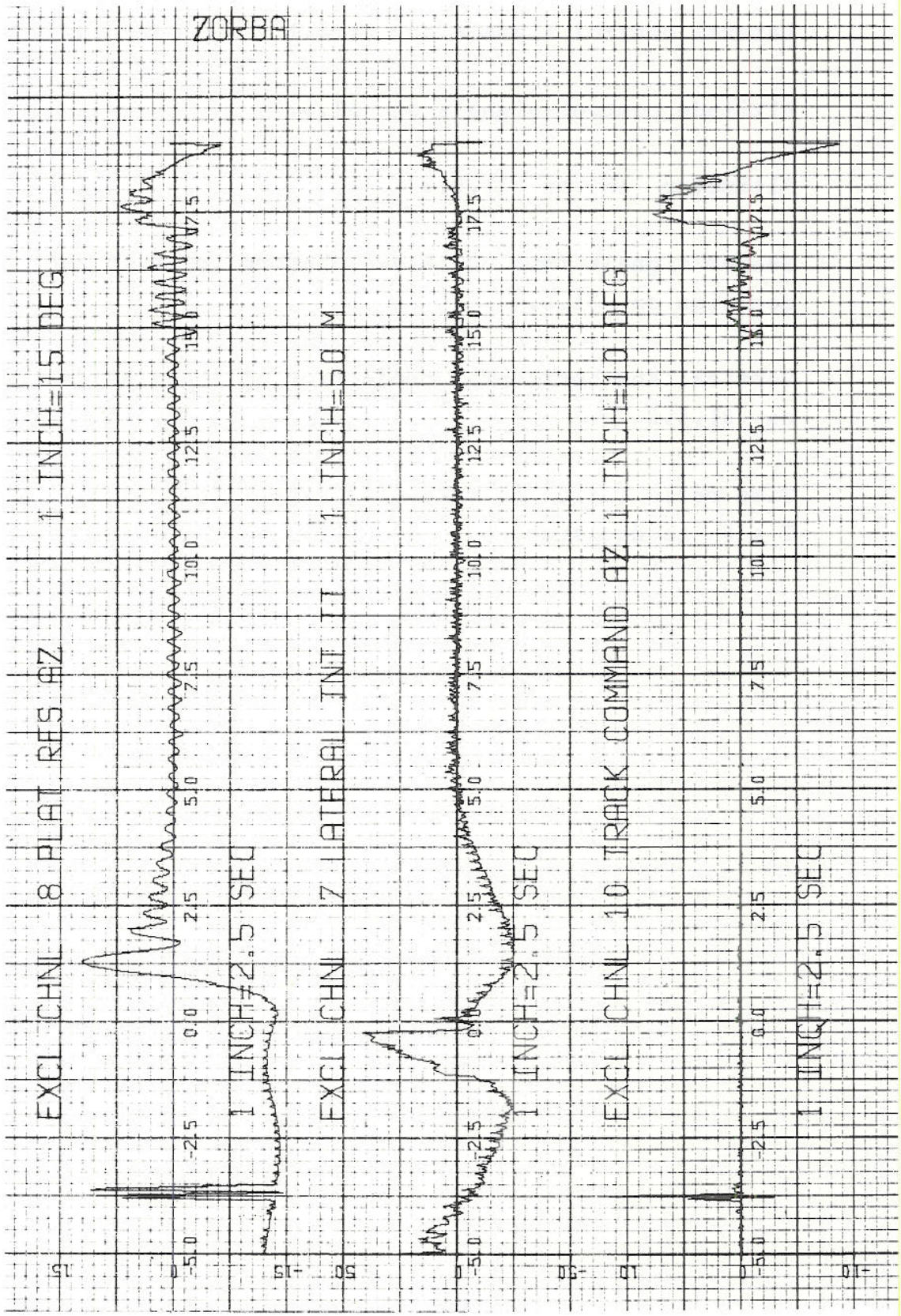
Altimeter ΔH on 31.5.3

Seeker signals from 0.15 sec before to 0.15 sec after decision on 31.5.4

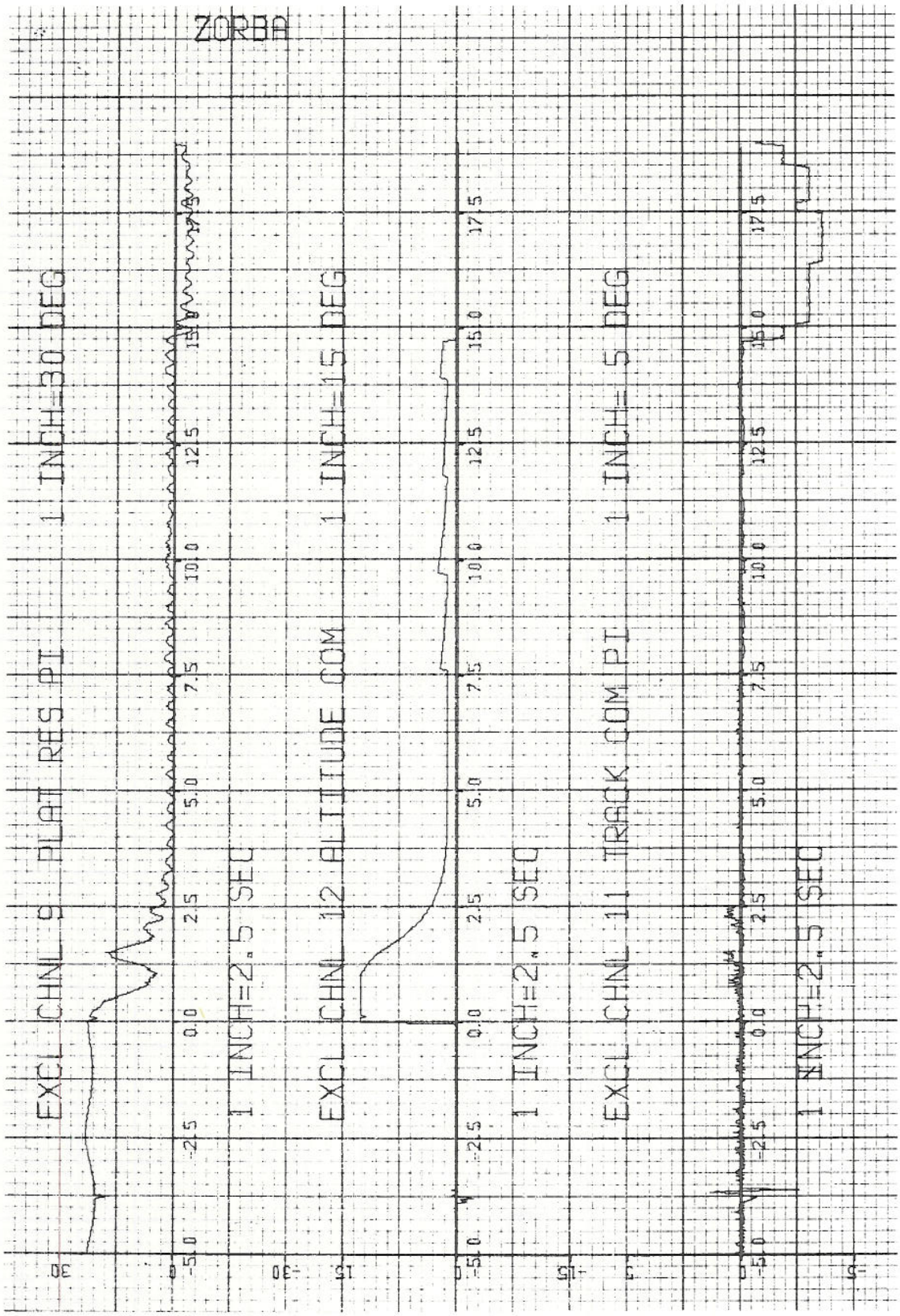
Vertical and horizontal projection of the missile trajectory on 31.5.5

Time ref: T = 0 is take-off, except for 31.5.4 where T = 0 is decision.

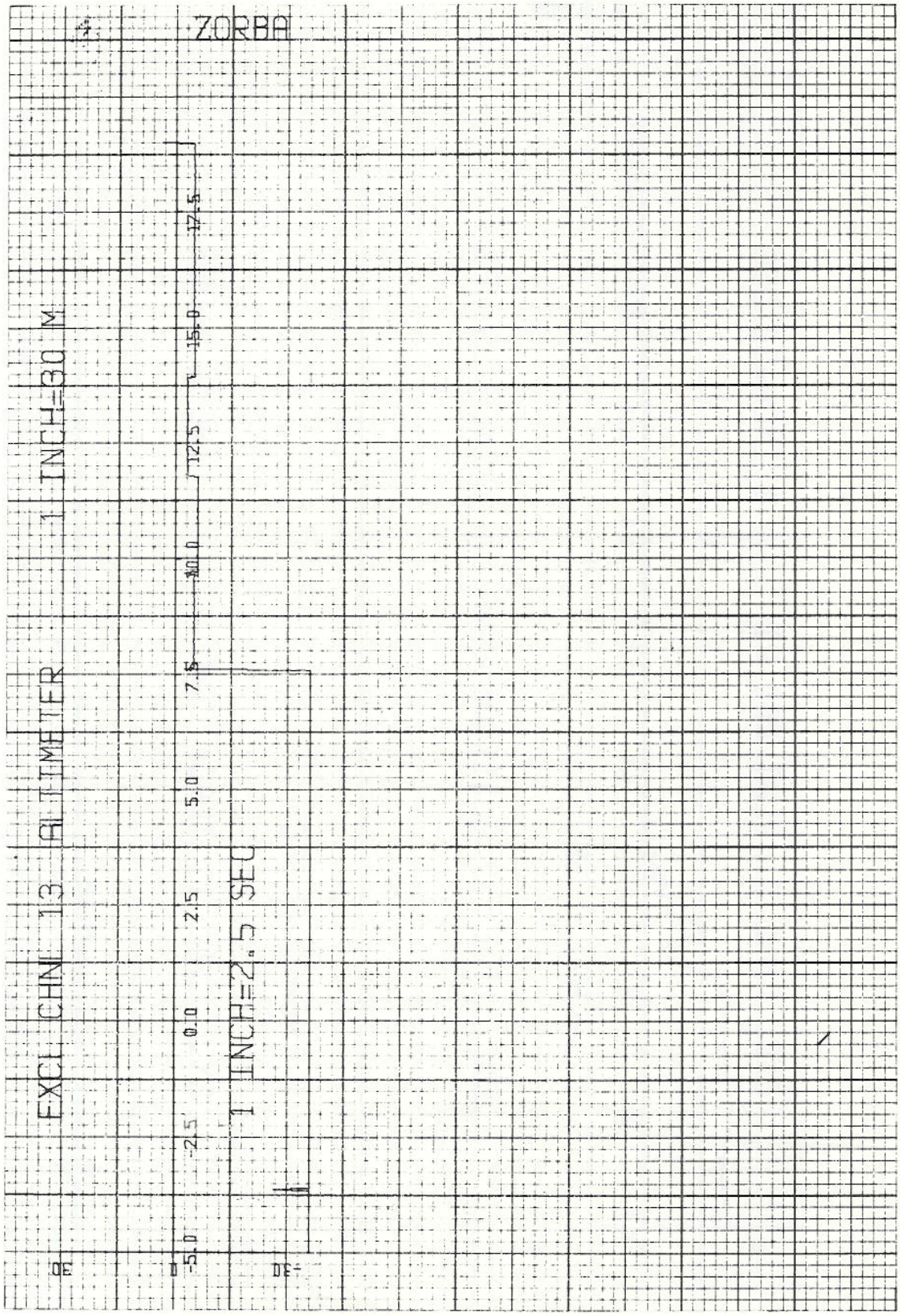
31.5.1 Lateral control signals



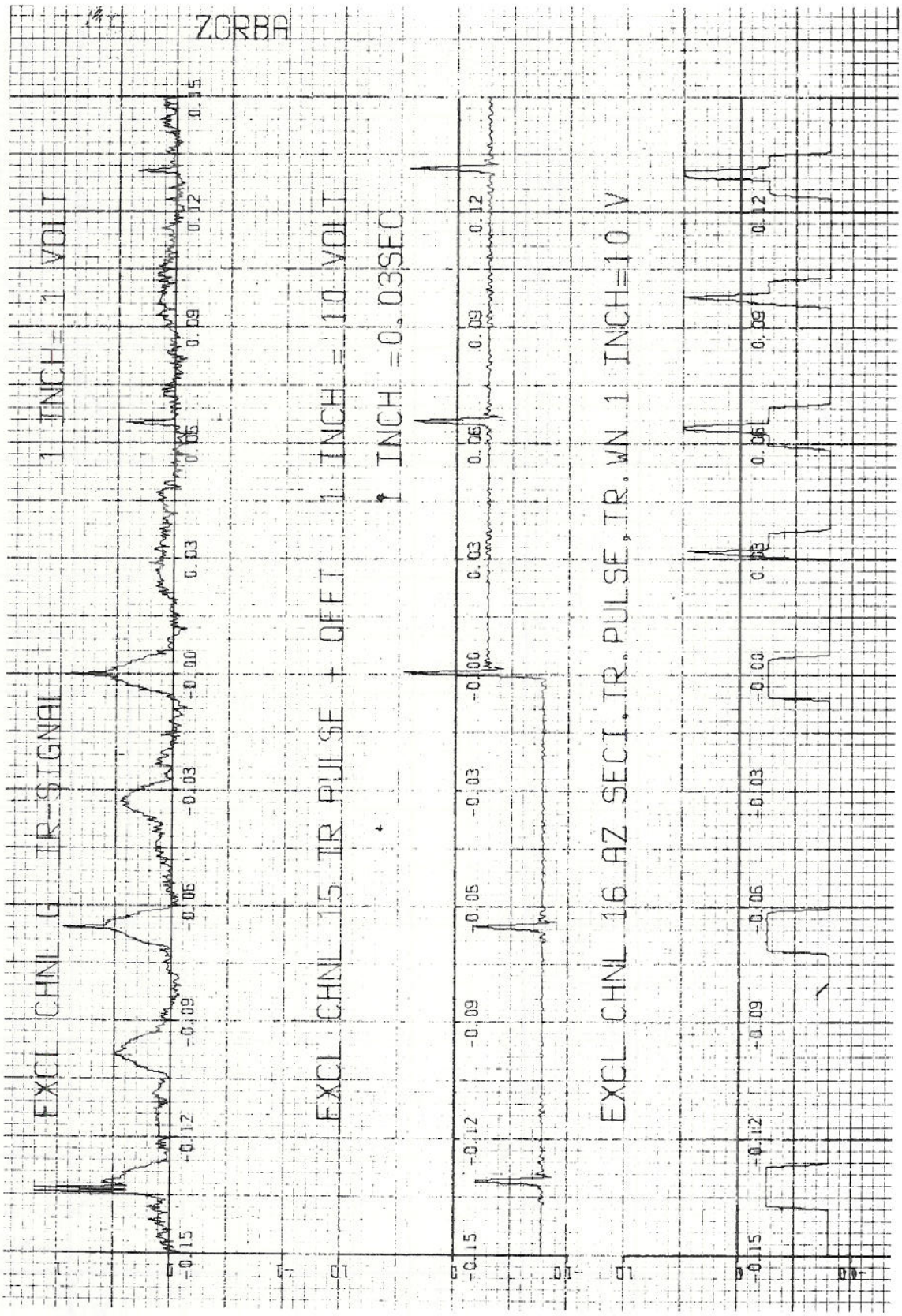
31.5.2 Altitude control signals



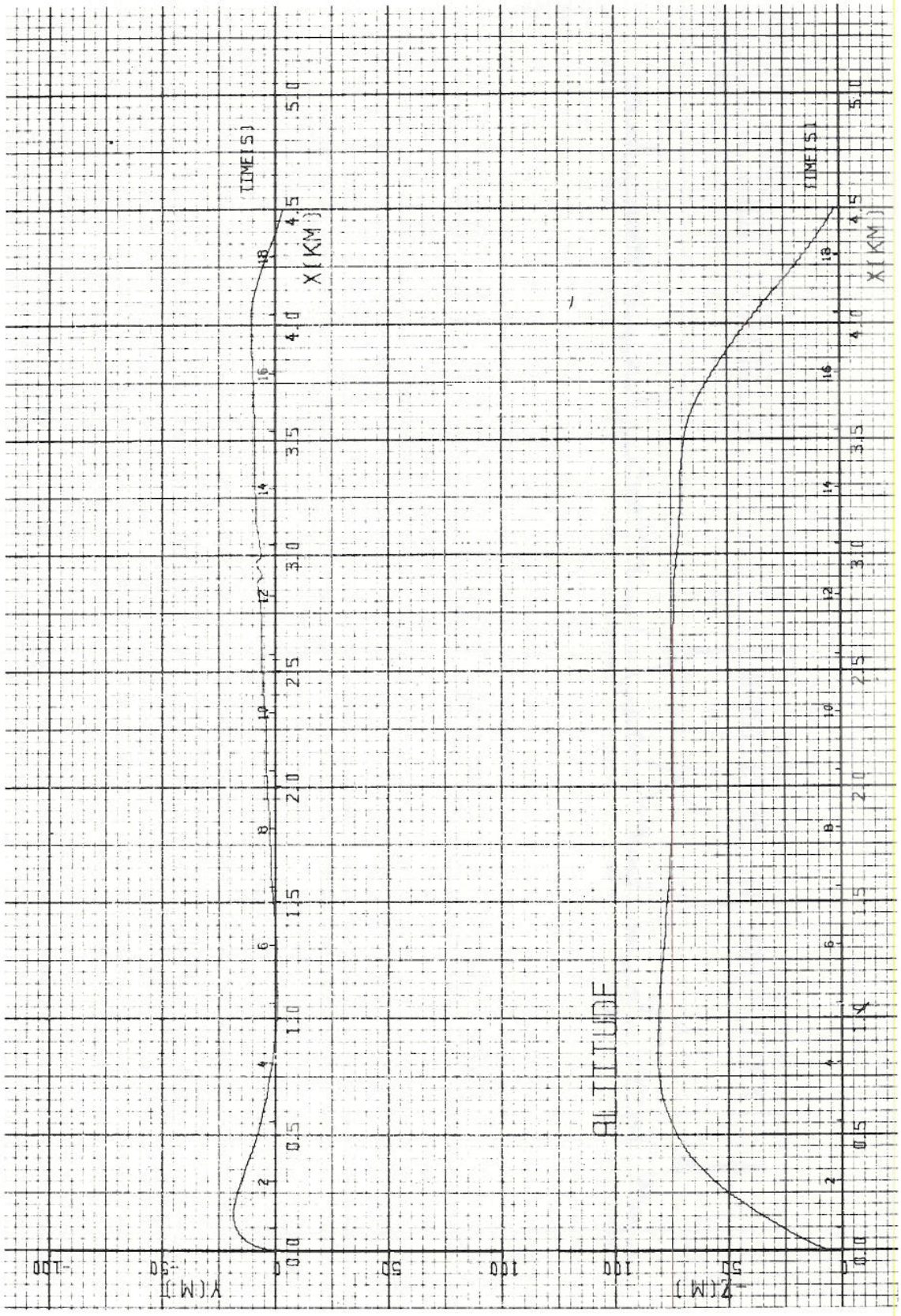
31.5.3 Altitude ΔH



31.5.4 Seeker signals



31.5.5 Missile trajectory



31.6 Summary

Missile Z was launched against ex-KNM "Reinøysund" 16/1 - 1971 at a distance of 4500 m. The target ship was moving in a circle, using own engines. The missile penetrated the bow of the target ship, and the warhead detonated half way between the two artificial IR-targets. All the missile subsystems functioned satisfactorily.

32 ERRORS DETECTED DURING TESTING

A great number of errors were detected. These were system errors, component errors and due to workmanship. All the errors detected are mentioned in the chapters of the missiles of question.

32.1 System errors

The system errors detected during testing and the changes in the design which were the results of these, are listed below.

32.1.1 Seeker

Noise from the Az motor interferred with the IR-signal. RF-EMI filters mounted on the Az motor wires and the IR-preamplifier power supply.

Slip-ring problems. The lubrication disappeared during storage. New lubrication method.

32.1.2 Altimeter

FET-switches on the output of ΔH and θRH were destroyed by transients from the teststand. Protecting resistors mounted

High voltage converter break down. R13 changed from 1/4 W to 1 W.

32.1.3 Platform

Power amplifier breakdowns. Capasitors mounted over the relay contacts of the gyro loops.

33 ERRORS DETECTED DURING MISSILE FLIGHTS

There were totally 12 errors on the 6 missiles which did not hit the target, and no errors on the 4 missiles which did hit the target. There were 8 different errors, 5 of these were system errors. All the errors are listed below.

33.1 Seeker

Seeker track threshold faulty generated. The track threshold was 80 - 90% instead of 50% of max IR-signal. System error. Missile R.

Barring time of down correction too long (0.5 sec). System error. Missile R.

IR-pulse on the left border of the sectors due to an in-coupling transient of the IR-signal. System error. Missile W.

Timer error. The seeker was armed to late. Component error. Missile W.

Short circuit of Az sector II to ground via the slip-ring or module 1706. Missile V.

33.2 Altimeter

No connection between A, i and Control on module 1813. Workmanship. Missile Q.

33.3 Platform

Pi misalignment because of high frequency noise sensitivity of the alignment system. System error. Missile R (-0.7^{o}), X (-2.8^{o}) and Y (-3.4^{o}).

33.4 Sustainer motor

Increasing motor pressure. This was probably because the charge moved, which caused an increased burning area. System error. Missile R (96 kp/cm^2 at splashdown), V (max 140 kp/cm^2) and Q (max approximately 160 kp/cm^2, motor burst).

34 CONCLUSION

The Penguin technical evaluation missile firing program consisted of 10 missiles, which were launched from KNM "Traust" at Vigdel firing range during Feb 1970 - Jan 1971. 9 of the missiles had inert warhead, 1 had live warhead. 4 of the missiles hit the target, including the one with live warhead. 2 different launching and control systems were evaluated, NDRE NOR2 and KV MK1 MOD 1. These were successfully used for launching of 2 respectively 3 missiles.

The 4 missiles which hit the target were launched under the following conditions:

Missile S: Min range, sea state 5

Missile T: Med range, the target was detected in the extreme verge of the scanning area

Missile U: Med range, the bow of the target pointed towards the launching vessel.

Missile Z: Med range, moving target, live warhead.

These 4 missile firings verified that the weapon system acted up to all the main specifications, except the max range specification. There were no successful missile firing at long range, in defiance of 5 missiles which were launched at a distance $\geq$ 15 000 m. The reasons of these missfirings had nothing to do with the long range, both the midcourse guidance system and the launching and control system proved to be very accurate, but were due to technical errors only.

It was decided to extend the Penguin technical evaluation program with 3 missiles taken from the serie 1 production. This was done of the following reasons:

- No successful missile firing at long range.

- Two of the changes of the design are not tested on missile flights.

- The production - and control system at KV is different for the serie 1 missiles from what it was for the 10 missiles used during the technical evaluation program.

These 3 missiles will be launched during the autumn 1971, before the Penguin tactical evaluation program starts.

List of Penguin Technical Notes

The Penguin Technical Notes listed below contain the complete telemetry recordings, except of ex ch 15, 16 and G, and the complete missile trajectory data, for the 10 missiles launched during the Penguin technical evaluation programme.

Johnsrud, T
P Sætre
- Richard, telemetry data,
Penguin Technical Note No 113 NDRE (1970)
Restricted

Heistad, E
- Richard's bane,
Penguin Technical Note No 117 NDRE (1970)
Begrenset

Johnsrud, T
P Sætre
- Sigurd, telemetry data,
Penguin Technical Note No 122 NDRE (1970)
Restricted

Heistad, E
B Jahren
- Sigurd's bane,
Penguin Technical Note No 126 NDRE (1970)
Begrenset

Johnsrud, T
P Sætre
- Tore, telemetry data,
Penguin Technical Note No 128 NDRE (1970)
Restricted

Heistad, E
B Jahren
- Tore Hund's bane,
Penguin Technical Note No 132 NDRE (1970)
Begrenset

Johnsrud, T
P Sætre
- Ulrik, telemetry data,
Penguin Technical Note No 129 NDRE (1970)
Restricted

Heistad, E
B Jahren
- Ulrik's bane,
Penguin Technical Note No 134 NDRE (1970)
Begrenset

Johnsrud, T
P Sætre
- Victor, telemetry data,
Penguin Technical Note No 130 NDRE (1970)
Restricted

Heistad, E
B Jahren
- Victor's bane,
Penguin Technical Note No 135 NDRE (1970)
Begrenset

Johnsrud, T
O Sandervåg
- Wilma,
Penguin Technical Note No 142 NDRE (1970)
Restricted

Heistad, E - Wilma's bane
Penguin Technical Note No 144 NDRE (1970)
Begrenset

Johnsrud, T
O Sandervåg - Xantippe, telemetry data,
Penguin Technical Note No 139 NDRE (1970)
Restricted

Heistad, E - Xantippe's bane,
Penguin Technical Note No 145 NDRE (1970)
Begrenset

Johansen, O
A R Tinderholt - Q,
Penguin Technical Note No 154 NDRE (1971)
Restricted

Tinderholt, A R - Q's bane,
Penguin Technical Note No 153 NDRE (1971)
Begrenset

Johansen, O
A R Tinderholt - Yngve, telemetry data,
Penguin Technical Note No 155 NDRE (1971)
Restricted

Tinderholt, A R - Yngve's bane,
Penguin Technical Note No 156 NDRE (1971)
Begrenset

Johansen, O
A R Tinderholt - Zorba, telemetry data,
Penguin Technical Note No 159 NDRE (1971)
Restricted

Tinderholt, A R - Zorba's bane,
Penguin Technical Note No 157 NDRE (1971)
Begrenset

References

(1) Lundh, Y - Description of the Penguin ship-to-ship weapon system, Intern rapport E-160, NDRE (1970) Secret

(2) Solbakken, A - Progress report no 1 on the development of midcourse guidance for the Penguin weapon system, Intern rapport E-132, NDRE (1968) Confidential

(3) Lundh, Y - Review of the completed Penguin development program, Teknisk notat E-313, NDRE (1970) Confidential

(4) Brodersen, E - Prøveinstallasjon ombord i MKB KNM "Traust" for fyring av styrte Penguin-raketter, Teknisk notat E-223, NDRE (1969) Begrenset

(5) Eriksen, E - Penguin missile system. Launching and control system, Intern rapport X-129, NDRE (1970) Restricted

(6) Bjørseth, L - Kort beskrivelse av Penguin system MK I MOD I, Teknisk rapport P-142, Kongsberg våpenfabrikk, Avd U (1970) Begrenset

(7) Brattensborg, R K Kolberg - Foreløpig testforskrift for Penguin neseseksjon, Teknisk rapport P-68, Kongsberg våpenfabrikk, Avd U (1969) Begrenset

(8) Brodersen, E Y Lundh - The Vigdel missile firing range, Teknisk notat E-277, NDRE (1970) Restricted

(9) Eggestad, M - A radio tracking system for low altitude guided missiles, Intern rapport E-146, NDRE (1969)

(10) Lundh, Y - Technical support facilities established for the Penguin development programme, Teknisk notat E-278, NDRE (1970) Restricted