ANNEXURE E

AGUSTA

AN AGUSTAWESTLAND COMPANY

Cascina Costa, 19.12.2005

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SUBJECT: Analysis on the possible effects of the main rotor servo actuator dynamics on the flight mechanics behaviour of the A109K2 helicopter

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LIST OF FIGURES

ACRONYMS

AFCS – Automatic Flight Control System
CG – Center of Gravity
IAS – Indicated Air Speed
OAT – Outside Air Temperature
P/N – Part Number
SL – Sea Level

REFERENCES

Ref.	Document	Title
[1]	TR-A109-205 (MICROTECNICA)	Investigation report on Main and Tail Rotor Servoactuator installed on A109K2 S/N 10035
[2]	NT1485 (MICROTECNICA)	SERVOCOMANDO ROTORE PRINCIPALE – A109 P/N 204/205/206-28007-00 (Agusta P/N 109-0110-42-124/125/126) P/N 4/5/6-28007 RevB (Agusta P/N 109-0110-42-4/5/6) DIFFERENZE COSTRUTTIVE E FUNZIONALI
[3]	109-24-14	ELICOTTERO A109K2 – Definizione distribuzione di massa ed inviluppi di volo
[4]		Pilot interview

1 INTRODUCTION

On September 3rd, 2005 at Richard's Bay (South Africa) the helicopter A109K2 S/N 10035 crashed while performing a marine pilot pick up on a vessel. The trim conditions and the helicopter configuration were:

level flight alongside the vessel, ISA SL, height 50 ft, weight 2500 kg, IAS 10 kts, lateral left wind 18 kts.

From ref. [4] we can read that: the helicopter pilot *'...was sitting in transition maintaining position on the vessel...'* when he *'...felt the machine begin a very gently roll to the right which he attempted to counter with left cyclic. This roll to the right continued despite... increasing left cyclic input...'*. The pilot remembers *'...the machine moving right despite the fact that he had full left cyclic. He remembers looking at his hand against his left leg confirming this fact.'*

The investigation performed by MICROTECNICA (ref. [1]) resulted in discovering that the main rotor servo actuators installed on the helicopter were of two different models (i.e. P/N 01-28007 and P/N 200-28007-00), the main differences lying in their frequency response (ref. [2]). This report is aimed at investigating the possible effects of the servo dynamics on the flight mechanics behaviour of the A109K2 helicopter.

It has to be said that the characteristics of the two different servo models, expressed in terms of frequency response, are sufficient to exclude the possibility of any dependence of the flight mechanics behaviour of the A109K2 helicopter from the different dynamic behaviour of the two servo models. In effect the two servos have different bandwidths (respectively 30 Hz the P/N 01-28007 and 12 Hz the P/N 200-28007-00), but for low frequency inputs, as the one given by the pilot during the accident development (sustained *'...full left cyclic')*, the frequency response are very similar. Anyway it was decided to perform a simulation activity with the flight mechanics code Flightlab to better support this fact.

2 MODELIZATION AND SIMULATION ACTIVITY

Due to the fact that the original Flightlab A109K2 model did not feature any main rotor servo representation, the simulations have been preceded by a modelization activity that has covered the following subjects:

- representation of the mechanical connection between the pilot controls and the control rod position of each servo;
- representation of the servos;
- representation of the mechanical link between servos and swashplate;

The mechanical connections have been represented using look-up tables while the servos have been represented by the transfer function (L(s)) between the servo control rod displacement and the servo displacement.

The transfer function used to represent the servo actuator identified by the P/N 01-28007 is:

$L(s) = 190/(s+190)$.

Its amplitude and phase are reported in Figure 1. The above transfer function guarantees the bandwidth of 190 rad/s (= 30 Hz) reported in ref. [2].

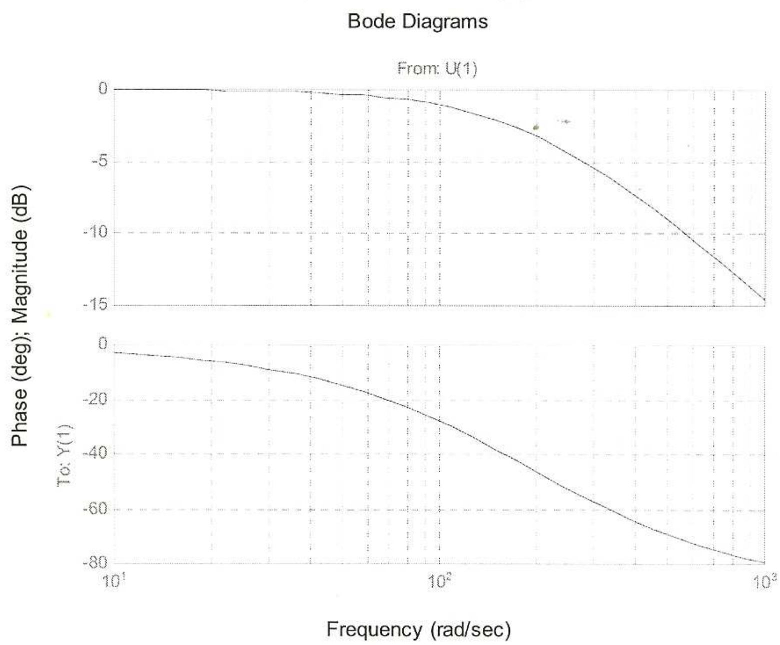

Figure 1 – P/N 01-28007 transfer function, amplitude and phase

To check the effects that the servo actuator dynamics might have on the helicopter handling qualities in the flight condition just described, the manoeuvre has been repeated three times with three different configurations of the main rotor servo actuators:

1. three ideal servo actuators. The transfer function of the actuator is L(s)=1;
2. three servo actuators with P/N 200-28007-00.
3. three servo actuators reproducing the configuration of the crashed helicopter, that is to say servo 2 and 3 of the P/N 200-28007-00 type and servo 1 of the P/N 01-28007 type (see Figure 3 for details).

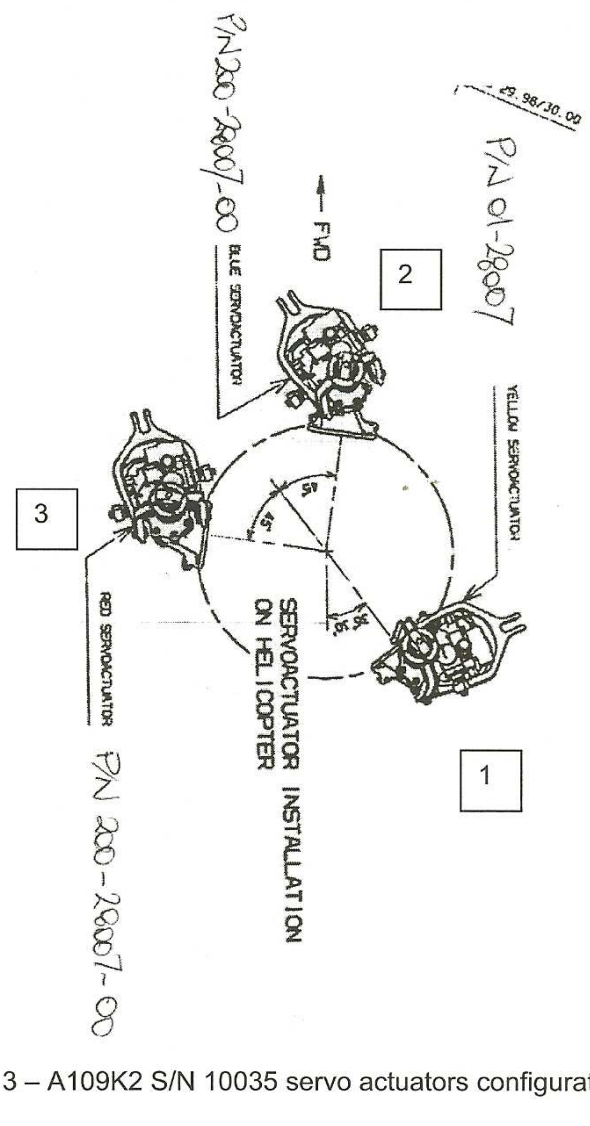

Figure 3 – A109K2 S/N 10035 servo actuators configuration

In the following figures are reported the results of the simulations. The blue lines refer to the configuration number 1), the red lines to the configuration number 2) and the green lines to the configuration number 3).

Figure 4 represents the cyclic doublet applied to the aircraft. Longitudinal cyclic, collective and pedal are maintained in the trim position. The trim lateral cyclic position is approximately 40 % of the control travel, where 0 % corresponds to full left cyclic, while 100 % to full right cyclic. From this initial position the stick is moved first to the left for all the available control travel and then, for the same quantity, to the right for another second.

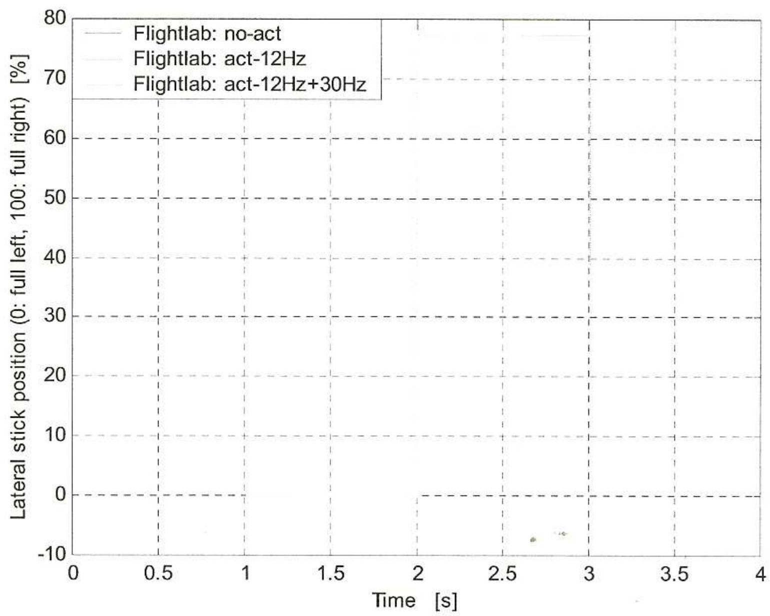

Figure 4 – Response to doublet, lateral cyclic position

Figure 5, Figure 6 and Figure 7 report the time histories of the helicopter attitude angles. Figure 8 reports the helicopter lateral position in the inertial frame and Figure 9 the indicated air speed. The last three figures report the main rotor servo displacements.

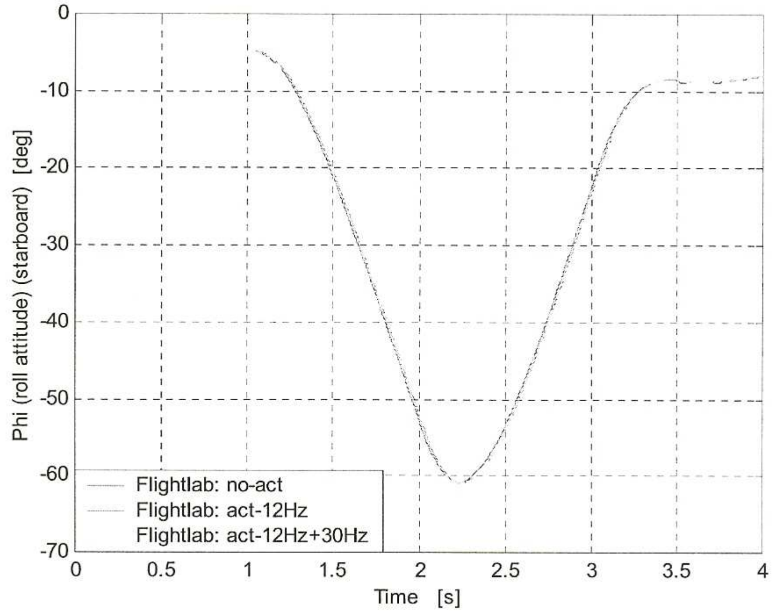

Figure 5 – Response to doublet, phi

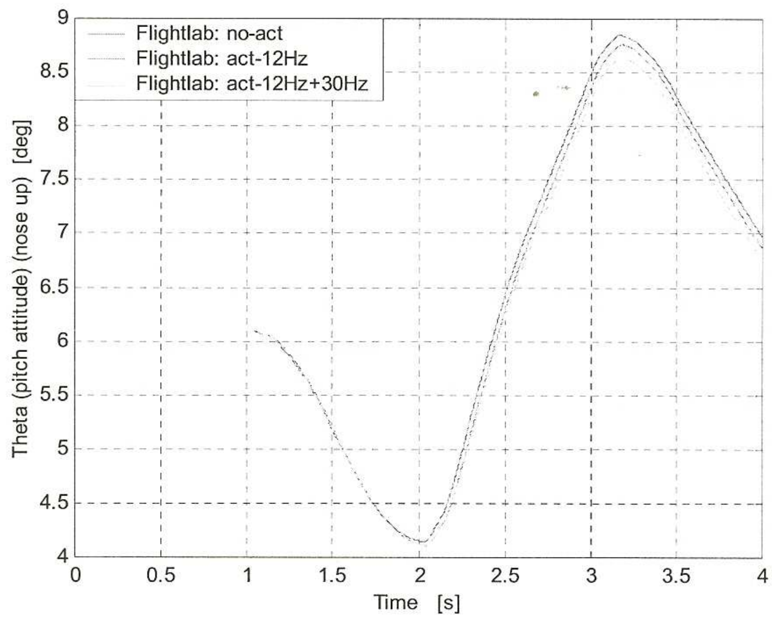

Figure 6 – Response to doublet, theta

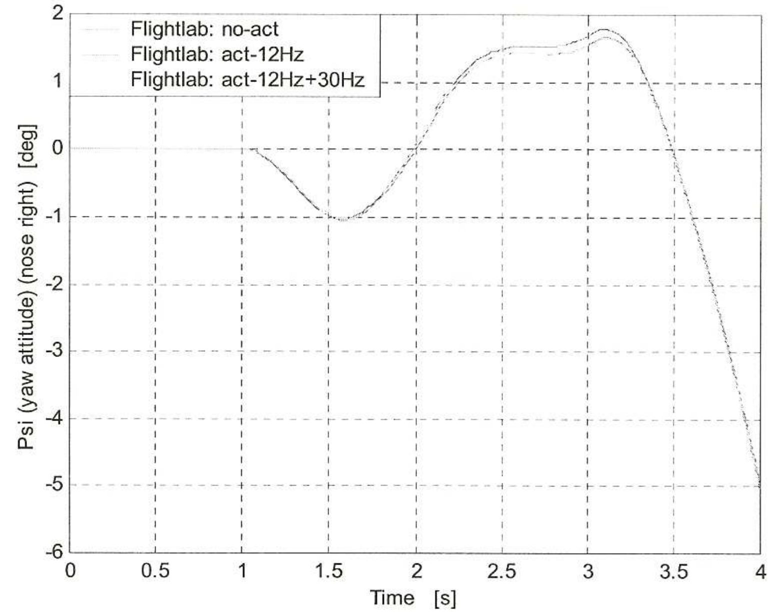

Figure 7 – Response to doublet, psi

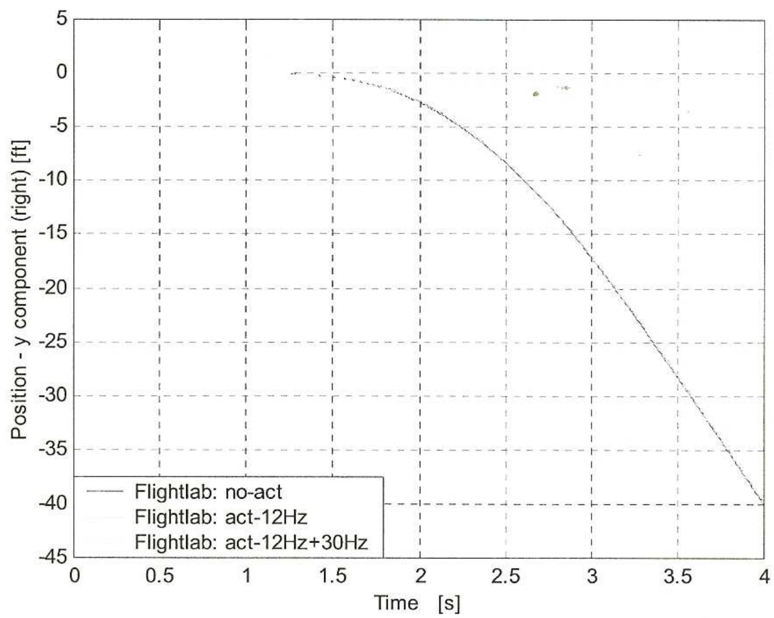

Figure 8 – Response to doublet, position, y component

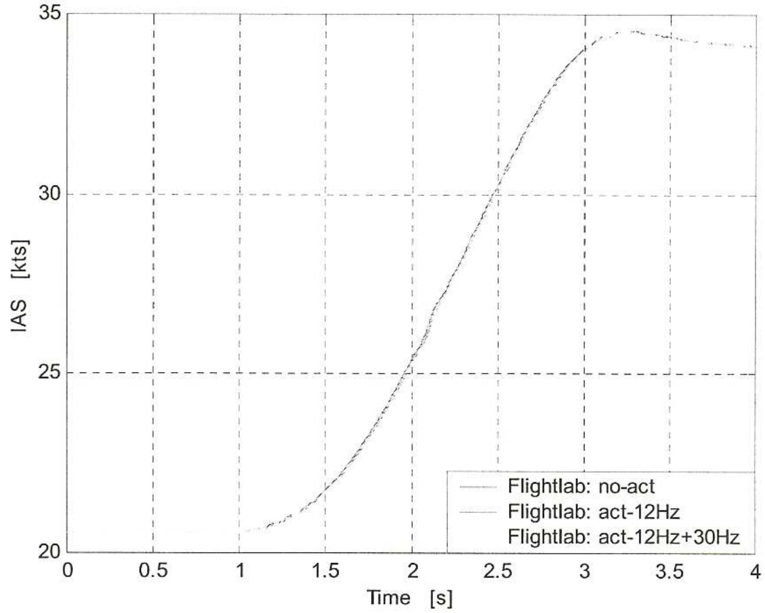

Figure 9 – Response to doublet, IAS

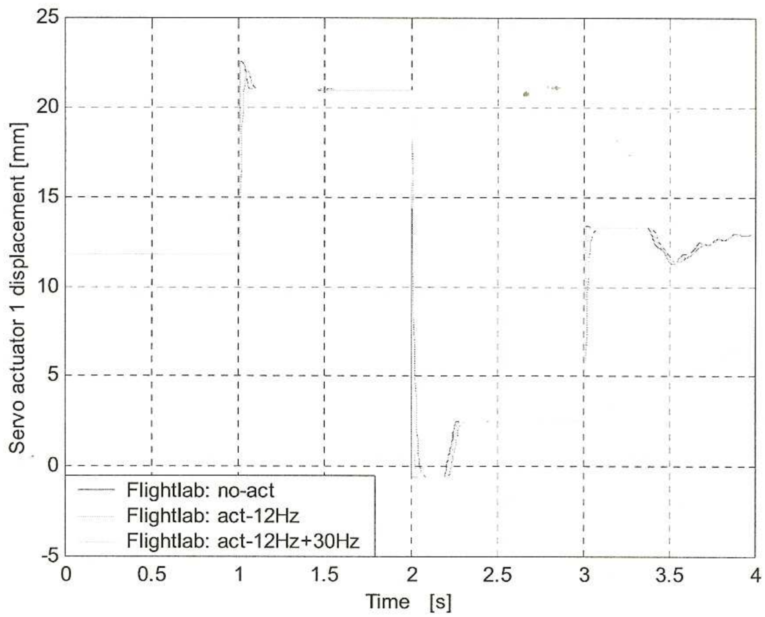

Figure 10 – Response to doublet, servo actuator 1 displacement

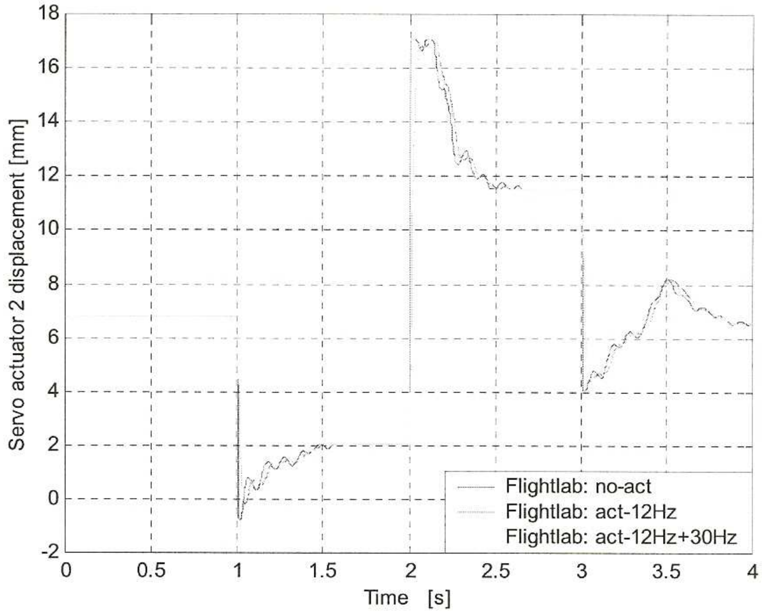

Figure 11 – Response to doublet, servo actuator 2 displacement

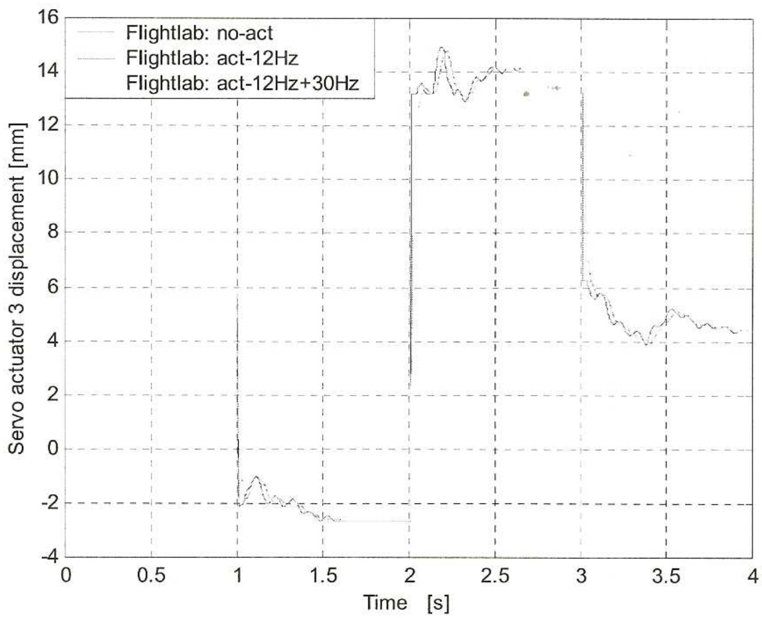

Figure 12 – Response to doublet, servo actuator 3 displacement

From the analysis of the above figures it can be seen that the aircraft flight mechanics behaviour is not significantly influenced by the servo actuator configuration, in fact indicated air speed, aircraft position and attitude angles vary only slightly from one servo actuator configuration to the other for the same input time history. In particular in all three cases a left command does result in a powerful roll to portboard and in a rapid translation to the left.

<u>ANNEXURE F</u>

Appendix S: CABIN EQUIPMENT AND RESPONSIBILITIES A109K2

1. Operational Equipment

- 6 x Headsets (2 front, 4 rear cabin)
- 2 x Strops (one with extension for double strop, i.e. seat, hoisting)
- Winching Glove
- Safety Harness
- Static discharge line
- Manual Cable Cutter with safety attachment rope.
- 1 x handheld spotlight for night operations (1 million-candle power) with safety attachment rope

- Flight Manual
- Airfield letdown procedures
- Chocks

Away from base:

- Tie Downs
- Pitot tube covers and engine exhaust bungs

2. Safety / Emergency Equipment

- Two Flash lights above pilots' seats
- Halon Fire extinguisher in cockpit
- Halon Fire Extinguisher in rear cabin
- First aid kit in rear cabin
- Passenger Safety and Briefing Card

- Mae West's worn by crew and passengers
- Emergency Mae West fitted in seat head rests
- 2 x one man dinghy's for pilots
- 1 x 7 man dingy in rear compartment

3. Cabin Safety Responsibilities

3.1 Pilot

- Pre take-off safety briefing (to cover emergencies, emergency exits, cabin layout etc)
- Managing emergencies

3.2 WINCHMAN

- Assist passengers in rear cabin during emergencies.
- Deploying life rafts
- If required, not with live cargo, cut cable as high as possible to prevent cable backlash into blades

ANNEXURE G

Statement by the Master of the Alpha Afovos:

A section of the statement from the Master of the vessel pertaining to the helicopter and Marine Pilot operation was extracted and is tabled below.

"The vessel completed loading a cargo of coal at berth 301, Richards Bay Coal Terminal, at 0850 hours on the 3rd September 2005. The discharge port for this coal cargo is Brindisi, Italy.

A sailing time of 1100Z hours on the 3rd September 2005 was agreed upon with the vessel agent, who then contacted Richards Bay Port Control and organised a Marine Pilot to board/sail the vessel at the time. Bridge gear was tested and engines placed on standby by 1000Z hours, in preparation for sailing.

The marine pilot arrived on board the vessel at 1110Z hours, being transported to the vessel by car. He was met at the gangway and escorted to the bridge by the second officer. At this time the pilot enquired if a helicopter could land on the deck of the vessel, and the second officer advised that it could land on No. 4 hatch covers.

During the pre-departing discussion between myself (master of the vessel) and the marine pilot, it was again confirmed that a helicopter could land on the vessel's No. 4 hatch covers.

The vessel completed unberthing, and the tug released at 1125Z hours, with the vessel proceeding under its own power towards the entrance channel of the harbour. At this time, the Chief Officer and his rescue team assembled at No. 3 hatch in preparation for the marine pilot to disembark by helicopter. In addition to myself and the Marine Pilot, on the bridge of the vessel was A.B. Reiner, P. Bereber, who was on the 'helm', steering the vessel as required, and the duty officer, second officer, Gerrie P. Bacong.

The extra second officer Ioannis Vrettos and deck apprentice officer Michail Aliprantis were summonsed to the bridge to subsequently escort and/or carry the marine pilot's bags to the helicopter embarkation area at No. 4 hatch when required. These two crew-members were present on the bridge when the Incident occurred.

Conversation between myself (master of the vessel) and the marine pilot was carried out in English, with communication well understood, generally cordial and friendly. There was an amount of pleasure craft activity in the harbour area in the form of jet ski's and a yacht waiting to enter the channel and when I remarked on this, the pilot answered that it was Saturday, and that as soon as the vessel had sailed, where did I think the Pilot would be? He was indicating that he would be relaxing/enjoying himself.

All communication between the marine pilot, the Port and the helicopter was carried out by walkie talkie, and I did not hear any of the instructions. As the vessel entered the harbour channel, the marine pilot advised me that he would be winched off the port bridge wing of the vessel.

I objected to this disembarkation method, and insisted that the helicopter should land on No. 4 hatch covers. However, at 1134Z hours the helicopter was adjacent to the main mast of the vessel, above the bridge wing, waiting to hoist the marine pilot, and the pilot re-confirmed the fact that he would be leaving via the port bridge wing of the vessel, despite my repeated objection.

At 1134Z hours, the vessel was proceeding down the channel towards the anchorage area, with engines on half ahead, giving the vessel a speed of 6.5 – 7 knots. Wind at this time was NNE x Beaufort Force 5 – 6, which meant that the wind was blowing beam on to the port side of the vessel.

At 1145Z hours the marine pilot fitted the harness onto himself, while positioned on the port bridge wing, and the helicopter commenced winching him up. I was situated at the starboard radar console, conning the vessel down the channel. The other four crew-members were also in the bridge area, this to escape the down draft caused by the helicopter.

While situated at the radar console, I heard a "pop pop pop pop" noise from the helicopter, indicating that it was possibly in trouble. I did not see what actually happened. However, due to the restricted area that the vessel was in, (inside the breakwater) I had to continue steaming out to sea to ensure the safety of the vessel and crew.

The second officer, Ioannis Vrettos had rushed onto the starboard bridge wing of the vessel, and reported that the helicopter was in the sea on the starboard quarter of the vessel, upright but with its nose underwater. Crew had thrown life rings into the water to assist with possible rescue of helicopter crew.

At 1146Z hours I advised the Richards Bay Port Control by VHF, Channel 16, that the helicopter had crashed into the sea in GPS position: S 28° 48,7 E 032° 05,8.

Once cleared of the harbour entrance, I was requested by Port control to anchor off the port, this to assist with enquiries into the incident".

Statement by the Chief Officer of the vessel (Alpha Afovos):

"When the vessel had left the Coal Quay, and was proceeding towards the harbour access channel, at approximately 1120Z hours on 3rd September, I in conjunction with the Bosun and several ABS representing the rescue team for helicopter operations, took up position at the aft end of No. 3 hatch cover, rigging fire hoses and fire extinguishers in anticipation of the marine pilot departing the vessel by helicopter. This operation expected to be carried out from No. 4 hatch cover, the designated helicopter access point of the vessel.

As the vessel was proceeding down the harbour channel, I saw the helicopter approach and hover above the port bridge wing of the vessel.

The helicopter was hovering approximately 6 to 7 meters above the bridge wing when the pilot was being hoisted. I saw the marine pilot who was attached by a hoist wire to the helicopter, bend his legs to clear the vessel bridge wing bulwark/railing as he was being hoisted.

As the marine pilot did this, the helicopter appeared to 'wobble', and the helicopter blades then struck the vessel.

The helicopter then crossed from port to starboard side of the vessel, falling into the sea on the starboard side of vessel.

I, and the rescue team rushed to the stern section of the vessel, and threw life rings into the water to assist with the rescue of the helicopter crew.

There was no further action we could take at that immediate moment".