Nationaal Lucht- en Ruimtevaartlaboratorium
National Aerospace Laboratory NLR

Executive summary

Korean-Dutch Flight Testing for Kamov KA32T Helicopter Training Simulator Development & Validation

Problem area
Together with (and contracted by) the Korea Aerospace Research Institute (KARI), the Dutch National Aerospace Laboratory (NLR) has performed a successful flight test campaign with the Kamov KA32T in South Korea in the summer of 2007. These trials were part of the KA-32 Helicopter Training Simulator Development Program, managed by KARI.

Description of work
Within this program, NLR developed the flight model and executed the flight tests in close co-operation with KARI and the helicopter operator. A very successful flight test campaign has been executed from 1 to 31 August 2007 at the Iksan airbase of the Forest Aviation Office.

Results and conclusions
The installation and calibration of the instrumentation was accomplished within 2 weeks. A total of about 30 hours of flight time has been performed in 22 flights. The very successful flight test campaign provided good quality data for the AC120-63 tuning process, thanks to good cooperation between Korean and Dutch engineers and the Korean helicopter operator.
During the model tuning process, a very good result was achieved, providing a simulation model that has a high (Level C) fidelity in representing the KA32T and an almost 100% fit to the flight test data

This paper describes an interesting project with an international touch, including some distinctive logistical challenges: Korean and Dutch engineers working on a Russian helicopter.

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Summary

Together with (and contracted by) the Korea Aerospace Research Institute (KARI), the Dutch National Aerospace Laboratory (NLR) has performed a successful flight test campaign with the Kamov KA32T in South Korea in the summer of 2007. These trials were part of the KA-32 Helicopter Training Simulator Development Program, managed by KARI. Within this program, NLR developed the flight model and executed the flight tests in close co-operation with KARI and the helicopter operator. A very successful flight test campaign has been executed from 1 to 31 August 2007 at the Iksan airbase of the Forest Aviation Office. The installation and calibration of the instrumentation was accomplished within 2 weeks. A total of about 30 hours of flight time has been performed in 22 flights. This paper describes an interesting project with an international touch, including some distinctive logistical challenges: Korean and Dutch engineers working on a Russian helicopter.

Contents

1 Project background

The objective of the KA-32 Helicopter Training Simulator Development Program is to acquire a helicopter simulator which meets level C requirements in accordance with the FAA AC 120-63. The Korea Aerospace Research Institute (KARI) managed the development program and was in charge of developing and validating the flight dynamics model based on simulator design data and flight test data. The helicopter chosen for this project was the Kamov KA32T, an 11-tonne twin engine helicopter with a co-axial rotor system (see Figure 1), operated by the Korean Forest Aviation Office (FAO), mainly for the fighting of forest fires.

KARI was presented with the challenge of finding sufficient data for the development of the flight dynamics model. The Netherlands' National Aerospace Laboratory (NLR) was awarded a contract to develop the flight model and gather flight test data, due to its experience with flight simulation development and flight testing for a competitive price.
The result is an interesting project with an international touch, including some distinctive logistical challenges: Korean and Dutch engineers working on a Russian helicopter.

Key innovations for NLR for this project are the non-intrusive measurement system and the setup of a flight test program with restrictions in operation and instrumentation. The project has been successfully finished in a short time and on a tight budget.

The KARI/NLR project consisted of three phases: flight mechanics model development, flight testing and model tuning. During the flight test phase the goal was to gather data for flight mechanics model improvement and data for the comparison between model and flight test (Qualification Test Guide). This paper presents the preparations and execution of the flight test program and discusses some of its results. At the end of the paper, the application of the measured flight test data within the project is discussed briefly.

Figure 1: The Kamov KA32T test helicopter

2 Helicopter configuration

The Kamov KA32T is an 11-tonne twin engine helicopter with a co-axial rotor system (see Figure 1). It is operated by the Korean Forest Aviation Office, mainly for the fighting of forest fires.

All flights have been performed with a crew of 2 pilots and 1 flight test engineer, complemented during several flights with a flight mechanic. The pilots of the test aircraft were senior pilots within the Forest Aviation Office, however without a formal test pilot training. The flight test engineer from KARI was in charge of the in-flight organization of the tests, managing the instrumentation system and recording of events using the event marker and flight test cards.

The FAO normally operates the KA32T with a Simplex Model 10900-050 Fire Attack water tank mounted below the fuselage. Since the water tank limits the maximum speed to 150 km/h, as opposed to the normal maximum speed of 230 km/h, it has been decided to perform the flight tests without the water tank to enable testing in a larger speed envelope.
Both engine inlets are equipped with a “Dust Protection Device” and an Anti-Icing System.

It has been decided by KARI to vary the helicopter weight with fuel quantity only. Since the external fuel tanks are not available at FAO, only the internal tanks were used. Using this configuration, weights between about 7300 and 8700 kg can be achieved. Additionally, the center of gravity range was varied with the position of a flight mechanic in the cabin.

The test helicopter was not equipped with:

- an external hoist
- air conditioning

The 'Dust Protection Device' and ‘Anti-Icing System’ were off for all tests except for those tests measuring the performance impact of these systems.

During normal operation of the helicopter, the autopilot is on, providing rate stabilization/attitude hold. During many of the flight tests the autopilot had to be switched on. However, some tests specified in the simulator qualification requirements (ref. 1) require maneuvers to be performed without autopilot. The required configuration (autopilot on or off) was indicated on the test cards. ‘Autopilot’ was referring only to the Yaw, Roll and Pitch channels on the Center Control Panel. Other modes, such as altitude hold, were not used during the test maneuvers.

3 Instrumentation system

Instrumentation system in helicopter

After several preparatory visits to South-Korea, the preliminary design of the instrumentation system was started, using NLR's "Generic Instrumentation System" (GIS) as a basis. The GIS is an advanced airborne measuring and recording system. It is capable of adequately measuring, conditioning and recording analogue signals, discrete signals, digital signals, synchro signals and manual data entry (i.e. record number).

A constraint for the instrumentation system design from the operator was to install equipment with as little impact on the helicopter as possible, both mechanically and electrically. For both operational reasons and safety the system had to be 'non-intrusive'. Therefore, the approach for the design of the instrumentation system was to use as many parameters going to the KA32's Flight Data Recorder (FDR) as possible. This required the design of a ‘breakout box’, which enabled recording these parameters by the NLR data acquisition system, while the Flight Data Recorder remained in operation. A second major part in the instrumentation system was a dedicated test Inertial Reference System (IRS), providing ring laser based attitudes, rates and accelerations.

To complement the parameters from the FDR and the NLR IRS, several additional sensors have been installed:

- On the landing light bracket a probe for outside air temperature has been installed.
- To satisfy concerns about flight safety, non-intrusive optical (laser) sensors have been used for longitudinal and lateral cyclic position, with reflectors installed on the longitudinal and lateral push-pull rods below the cockpit floor (see Figure 2):

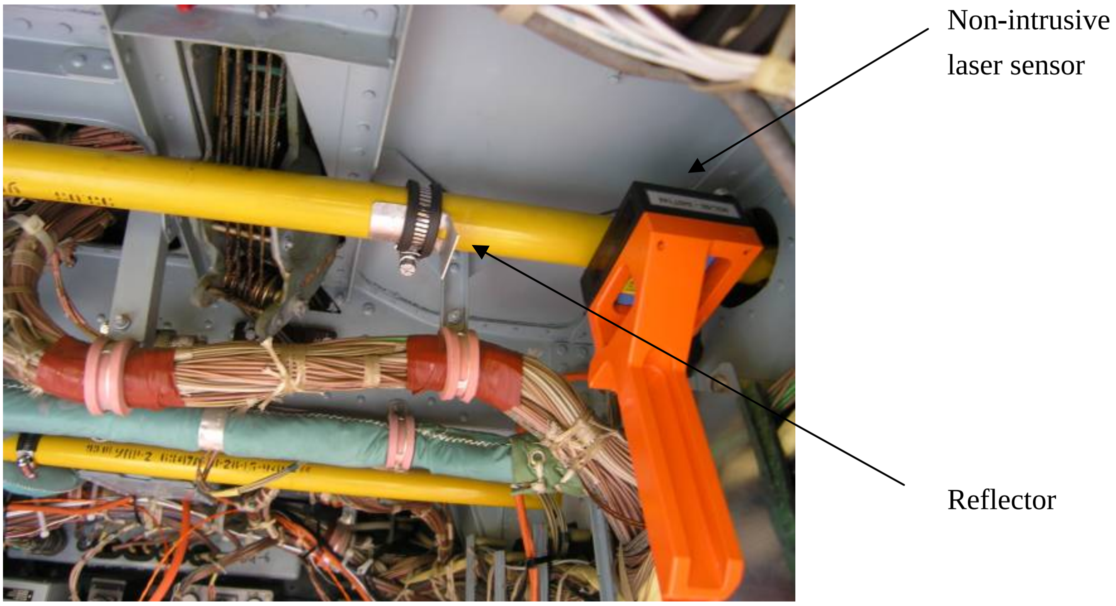


Figure 2: Non-intrusive laser sensor (on orange bracket) and reflector (on yellow push-pull rod) below cockpit floor to measure stick position

- To measure engine temperature, a break-out connector was installed in the signal from the engine thermocouples. Because it was not possible to measure the cold junction temperature, the measurement will vary with cold junction temperature. This deficiency has been solved by correcting the measurement with observations of the cockpit instruments from video (for ground tests) and from the flight test engineer (for flight tests).
- A temporary transducer, for ground test only, was connected to the engine throttles to measure the deflections during engine start up, (ground) operation and shut down.
- The engine pressure ratio, an indication of engine power, has been measured by installing a breakout connector in the signal to the cockpit instrument.

In order to create the breakout connectors for Flight Data Recorder, engine pressure and temperature, several Russian connectors had to be purchased, which proved to be a very critical part of the design.

A video camera was used to record engine instruments during ground runs in the engine start procedure.

All flight test data was recorded on a Solid State data recorder, and was processed direct after the flight in the Omega data processing system to enable analysis of the data before the next day. The Omega system contains all the calibration data of the individual parameters and calculates the engineering units from the raw recorder data. The block diagram of the Generic Instrumentation System is shown in Figure 3, the system as installed in the helicopter is shown in Figure 4. The parameter list can be found in Table 1. The instrumentation design was concluded with a safety analysis report, showing that the instrumentation design has a high degree of reliability and damage tolerance and that it has provisions to protect the helicopter signals in the event of a failure.

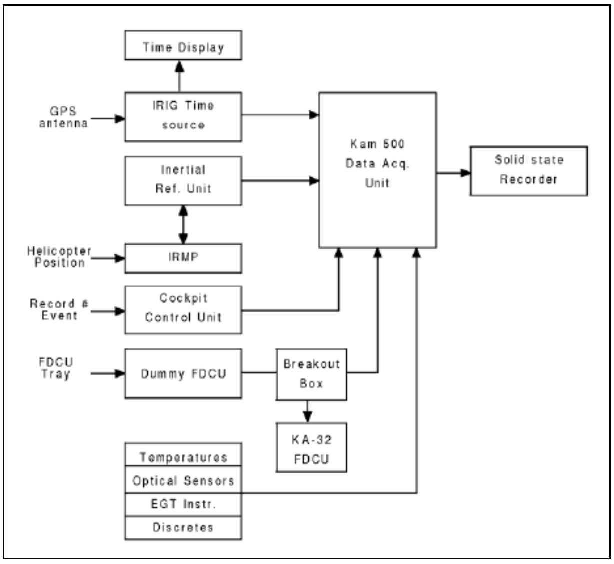


Figure 3: Generic Instrumentation System block diagram

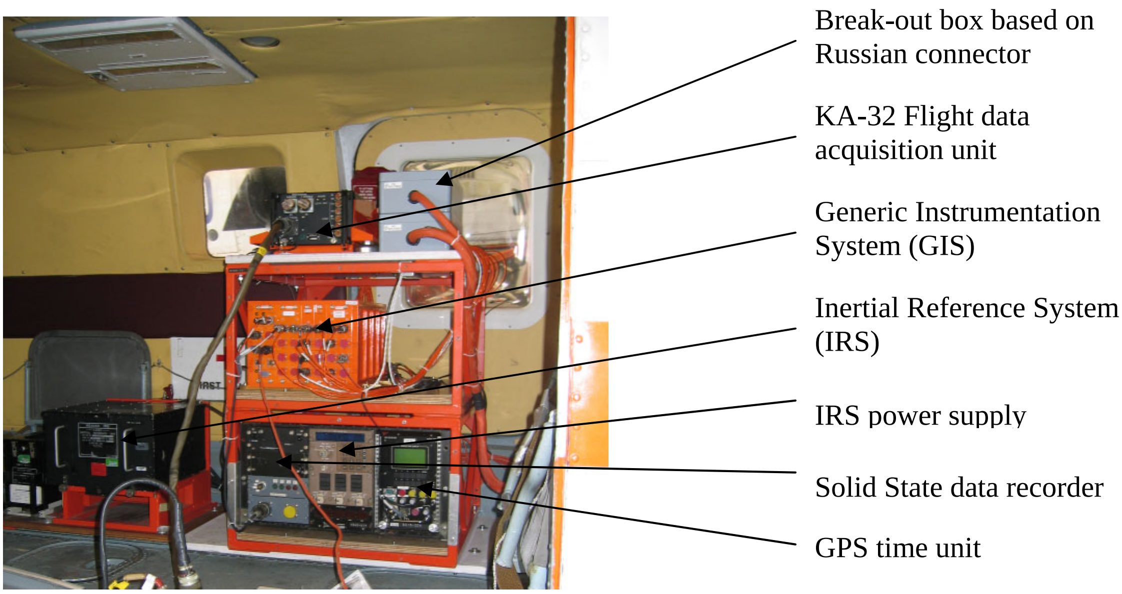


Figure 4: The ring laser gyro and measurement system in the KA32T

Instrumentation systems on ground

A ground station was located at the FAO base at Iksan. It consisted of a KARI portable office container, in which the NLR ground station was installed.

The NLR ground station is based on a WYLE Omega processing system in a server-client network environment. The server is operated by the instrumentation engineer and processes and distributes all available data from helicopter and ground instrumentation.The Omega system contains all the calibration data of the individual parameters and calculates the engineering units from the raw recorder data. The system design allows for quick configuration changes for different test programmes. A shared hard disk unit is used for securely archiving the acquired data. The specialists were provided with client laptop computers, enabling them to analyse the distributed data on- or offline as necessary. The network is completed with a network printer.

Weather data was gathered with a mobile meteo system, consisting of temperature, pressure, humidity, wind speed and direction sensors. These transducers are mounted on a transportable 10 meter high meteo mast. The system can be powered by a car. The data is logged onto a PC. The meteo system was used during several hover trials at the FAO base at Iksan and the low speed trials at Jeonju airbase (see Figure 10).

4 Installation and calibration activities

The flight test campaign in the summer of 2007 was started with the installation and calibration of the instrumentation system. Because most of the design was performed in the Netherlands, some minor adjustments had to be made in Korea to the mechanical interface.
After the instrumentation installation, the parameter calibration was started. As far as possible parameters were calibrated on the ground. For example: the fuel gauge was calibrated through a weight and balance procedure at several fuel weights, the airspeed and pressure altitude were calibrated with a pitot-static test set and the flight control rigging was checked through a ground test with hydraulic power. Other parameters were calibrated during a ground run, like the engine temperatures, gas generator speeds and rotor speed. The engine pressure parameters (substitute for engine torque) could only be calibrated in flight.

After the first ground runs for a general instrumentation check and EMI/EMC test, a first test flight took place for instrumentation check and final calibration. Several runs have been included to determine the error in the pitot-static system.
The activities described above were performed in a 2-week period, ending on 31st of July 2007.

5 Data processing and analysis

Data from the instrumentation system is processed directly after flight and, after calibration in the Omega data processing station, converted to Matlab®- data files. Several tools have been developed for quick post-processing and analysis of the flight test results:

- A Matlab®-based graphical user-interface (see) for fast presentation of flight test data. This tool can represent both steady state data (average values and standard deviations) as well as time history data (parameters as a function of time). The appropriate parameters are displayed, depending on the type of test. Additional parameters can easily be added manually. A provision has been made to show AC120-63 tolerances. Figure 5 shows data for an approach and landing. Shown are, in the left column of graphs, from top to bottom: airspeed, radio altitude, lateral stick position, pedal position, roll angle, engine 1 power. In the right column of graphs, from top to bottom: pressure altitude, collective stick position, longitudinal stick position, pitch angle, true heading and finally main rotor RPM.

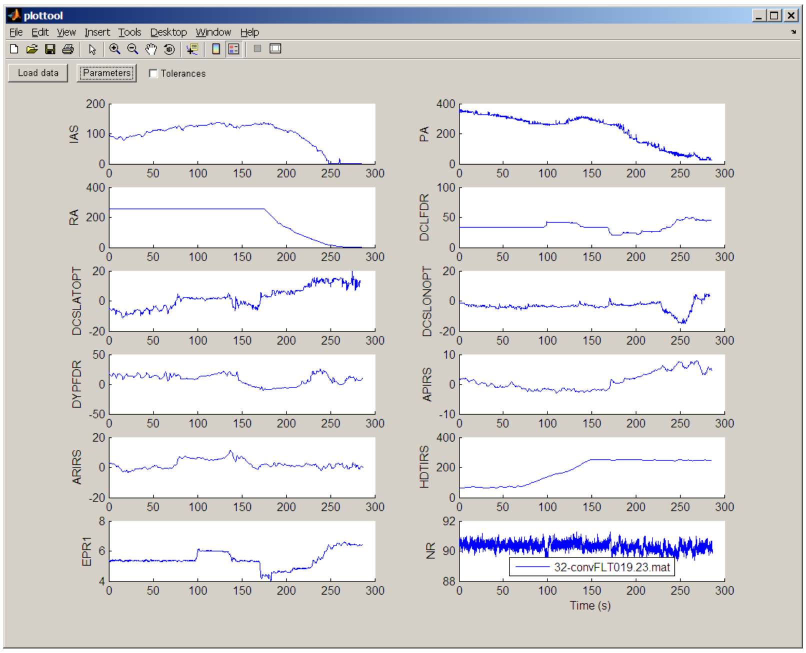


Figure 5: Flight test data plotting tool

- A Matlab®-based graphical user-interface (see Figure 6) for the selection of steady state (trim) data. From time history data selections can be made manually, automatically showing the average value and standard deviation. Figure 6 shows indicated airspeed in the top graph, and pitch attitude in the lower graph. The two grey bands are manually selected areas. The red dot and lines indicate the average value and standard deviation. The result from this selection would be two test points, with flight parameters like pitch attitude as a function of airspeed.

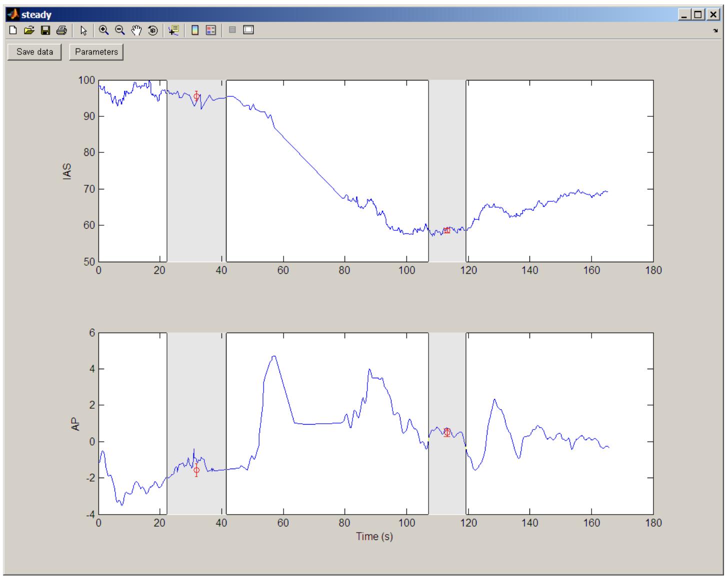


Figure 6: Steady state data selection tool

- Flight test replay tool: HeliX is a 3-D representation of flight path and helicopter motion (see Figure 7, both from an outside view or a cockpit view with head-up display, including stick positions, enabling the replay of test data. This was found to be a highly valued aid in the post-flight data analysis.

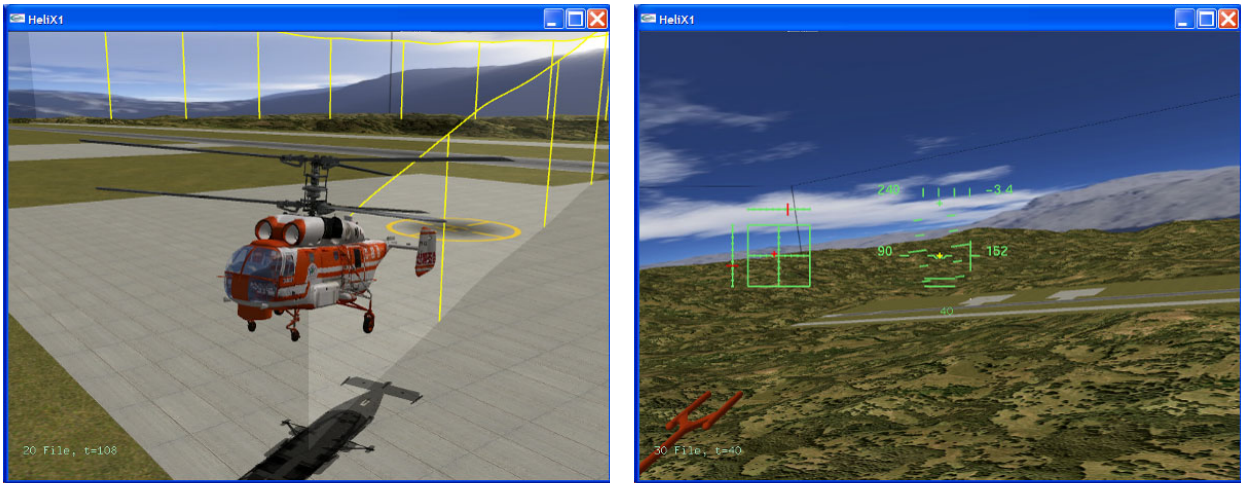


Figure 7: HeliX flight test replay tool

6 Flight test plan

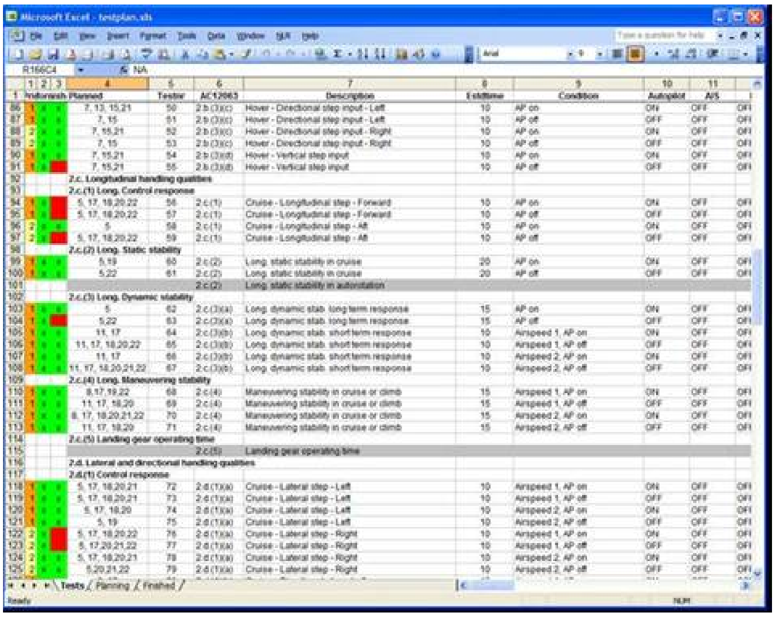
The KARI flight test engineer was responsible for the onboard flight test managing, briefing and debriefing, while NLR engineers were responsible for the test planning, data processing and analysis. FAO pilots and mechanics were in charge of the safety for the flight and instrumentation.

In preparation of the flight test campaign, the test plan was drafted, as well as a ‘flight test execution guide’. The test plan described in detail which configuration and maneuvers were planned, while the flight test execution guide provided guidelines to the pilots on how to perform the maneuvers. Due to FAO operational limitations, no autorotation or (simulated) single engine flights could be performed. Also, no torque measurement was available. Due to the KA32's design philosophy it has no torque indicators in the cockpit. The gearbox is designed to absorb all engine power at all times, also with one engine inoperative. Therefore, a torque indication is not required. To provide the pilot with a measure of engine power, 'Engine Pressure Ratio', is displayed instead of torque. This is a measure of engine power, but cannot be converted to horse power directly.

Sideslip angle has not been measured, due to limitations on flight test instrumentation by the operator. This makes judging the initial condition for cruise flight difficult. For dynamic tests with a tolerance for sideslip angle it was decided to replace it by rate of yaw, with a tolerance of 2°/s (similar to the directional step inputs in cruise).

The majority of the test plan consisted of AC120-63 validation tests (see ref. 1). Additional tests were included in the test plan for validation outside the AC120-63 requirements, like accel-decel maneuvers and hover turns. These maneuvers were based on ref. 3). Other tests, like autopilot and engine performance checks were performed to provide additional data for the simulation model. A total of 143 test cards were prepared, distributed as follows:

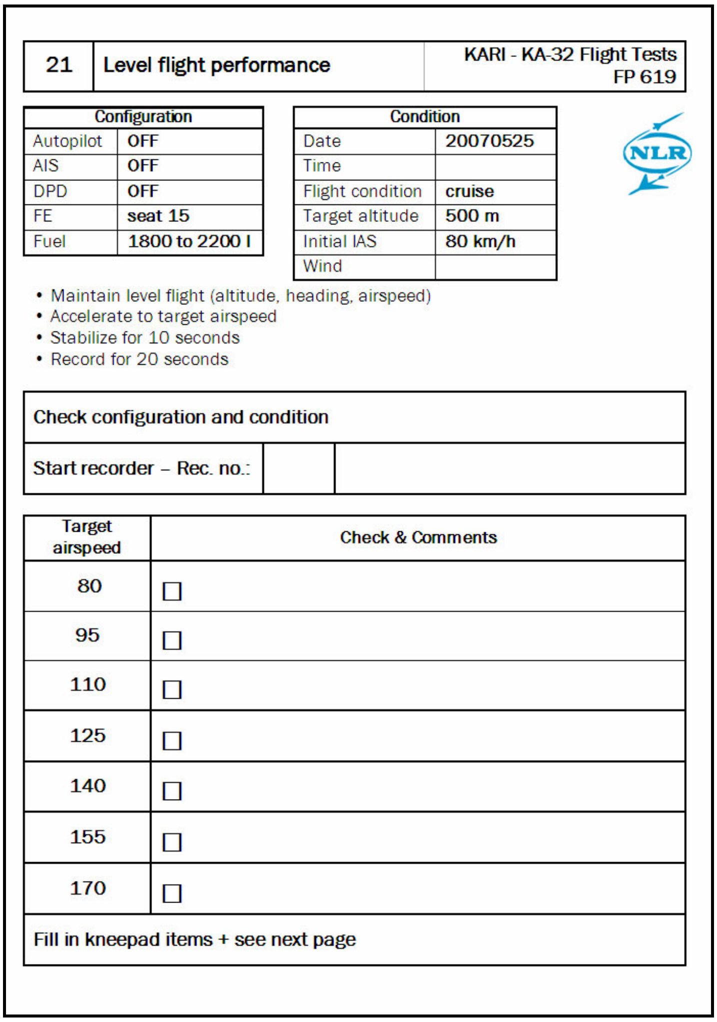
- 14% ground
- 19% hover
- 8% low speed
- 5% climb & descent
- 54% cruise



	1	2	3	4	5	6	7	8	9	10	11	
1	Prio/Finish			Planned	Testnr	AC12063	Description	Estdtime	Condition	Autopilot	A/S	
86	1	🟩	🟩	7, 13, 15,21	50	2.b.(3)(c)	Hover - Directional step input - Left	10	AP on	ON	OFF	OF
87	1	🟩	🟩	7, 15	51	2.b.(3)(c)	Hover - Directional step input - Left	10	AP off	OFF	OFF	OF
88	2	🟩	🟩	7, 15,21	52	2.b.(3)(c)	Hover - Directional step input - Right	10	AP on	ON	OFF	OF
89	2	🟩	🟩	7, 15	53	2.b.(3)(c)	Hover - Directional step input - Right	10	AP off	OFF	OFF	OF
90	1	🟩	🟩	7, 15,21	54	2.b.(3)(d)	Hover - Vertical step input	10	AP on	ON	OFF	OF
91	1	🟩	🟥	7, 15,21	55	2.b.(3)(d)	Hover - Vertical step input	10	AP off	OFF	OFF	OF
92				2.c. Longitudinal handling qualities								
93				2.c.(1) Long. Control response								
94	1	🟩	🟥	5, 17, 18,20,22	56	2.c.(1)	Cruise - Longitudinal step - Forward	10	AP on	ON	OFF	OF
95	1	🟩	🟥	5, 17, 18,20,22	57	2.c.(1)	Cruise - Longitudinal step - Forward	10	AP off	OFF	OFF	OF
96	2	🟩	🟩	5	58	2.c.(1)	Cruise - Longitudinal step - Aft	10	AP on	ON	OFF	OF
97	2	🟩	🟥	5, 17, 18,20,22	59	2.c.(1)	Cruise - Longitudinal step - Aft	10	AP off	OFF	OFF	OF
98				2.c.(2) Long. Static stability								
99	1	🟩	🟩	5,19	60	2.c.(2)	Long. static stability in cruise	20	AP on	ON	OFF	OF
100	1	🟩	🟩	5,22	61	2.c.(2)	Long. static stability in cruise	20	AP off	OFF	OFF	OF
101						2.c.(2)	Long. static stability in autorotation					
102				2.c.(3) Long. Dynamic stability								
103	1	🟩	🟩	5	62	2.c.(3)(a)	Long. dynamic stab. long term response	15	AP on	ON	OFF	OF
104	1	🟩	🟥	5,22	63	2.c.(3)(a)	Long. dynamic stab. long term response	15	AP off	OFF	OFF	OF
105	1	🟩	🟩	11, 17	64	2.c.(3)(b)	Long. dynamic stab. short term response	10	Airspeed 1, AP on	ON	OFF	OF
106	1	🟩	🟩	11, 17, 18,20,22	65	2.c.(3)(b)	Long. dynamic stab. short term response	10	Airspeed 1, AP off	OFF	OFF	OF
107	1	🟩	🟩	11, 17	66	2.c.(3)(b)	Long. dynamic stab. short term response	10	Airspeed 2, AP on	ON	OFF	OF
108	1	🟩	🟩	11, 17, 18,20,21,22	67	2.c.(3)(b)	Long. dynamic stab. short term response	10	Airspeed 2, AP off	OFF	OFF	OF
109				2.c.(4) Long. Manoeuvring stability								
110	1	🟩	🟩	8,17,19,22	68	2.c.(4)	Maneuvering stability in cruise or climb	15	Airspeed 1, AP on	ON	OFF	OF
111	1	🟩	🟩	11, 17, 18,20	69	2.c.(4)	Maneuvering stability in cruise or climb	15	Airspeed 1, AP off	OFF	OFF	OF
112	1	🟩	🟩	8, 17, 18,20,21,22	70	2.c.(4)	Maneuvering stability in cruise or climb	15	Airspeed 2, AP on	ON	OFF	OF
113	1	🟩	🟩	11, 17, 18,20	71	2.c.(4)	Maneuvering stability in cruise or climb	15	Airspeed 2, AP off	OFF	OFF	OF
114				2.c.(5) Landing gear operating time								
115						2.c.(5)	Landing gear operating time					
116				2.d. Lateral and directional handling qualities								
117				2.d.(1) Control response								
118	1	🟩	🟩	5, 17, 18,20,21	72	2.d.(1)(a)	Cruise - Lateral step - Left	10	Airspeed 1, AP on	ON	OFF	OF
119	1	🟩	🟩	5, 17, 18,20,21	73	2.d.(1)(a)	Cruise - Lateral step - Left	10	Airspeed 1, AP off	OFF	OFF	OF
120	1	🟩	🟩	5, 17, 18,20	74	2.d.(1)(a)	Cruise - Lateral step - Left	10	Airspeed 2, AP on	ON	OFF	OF
121	1	🟩	🟩	5, 19	75	2.d.(1)(a)	Cruise - Lateral step - Left	10	Airspeed 2, AP off	OFF	OFF	OF
122	2	🟩	🟥	5, 17, 18,20,22	76	2.d.(1)(a)	Cruise - Lateral step - Right	10	Airspeed 1, AP on	ON	OFF	OF
123	2	🟩	🟥	5, 17,20,21,22	77	2.d.(1)(a)	Cruise - Lateral step - Right	10	Airspeed 1, AP off	OFF	OFF	OF
124	2	🟩	🟩	5, 17, 18,20,21	78	2.d.(1)(a)	Cruise - Lateral step - Right	10	Airspeed 2, AP on	ON	OFF	OF
125	2	🟩	🟩	5,20,21,22	79	2.d.(1)(a)	Cruise - Lateral step - Right	10	Airspeed 2, AP off	OFF	OFF	OF

Figure 8: Excel sheet for flight test planning

The test plan was summarized in an Excel sheet (Figure 8), which was the main flight test planning tool. It provides a quick overview of progress and includes test priority and pass/fail indication. Also, from this sheet, test cards are generated automatically, including a short description on how to perform the test, required configuration for the test and room for remarks of the flight test engineer (see Figure 9).



21	**Level flight performance**	KARI - KA-32 Flight Tests FP 619

Configuration	
Autopilot	**OFF**
AIS	**OFF**
DPD	**OFF**
FE	**seat 15**
Fuel	**1800 to 2200 l**

Condition	
Date	**20070525**
Time	
Flight condition	**cruise**
Target altitude	**500 m**
Initial IAS	**80 km/h**
Wind	

- Maintain level flight (altitude, heading, airspeed)
- Accelerate to target airspeed
- Stabilize for 10 seconds
- Record for 20 seconds

Check configuration and condition		
Start recorder – Rec. no.:		

Target airspeed	Check & Comments
80	☐
95	☐
110	☐
125	☐
140	☐
155	☐
170	☐

Fill in kneepad items + see next page

Figure 9: Example of a test card

7 Flight test execution

After a 2-week instrumentation installation period, the test campaign started at the Iksan airbase of the Forest Aviation Office on 1 August 2007. Nearly 5 weeks of flight tests followed.
The flight tests were performed in a daily schedule of up to two flights a day.

After acquiring the actual meteo information, the test cards were selected for each flight, based on:

- Weather conditions
- Progress of the test program based on analyzed test results
- An efficient combination of maneuvers with respect to helicopter mass, required altitude and airspeed, pilot's workload etc.

The test program of the flight consisted of the sequence of the selected test cards.
The resulting test program was briefed to the KARI flight test engineer by NLR in English.
Subsequently, the helicopter crew was briefed by the flight test engineer in Korean.
Next, the flights were executed by the helicopter test crew. During the test flight, previously acquired data was analyzed by NLR on the ground. The main objective of the analysis was approval or rejection of the data as a source for tuning. The approval of data defined the status and progress of the test program.
After landing, the acquired data was processed by the NLR instrumentation engineer while the other NLR engineers were debriefed by the KARI flight test engineer.

Low speed flight tests

Since the FAO base at Iksan has only a helicopter platform, the low-speed flight tests requiring a runway were performed at the Jeonju air force base, which is only 4.5 nautical miles from the FAO base. For these tests a mobile meteo team deployed to Jeonju air force base to set up the 10 m wind measuring mast just outside the base perimeter for security reasons, in close proximity of the runway (see Figure 10). This team operated from a car with power supply, laptop and data acquisition system, connected to the measuring mast.

Figure 10: Installation site of meteo mast at Jeonju air force base

8 Flight test results

In the period from 1 to 31 August 2007, the flight trials at the Iksan airbase of the Forest Aviation Office yielded the following results:

- A total of about 30 hours of flight time has been performed in 22 flights.
- A distinction was made between 'performed' tests and 'approved' tests: A test was 'performed' once it has been executed during a flight. Only when the data of the test shows that it has been executed satisfactorily and provides sufficient data for model tuning, it was approved.
- 99% of the test program has been executed. Of the planned tests only the engine start/shutdown at altitude was not performed (low priority).

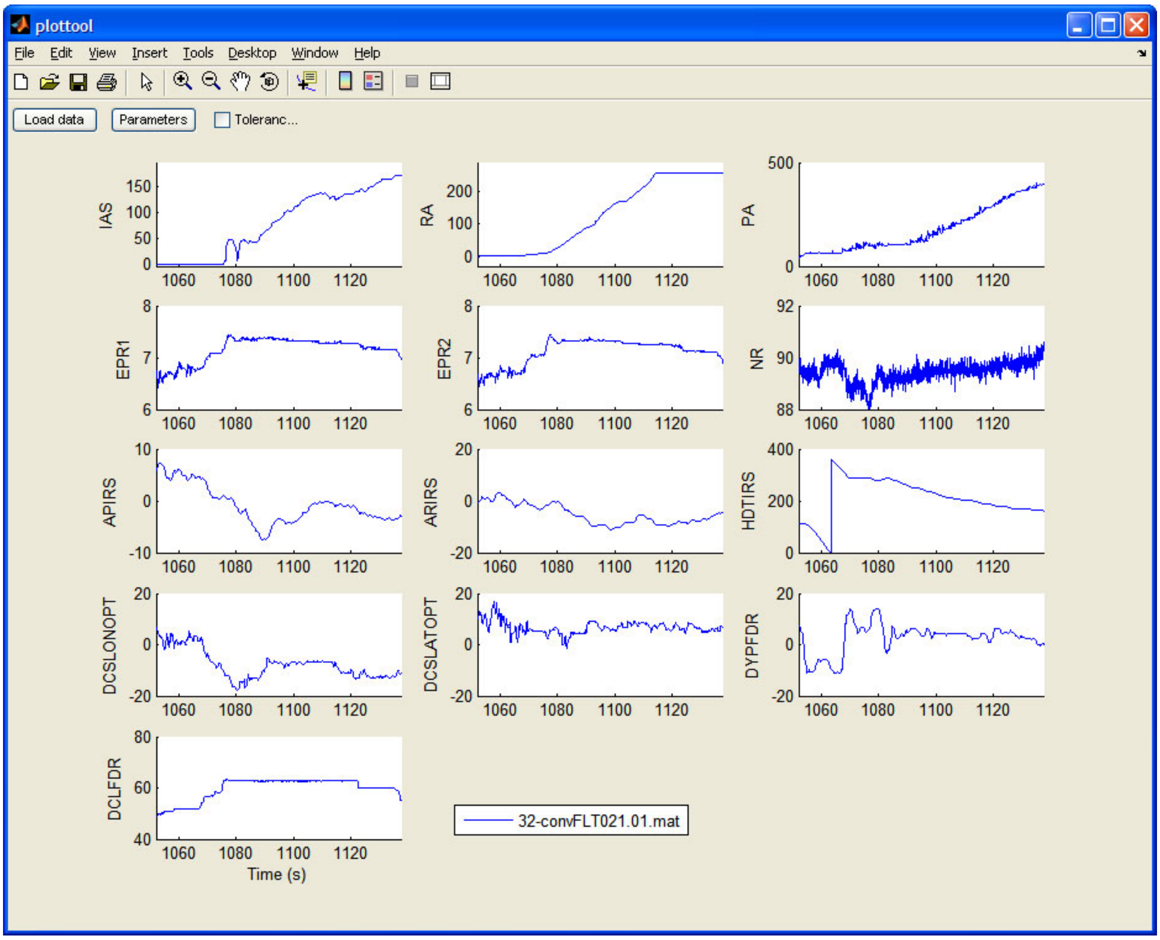


Figure 11: Example of parameter plots used during analysis of the acquired test data

- With the Matlab®-based analysis tools, described earlier, the acquired test data was analyzed. The analysis consisted of verifications of:
- data quality
- steady initial conditions
- steady data i.e. correct performed maneuver
- control inputs applied conform the definition required for tuning.

In Figure 11 an example is given of a graphical presentation of a take–off. To save space on the screen, only the acronyms without engineering units are listed at the vertical axes.

Presented in Figure 11 are:

IAS:	Indicated airspeed (km/h)
RA:	Radio altitude (m)
PA:	Barometric altitude (m)
EPR1:	Engine Pressure Ratio 1 (-)

EPR2:	Engine Pressure Ratio 2 (-)
NR:	Rotor speed (%)
APIRS:	Pitch angle (deg)
ARIRS:	Roll angle (deg)
HDTIRS:	Heading (deg)
DCSLONOPT:	Longitudinal cyclic stick pos. (%)
DCSLATOPT:	Lateral cyclic stick pos. (%)
DYPFDR:	Pedal position (%)
DCLFDR:	Collective stick position (%)

9 Application of the flight test results

During the flight test phase as described in the previous section, the goal was to gather data for flight mechanics model improvement and data for the comparison between model and flight test (Qualification Test Guide). This chapter presents a brief discussion of how the flight test data was used within the project. The complete results of the model development and subsequent tuning process are presented in reference 2.

Before starting the tuning phase, the flight mechanics model was updated with data measured during the flight test phase. This included:
- airspeed calibration
- flight control rigging
- engine performance data
- autopilot performance (gains and limits)

The tuning process consisted of an iterative loop. Together with post-processing the flight test data, an appropriate selection of the flight test data was made: for example selection of the most successful control inputs or best steady data.

This data was input for the creation of scripts that enabled automatic simulation of all test points. The subsequent data analysis led to changes in the model, or changes in data selection, after which another iteration was performed.

An example of the result of the tuning phase is shown in Figure 12: the 'All Engines Take-Off'. The green and blue lines present the simulation and flight test results respectively and the shaded area indicates the tolerance defined in the simulator qualification requirements (ref. 1).

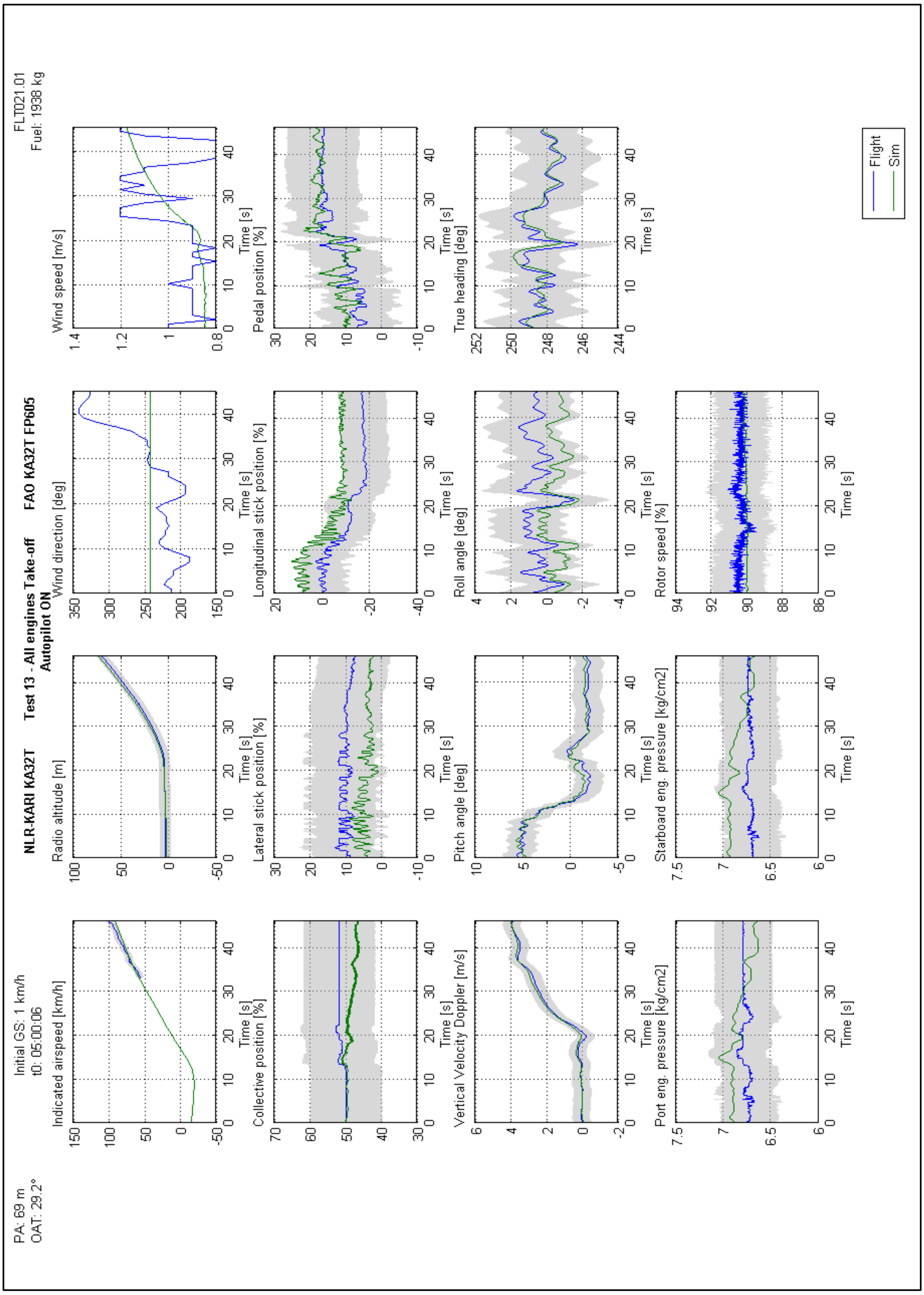


Figure 12: Comparison between model and flight test data for the take-off maneuver

During the tuning phase a number of challenges have been encountered due limitations in instrumentation and allowable flight test maneuvers (no single engine or autorotation), lack of wind tunnel data *(only CFD)*, etc.
Despite these limitations a very good result has been achieved, providing a simulation model that has a high (Level C) fidelity in representing the KA32T and an almost 100% fit to the flight test data.

10 Conclusions

A very successful flight test campaign has been executed from 1 to 31 August 2007 at the Iksan airbase of the Forest Aviation Office in Korea. The installation and calibration of the instrumentation was accomplished within 2 weeks. A total of about 30 hours of flight time has been performed in 22 flights
The efficient and flexible set-up of the NLR flight testing tools enabled a small test team to quickly analyze the acquired data on-site, resulting in efficient monitoring of the program progress and flexible adaptation of the test program to ambient weather conditions and operational constraints.

The flight test campaign provided good quality data for the AC120-63 tuning process, thanks to a good co-operation between Korean and Dutch engineers and the Korean helicopter operator.

Table 1: Parameter list

ATA	Description
	General
0	Event Marker
0	Record number
0	Cold Junction Temperature
	Calibration Tool Arms & legs
0	Time
	Air Data
1	Indicated Airspeed
1	Outside Air Temp at heli
1	Altitude (baralt)
1	Altitude (radalt); upto 300 m
	Meteo
15	Wind Direction
15	Wind Speed
15	Air Pressure Groundstation
15	OAT Groundstation
	Flight Controls
27	Cyclic Lateral Position_FDR
27	Cyclic Longitudinal Position_FDR
27	Collective Position
27	Cyclic Lateral Position_NLR
27	Cyclic Longitudinal Position_FDR
27	Collective Position
27	Cyclic Lateral Position_NLR
27	Cyclic Longitudinal Position_NLR
27	Differential Pitch
	Pedal Position
	Collective Pitch
	Trim button on pilot Cyclic Stick
	Landing Gear
32	Weight-on-wheel signal
	Navigation
34	Lateral Acceleration
34	Longitudinal Acceleration
34	Pitch Attitude_FDR
	Navigation
34	Roll Attitude_FDR
34	Normal Acceleration
34	Heading_FDR
34	Lateral Velocity Doppler
34	Longitudinal Velocity Doppler
34	Vertical Velocity Doppler
34-28	Pitch Angle
34-28	Roll Angle
34-28	Ground Track True
34-28	Body Longitudinal Accel.
34-28	Body Lateral Accel.
34-28	Body Normal Accel.
34-28	Vertical Acceleration
34-28	Ground Speed
34-28	Magnetic Heading
34-28	True Heading
34-28	Present Position Latitude
34-28	Present Position Longitude
34-28	Body Pitch Rate
34-28	Body Roll Rate
34-28	Body Yaw Rate
34-28	Velocity N S IRS
34-28	Velocity E W IRS
	Engine
72	Engine Pressure Ratio 1
72	Engine Pressure Ratio 2
72	Gas Generator Speed Engine 1
72	Gas Generator Speed Engine 2
72	Rotor Speed
72	Total fuel quantity
72	Separate Throttle Control Lever
72	Turbine Gas Temperature Engine 1
72	Turbine Gas Temperature Engine 2

References

1) Federal Aviation Administration Advisory Circular, "Helicopter Simulator Qualification," FAA AC 120-63, October 1994.
2) “Flight mechanics model development for a KA32 training simulator”; Jasper van der Vorst, Koen D.S. Zeilstra, National Aerospace Laboratory NLR, Dae Keun Jeon, Hyoung Sik Choi, Hyang Sig Jun, Korea Aerospace Research Institute, KARI. Presented at ERF-35, September 2009
3) Longo, "Data Standards For Helicopter Simulators Using A Blade Element Rotor Model", AIAA-95-3423-CP, American Institute of Aeronautics and Astronautics, 1995.