



## Executive summary

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



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NLR-TP-2010-034

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

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## Summary

Together with (and contracted by,) the Korea Aerospace Research Institute (KARI) the Dutch National Aerospace Laboratory performed a successful flight test campaign with the Kamov KA32T in South Korea during the summer of 2007. These trials were part of the KA-32 Helicopter Training Simulator Development Program managed by KARI. Within this program, National Aerospace Laboratory developed the flight model and executed the flight tests in close cooperation with KARI and the helicopter operator. A very successful flight test campaign was executed from August 1 to 31, 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 was performed in 22 flights. This article describes an interesting project with an international touch, including some distinctive logistical challenges: Korean and Dutch engineers working on a Russian helicopter.

**Key words:** Flight test program; helicopter; Iksan airbase; international collaboration; Jeonju airbase; Kamov KA32T; Korea; simulator development; test data; test plan.

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## 1 Project background

The objective of the KA-32 Helicopter Training Simulator Development Program is to acquire a helicopter simulator that meets level C requirements in accordance with 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 (Figure 1) operated by the Korean Forest Aviation Office (FAO), mainly used for fighting 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 because of its experience with flight simulation development and flight testing for a competitive price. The result was 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 article presents the preparations and execution of the flight test program and discusses some of its results. At the end of the article, 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 coaxial rotor system.

All flights were performed with a crew of two pilots and one 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, they had no 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 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. Because the water tank limits the maximum speed to 150 km/h, as opposed to the normal maximum speed of 230 km/h, it was decided to perform the flight tests without the water tank to enable testing over a larger speed envelope. Both engine inlets are equipped with a dust protection device and an anti-icing system.

It was decided by KARI to vary the helicopter weight using fuel quantity only. Because the external fuel tanks are not available at FAQ, only the internal tanks were used. Using this configuration, weights between about 7,300 and 8,700 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 or 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 and attitude hold. During many of the flight tests, the autopilot had to be switched on. However, some tests specified in the simulator qualification requirements (FAA, 1994) require maneuvers to be performed without the autopilot. The required configuration (autopilot on or off) was indicated on the test cards. "Autopilot" referred 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.





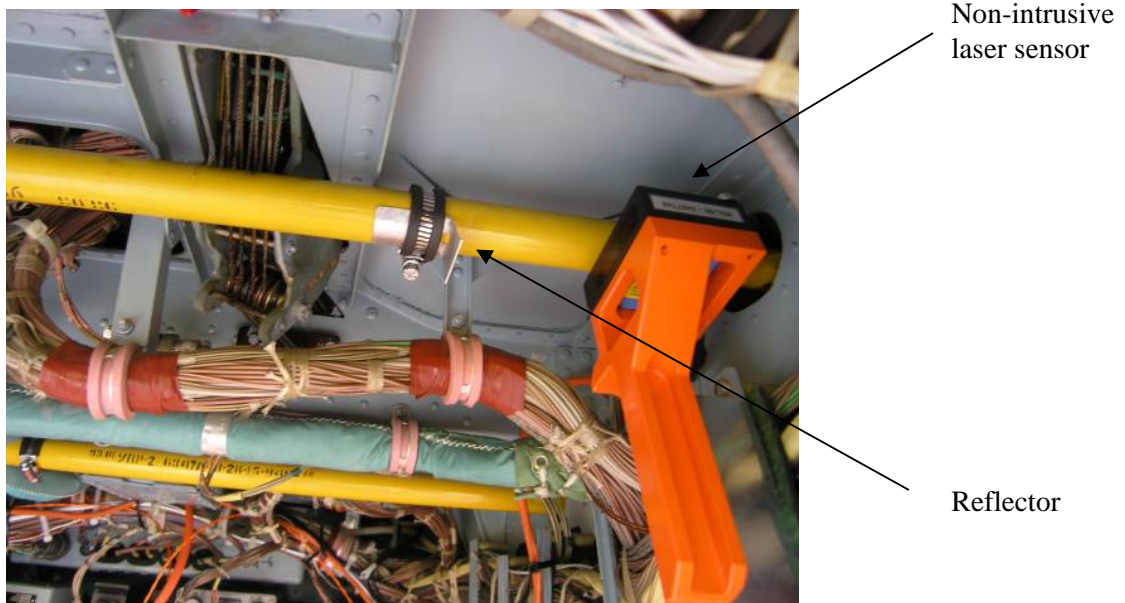
### **3 Instrumentation system**

#### **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 analog signals, discrete signals, digital signals, synchro signals, and manual data entry, e.g., 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 and safety reasons, the system had to be nonintrusive. 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 FDR remained in operation. A second major part in the instrumentation system was a dedicated test inertial reference system, providing ring-laser—based attitudes, rates, and accelerations.

To complement the parameters from the FDR and the NLR inertial reference system, we installed several additional sensors. On the landing light bracket, a probe for outside air temperature was installed. To satisfy concerns about flight safety, we used nonintrusive optical (laser) sensors for longitudinal and lateral cyclic position, with reflectors installed on the longitudinal and lateral push—pull rods below the cockpit floor (Figure 2). To measure engine temperature, we installed a breakout connector in the signal from the engine thermocouples. Because it was not possible to measure the cold junction temperature, the measurement varies with cold junction temperature. This deficiency was 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 shutdown. The engine pressure ratio, an indication of engine power, was measured by installing a breakout connector in the signal to the cockpit instrument.



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

To create the breakout connectors for the flight data recorder, and engine pressure and temperature, we had to purchase several Russian connectors, 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 were recorded on a solid state data recorder and were processed directly 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 GIS is shown in Figure 3, and the system as installed in the helicopter is shown in Figure 4. The parameter list can be found in Table .1. The instrumentation design 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.

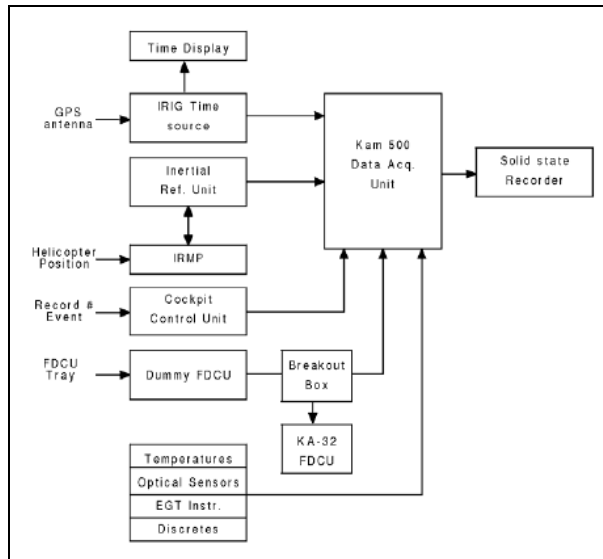


Figure 3: Generic Instrumentation System block diagram



- Break-out box based on Russian connector
- KA-32 Flight data acquisition unit
- Generic Instrumentation System (GIS)
- Inertial Reference System (IRS)
- IRS power supply
- Solid State data recorder
- GPS time unit

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

**Instrumentation systems on ground**

A ground station was located at the PAO 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 sewer—client network environment. The sewer 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 programs. A shared hard-disk unit is used for securely archiving the acquired data. The specialists were provided



with client laptop computers, enabling them to analyze the distributed data on- or offline as necessary. The network is completed with a network printer.

Weather data were gathered with a mobile meteorology (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 are 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.

Table 1: Parameter list

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

## 4 Installation and calibration activities

The flight test campaign in the summer of 2007 started with the installation and calibration of the instrumentation system. Because most of the design work 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 began. 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, like the engine temperatures, gas generator speeds, and rotor speed, were calibrated during a ground run. 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 electromagnetic interference and electromagnetic compatibility test, a first test flight took place for instrumentation check and final calibration. Several runs were included to determine the error in the pitot-static system. The activities just described were performed in a 2-week period, ending on July 31, 2007.

## 5 Data processing and analysis

Data from the instrumentation system are 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 (Figure 5) 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.

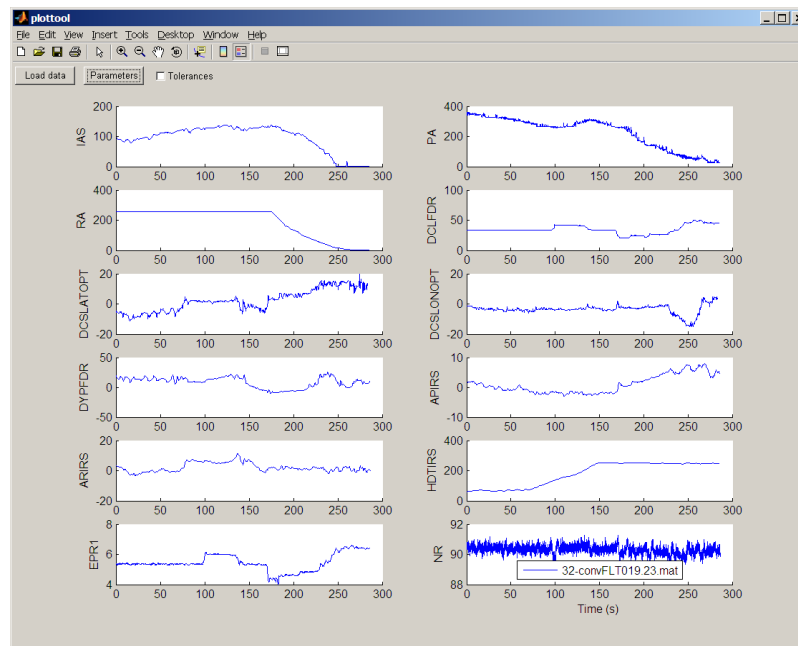


Figure 5: Flight test data plotting tool

- A Matlab—based graphical user interface (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.

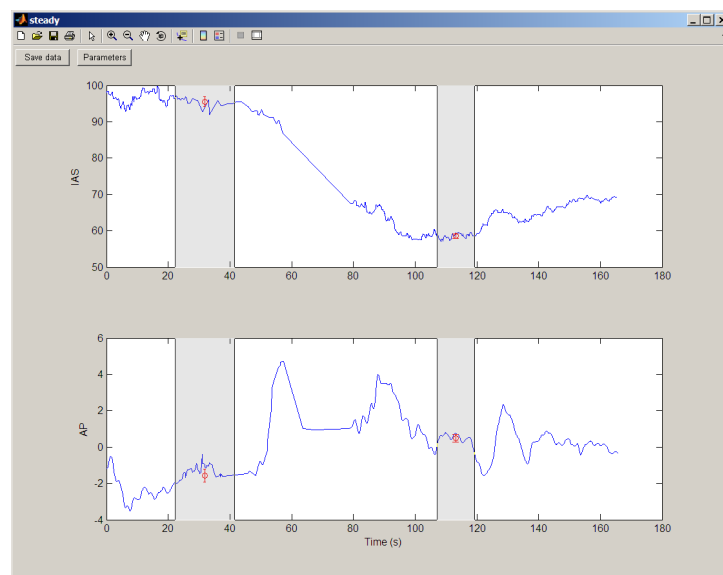


Figure 6: Steady state data selection tool

- Flight test replay tool: HeliX is a three- dimensional representation of flight path and helicopter motion (Figure 7) from either 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 postflight data analysis.

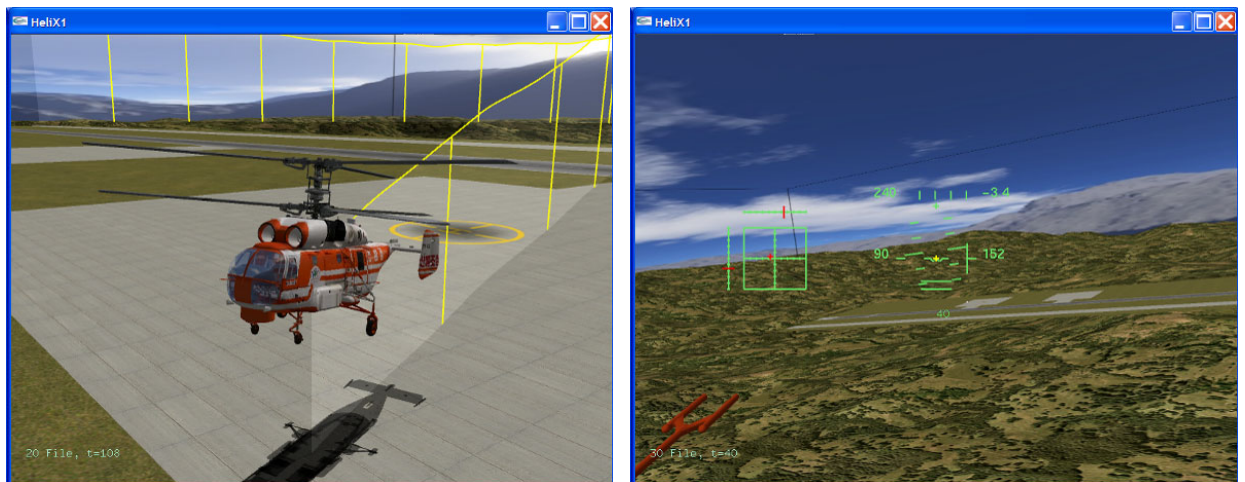


Figure 7: HeliX flight test replay tool

## 6 Flight Test plan

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

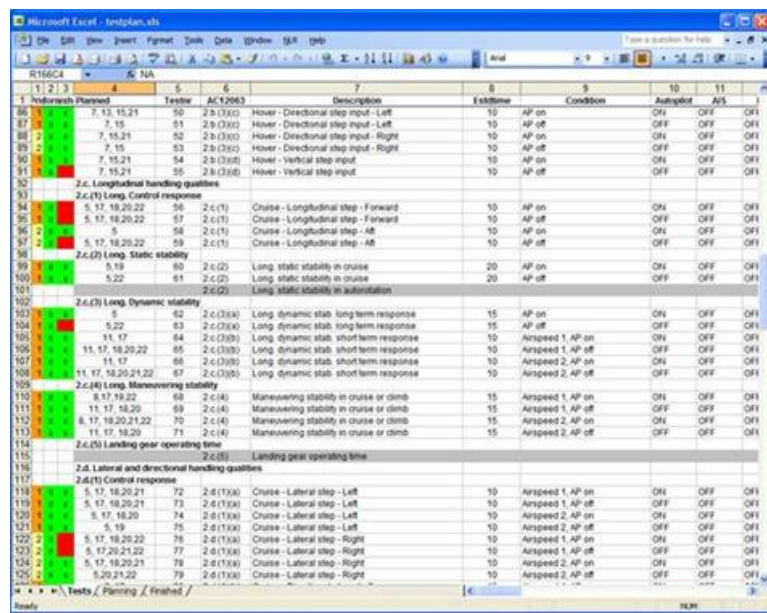
Sideslip angle has not been measured, due to limitations on flight test instrumentation by the operator. This makes judging the initial condition for cruise flight difficult. For dynamic tests with a tolerance for sideslip angle it was decided to replace it by rate of yaw, with a tolerance of  $2^\circ/\text{s}$  (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.

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 by the flight test engineer (Figure 9)



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

Figure 8: Excel sheet for flight test planning



<b>21</b>	<b>Level flight performance</b>	<b>KARI - KA-32 Flight Tests FP 619</b>																										
<table border="1" style="width: 100%; border-collapse: collapse;"> <thead> <tr> <th colspan="2" style="text-align: left;">Configuration</th> </tr> </thead> <tbody> <tr><td>Autopilot</td><td>OFF</td></tr> <tr><td>AIS</td><td>OFF</td></tr> <tr><td>DPD</td><td>OFF</td></tr> <tr><td>FE</td><td>seat 15</td></tr> <tr><td>Fuel</td><td>1800 to 2200 l</td></tr> </tbody> </table>		Configuration		Autopilot	OFF	AIS	OFF	DPD	OFF	FE	seat 15	Fuel	1800 to 2200 l	<table border="1" style="width: 100%; border-collapse: collapse;"> <thead> <tr> <th colspan="2" style="text-align: left;">Condition</th> </tr> </thead> <tbody> <tr><td>Date</td><td>20070525</td></tr> <tr><td>Time</td><td></td></tr> <tr><td>Flight condition</td><td>cruise</td></tr> <tr><td>Target altitude</td><td>500 m</td></tr> <tr><td>Initial IAS</td><td>80 km/h</td></tr> <tr><td>Wind</td><td></td></tr> </tbody> </table>	Condition		Date	20070525	Time		Flight condition	cruise	Target altitude	500 m	Initial IAS	80 km/h	Wind	
Configuration																												
Autopilot	OFF																											
AIS	OFF																											
DPD	OFF																											
FE	seat 15																											
Fuel	1800 to 2200 l																											
Condition																												
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Target altitude	500 m																											
Initial IAS	80 km/h																											
Wind																												
<ul style="list-style-type: none"> <li>Maintain level flight (altitude, heading, airspeed)</li> <li>Accelerate to target airspeed</li> <li>Stabilize for 10 seconds</li> <li>Record for 20 seconds</li> </ul>																												
<table border="1" style="width: 100%; border-collapse: collapse;"> <tr> <td colspan="2" style="text-align: center;"><b>Check configuration and condition</b></td> </tr> <tr> <td style="width: 40%;">Start recorder – Rec. no.:</td> <td></td> </tr> </table>			<b>Check configuration and condition</b>		Start recorder – Rec. no.:																							
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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 August 1, 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 start IAs were selected for each flight based on weather conditions; progress of the test program based on analyzed test results; and an efficient combination of maneuvers with respect to helicopter mass, required altitude and airspeed, pilot’s workload, etc.

The test program consisted of the sequence of the selected test cards. The resulting 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 test crew executed the test flight. During the test flight, previously acquired data were 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 were processed by the NLR instrumentation engineer while the other NLR engineers were debriefed by the KARI flight test engineer.

### **Low speed flight tests**

Because 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 FAQ base. For these tests a mobile meteo team deployed to Jeonju air force base to set up the 10-rn wind measuring mast just outside the base perimeter for security reasons, in close proximity of the runway (Figure 10). This team operated from a car with a 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 August 1 to 31, 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 show that the test has been executed satisfactorily and provides sufficient data for model tuning, were the data approved;
- Of the test program, 99% was executed. Of the planned tests, only the engine start and shutdown at altitude was not performed (low priority).

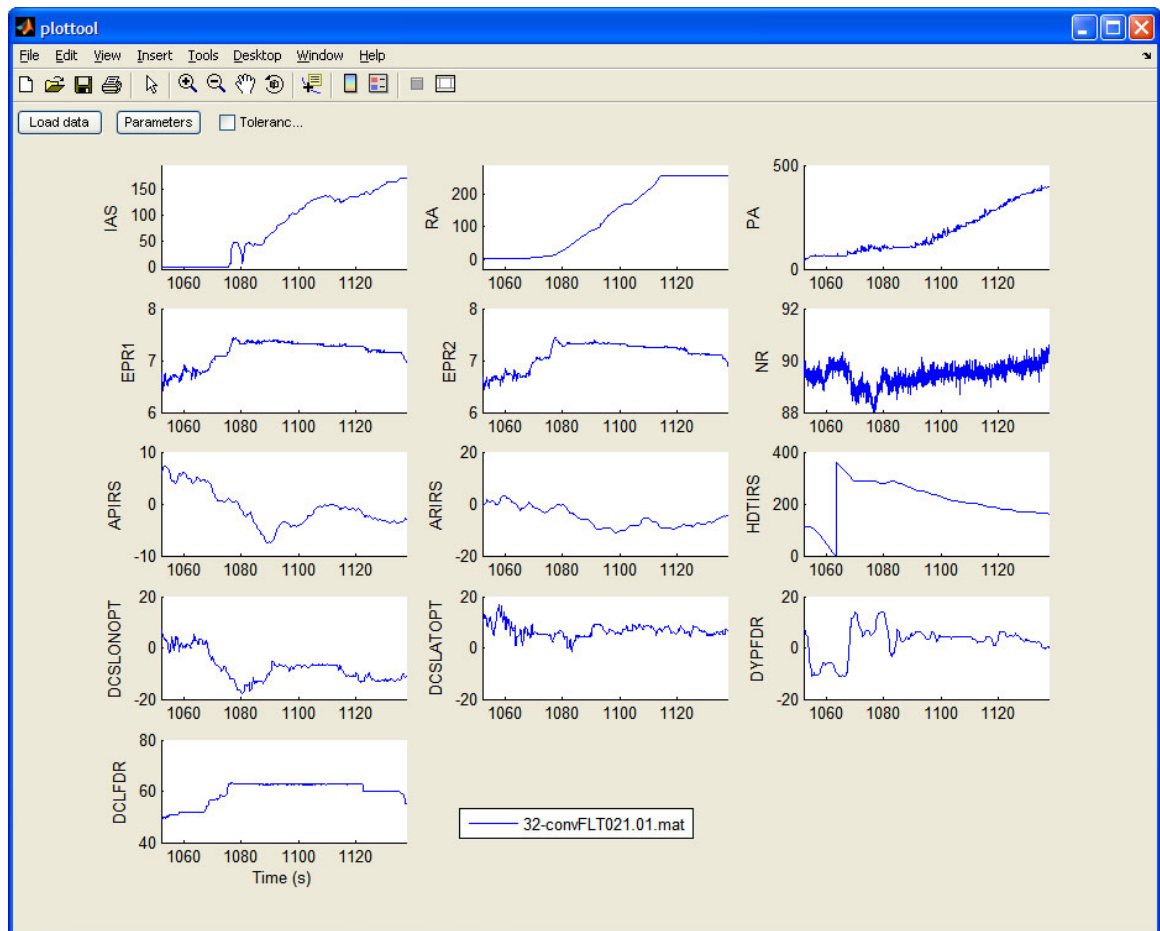


Figure 11: Example of parameter plots used during analysis of the acquired test data

The Matlab-based analysis tools, described earlier were used to analyze the acquired test data. The analysis consisted of verifications of data quality; steady initial conditions; and steady data,

i.e., correctly performed maneuver; the analysis also verified that control inputs applied conformed to the definition required for tuning.

In Figure 11 an example is given of a graphical presentation of a takeoff. To save space on the screen, we list only the acronyms without engineering units on the vertical axes.

## 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 section presents a brief discussion of how the flight test data were used within the project. The complete results of model development and subsequent tuning process are presented in van der Vorst et al. (2009).

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, and autopilot performance (gains and limits). The tuning process consisted of an iterative loop. Together with postprocessing 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.

These data were 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 takeoff. 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 (FAA, 1994).

During the tuning phase a number of challenges were encountered because of limitations in instrumentation and allowable flight test maneuvers (no single engine or autorotation), lack of wind tunnel data (only computational fluid dynamics), etc. Despite these limitations 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.

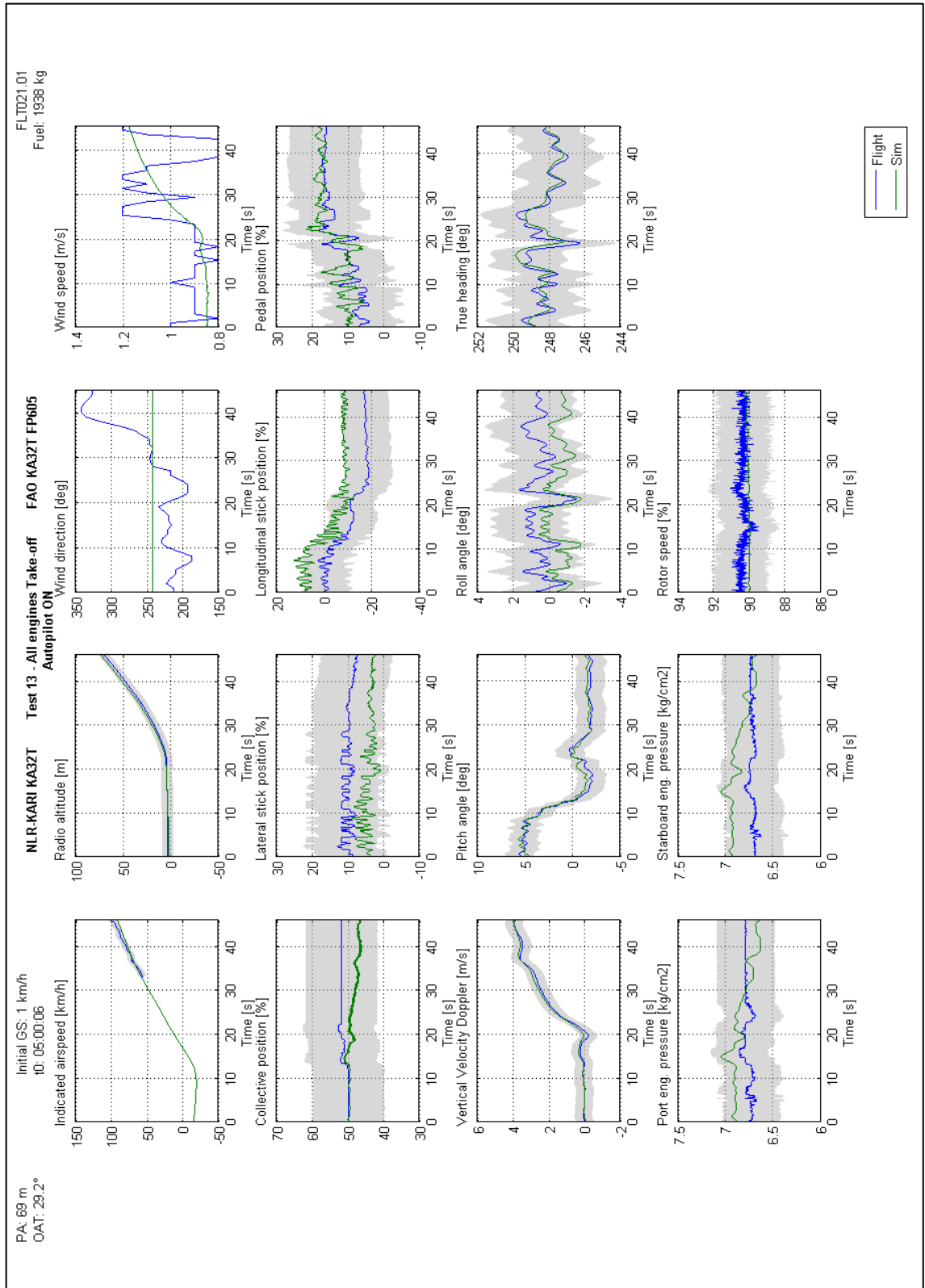


Figure 12: Comparison between model and flight test data for the take-off maneuver



## **10 Conclusions**

A very successful flight test campaign was executed from August 1 to 31, 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 was performed in 22 flights. The efficient and flexible setup 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 good cooperation between Korean and Dutch engineers and the Korean helicopter operator.

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