National Defence University

MPKK 1993–2013

INTRODUCTION OF THE T-10 STATIC LINE PARACHUTING CAPABILITY TO THE NH90 HELICOPTER

Ville Siiropää

Department of Military Technology

Publication series 1
Number 35/2013

NATIONAL DEFENCE UNIVERSITY

INTRODUCTION OF THE T-10 STATIC LINE PARACHUTING CAPABILITY TO THE NH90 HELICOPTER

Study

Captain (Eng.)
Ville Siiropää

SSOC 65
Air Warfare Branch

April 2013

Department of Military Technology
Series 1 Number 35

Taitto: Heidi Paananen/TKKK

ISSN 1796–4059
ISBN 978–951–25–2504–1 (print)
ISBN 978–951–25–2505–8 (PDF)

Juvenes Print Oy
Tampere
2013

NATIONAL DEFENCE UNIVERSITY

Course	Branch
Senior Staff Officer Course 65	**Air Warfare Branch**
Author **Captain (Eng.) Ville Siiropää**	
The name of the study **INTRODUCTION OF THE T-10 STATIC LINE PARACHUTING CAPABILITY TO THE NH90 HELICOPTER**	
Discipline under which the study was done Military Technology	Held at NDU’s Library, Santahamina, Finland
Month and Year April 2013	Number of text pages: 43 Number of appendix pages: 32

ABSTRACT

The purpose of this study was to investigate the suitability of the Finnish Defence Forces’ NH90 helicopter for parachuting operations with the T-10 static line parachute system. The work was based on the Army Command’s need to compensate for the reduction in the outsourced flight hours for the military static line parachuting training.

The aim of the research was to find out the procedures and limitations with which the NH90 IOC+ or FOC version helicopter could be used for static line parachutist training with the T-10B/MC1-1C parachutes. The research area was highly complicated and non-linear. Thus analytical methods could not be applied with sufficient confidence, even with present-day computing power. Therefore an empirical research method was selected, concentrating on flight testing supported with literature study and some calculated estimations.

During three flights and 4.5 flight hours in Utti, Finland on 17–20 September 2012, a total of 44 parachute drops were made. These consisted of 16 dummy drops and 28 paratrooper jumps. The test results showed that when equipped with the floor mounted PASI-1 anchor line, the deflector bar of the NHIndustries’ Parachuting Kit and Patria’s floor protection panels the Finnish NH90 variant could be safely used for T-10B/MC1-1C static line parachuting operations from the right cabin door at airspeed range of 50–80 KIAS (~90–150 km/h). The ceiling mounted anchor lines of the NHI’s Parachuting Kit were not usable with the T-10 system. This was due to the static lines’ unsafe behaviour in slipstream when connected to the cabin ceiling level.

In conclusion, the NH90 helicopter can be used to meet the Army Command’s requirement for an additional platform for T-10 static line parachutist training. Material dropping, the effect of additional equipment and jumping from the rear ramp should be further studied.

KEY WORDS

Static line, parachuting, NH90, helicopter, flight testing, T-10

Classification

Unclassified – distribution unlimited

MAANPUOLUSTUSKORKEAKOULU

Kurssi	Linja
Esiupseerikurssi 65	**Ilmasotalinja**

Tekijä

Insinöörikapteeni Ville Siiropää

Tutkielman nimi

INTRODUCTION OF THE T-10 STATIC LINE PARACHUTING CAPABILITY TO THE NH90 HELICOPTER

Oppiaine, johon työ liittyy	Säilytyspaikka
Sotatekniikka	MPKK:n kurssikirjasto, Santahamina
Aika	**Tekstisivuja 43**
huhtikuu 2013	Liitesivuja 32

TIIVISTELMÄ

Tämän tutkimuksen tarkoituksena oli selvittää Suomen Puolustusvoimien käyttämän NH90-kuljetushelikopterin soveltuvuus pakkolaukaisulla tapahtuvaan laskuvarjohyppykoulutukseen T-10-laskuvarjojärjestelmää käyttäen. Aihevalinta perustui Maavoimien tarpeeseen saada NH90-helikopteri hyppykoulutuskäyttöön, tähän tarkoitukseen aiemmin osoitettujen ulkoistettujen lentotuntikiintiöiden pienennyttyä.

Tutkimuksen tavoitteena oli määrittää ne menetelmät ja rajoitukset, joilla NH90 IOC+ tai FOC -version helikopteria voitaisiin käyttää laskuvarjohyppykoulutukseen T-10B/MC1-1C -laskuvarjokalustolla. Aihealue oli fysikaalisesti hyvin monimutkainen, joten laskennallisia menetelmiä ei voitu luotettavasti käyttää. Tästä johtuen työ tehtiin empiirisin menetelmin, painottuen koelentoihin sekä niitä tukeneeseen kirjallisuustutkimukseen ja analyysiin.

Koelennot toteutettiin Utin Jääkärirykmentissä 17.–20. syyskuuta 2012. 4,5 lentotunnin aikana suoritettiin yhteensä 44 koepudotusta, koostuen 16 nukkepudotuksesta ja 28 koehypystä. Tulokset osoittivat, että NH90-helikopteria oli turvallista käyttää hyppykoulutukseen T-10-kalustolla matkustamon oikeasta sivuovesta lentonopeusalueessa 50–80 KIAS (90–150 km/h). Edellytyksenä oli, että koneeseen oli asennettuna lattiaan kiinnitetty PASI-1-ankkurihihna, NHIndustries:n laskuvarjohyppyjärjestelmän suojatanko sekä Patrian lattiasuojalevyt. Kokeet osoittivat myös, että NHI:n laskuvarjohyppyjärjestelmän matkustamon kattoon kiinnitetyt ankkurihihnat eivät soveltuneet hyppytoimintaan T-10-kalustolla.

NH90-pakkolaukaisuhyppäämisen osalta tulisi jatkossa tutkia hyppääjien käyttämän varustuksen vaikutusta, materiaalinpudotuksia ja perärampin käyttöä.

Tutkielma on laadittu englanninkielisenä huomioiden keskeisen lähdemateriaalin vakiintunut termistö ja tarkoitus hyödyntää tekstiä European Defence Agencyn (EDA) NH90-käyttäjämaiden tiedonvaihdossa [4]. Työn tietoturvaluokitus on julkinen.

AVAINSANAT

Pakkolaukaisu, laskuvarjohyppääminen, NH90, helikopteri, koelentotoiminta, T-10

Index

INTRODUCTION OF THE T-10 STATIC LINE PARACHUTING CAPABILITY TO THE NH90 HELICOPTER

1. INTRODUCTION

In early 2012, following a major reduction in the outsourced flight hours for the static line parachutist training, the Finnish Defence Forces' (FDF) Army Command initiated actions to have the Army's own NH90 helicopter approved for this purpose. Otherwise a considerable drop was foreseen in the number of static line parachute training jumps, especially for the enlisted personnel. The NH90 transport helicopter was a natural choice as the fleet was already located in the same Army unit as the paratroopers, the Utti Jaeger Regiment (UTJR).

The 2001 acquisition contract between the Finland's Ministry of Defence (MOD) and the supplying company NHIndustries (NHI) required the NH90 to be capable for static line parachute jumping. Due to various developments during the program this capability was never fully substantiated as required by the contract (see extract in Appendix 2's Figure 28). Until 2012, only partial evidence was delivered by the NHI using calculations and analysis [10; 11; 13; 15]. Due to the Army Command's requirement, the Finnish Defence Forces now needed to complete the substantiation, in practice with flight testing, as the first operator worldwide.

As a preparation for the national qualification of the parachuting system, the FDF and the NHI agreed the following: the NHI would deliver a draft test plan for the necessary flight tests and the FDF would provide the helicopter, parachutes, jumpers, flight test personnel and other required assets. It was also agreed that the NHI was financially responsible for potential test related damage and modification costs, if these were caused by the NH90 design characteristics. [22]

The responsibility to carry out the necessary tests was given to the Utti Jaeger Regiment's flight test office. This was the starting point for the research and the author's involvement in it as a flight test engineer. The study was written in English to facilitate information exchange within the European Defence Agency's (EDA) NH90 User Group. The used concepts and definitions are clarified in Chapter 1.2 and the terms and abbreviations in Appendix 1.

1.1 The question and scope of the research

The main question of the research was:

1. With which procedures and limitations can the NH90 helicopter be used for static line parachutist training with the T-10B/MC1-1C parachutes?

The following sub questions were raised to support in answering the main question:

2. What are the NH90 helicopter and the T-10B/MC1-1C parachute systems?

3. What are the relevant user and authority requirements for the NH90 static line parachuting system and capability?

3. How does the static line parachuting system, as incorporated in the NH90 helicopter, behave during flight tests and what are the possible areas requiring further development?

The scope of the research covered static line parachute jumping with T-10B/MC1-1C parachute system from the Finnish Defence Forces' NH90 Tactical Transport Helicopter's IOC+ version, concentrating on the aircrew point of view. The research emphasis was on the flight test planning, test results and the limitations and procedures based on the results. The testing was limited to day time visual meteorological flight conditions, jumping from the right cabin door, maximum airspeed of 80 knots (150 km/h) and to the maximum jumper weight of 150 kg. The detailed test setup and conditions are in Chapter 4.1. The paratrooper techniques and procedures were only covered to the necessary extent to understand the conclusions. The military aviation authority approval process was not covered by more than a brief outline in Chapter 3.2, where also the requirements concerning the approval are presented.

The security classification of this study is unclassified based on the NH90 program's Classification Guide (see Appendix 3) and on the classification of the US Army Field Manual for static line parachuting [32], containing comparable level of information.

1.2 Concepts and definitions

The concepts requiring specific definition in the study are *static line parachute jumping, anchor line, incremental approach (in testing),* and *slip ball*. Other terms and abbreviations are explained in Appendix 1, with the exception of the most common SI units such as "kilogram". These have been assumed as generally known. In expressing numbers, thousands are not separated by commas or spaces to avoid misunderstandings among people not used to the English convention. For example one thousand is expressed as 1000 (not 1,000 or 1 000). The decimal indicator is a dot in the English text and a comma in the Finnish abstract.

Static line (SL) parachuting (method) means a system where a line attached to a jump platform automatically opens a jumper's main parachute after exit from the platform. The jump platform is usually an airplane or a helicopter. For example the massive airborne assaults to Normandy in 1944 were done using the static line parachuting method. See an example of military static line parachuting training with the T-10 parachutes in Figure 1.

Figure 1. Static line jumping with the T-10 parachute system from a C-130 aircraft. In the middle of the picture a jumper has just exited the aircraft. The arced canopy suspension lines are exposed and the main canopy has been pulled out from its container by the static line (not visible) attached to the aircraft [38]

Anchor line is a cable or webbing connected to a jump platform (e.g. an aircraft) in order to provide a hard point for attaching the jumpers' static lines.

Incremental approach is a term used in flight testing to describe a philosophy of progressing in small steps from the known to the unknown regime. This is the basic method for controlling risks when for example expecting strong non-linear responses or when testing complicated systems. Incremental approach is also used to mitigate the adverse effects of the so-called "cliff-edge points", where a small increase in input results in an abrupt and a non-linear response – often to a dangerous direction and with no preceding warning.

Slip ball or slip indicator (Figure 2) is a basic indicator in almost any aircraft where the pilot is protected from the airstream and thus cannot feel the direction of the relative wind. The slip ball indicates the direction and the relative strength of the side slip of a fuselage. In the cockpit a side slip is felt as a lateral force. Normally side slip is not desired, as it creates additional drag increasing fuel consumption. Potentially it also increases structural vibrations.

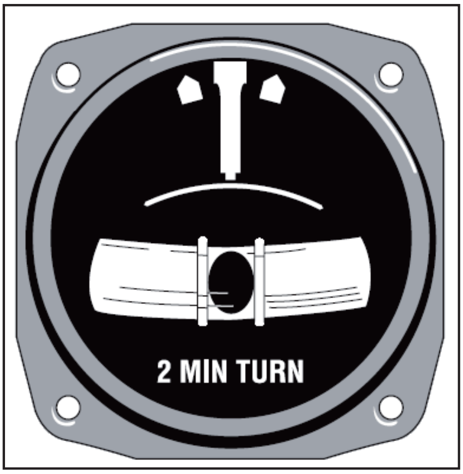

Figure 2. The slip ball or slip indicator is often a combination of a curved tube and a ball inside it (mechanical version) or a similar presentation on a display. In this picture the slip indicator is part of a "Turn and Bank" indicator [39], an essential device in instrument flying. When there is no side slip, the ball is in the middle between the brackets

1.3 Research methods

The main unknown was the dynamic behaviour of the static line + deployment bag combination after a parachutist separation. This resulted in an extremely complicated problem for the analytical methods. Modelling was needed for the time dependent path of a non-rigid body (the static line + deployment bag) in a turbulent airstream with several initial values around a complex structural boundary of the helicopter's fuselage. Based on the author's previous knowledge of the limitations of computational fluid dynamics (CFD), this kind of a scenario was practically impossible to solve reliably even with modern computing power. Thus a quantitative research method was chosen, based on the empirical observations and conclusions made during the ground and flight testing phase. The empirical work was supported by literary study and interviews, which provided the input values, initial constraints and valuable considerations on the safe conduct of the tests.

The literary study was the main source of information for Chapters 2 and 3 whereas the empirical part is covered by Chapter 4.

1.4 The main reference sources and source criticism

The main reference sources were the NH90 program's qualification documentation concerning static line parachuting system [10; 11; 13; 14; 15] & [21; 22], the NH90 Interactive Electronic Technical Publication (IETP) [17; 19], Dan Poynter's "The Parachute Manual" [26], U.S Army Field Manual for static line parachuting systems and training [32], NHIndustries' test plan draft for static line jumping [18], Eurocopter's experimental test pilot Didier Delsalle [2], UTJR's paratrooper instructors' experiences about similar systems [34] and finally the test team's flight test results [3].

Majority of the sources were well recognised and had established their position. The author considers the sources reliable with the following reservations and considerations.

The NH90 qualification documentation about the parachuting system was purely analytical and based on approximated calculations. Neither Eurocopter nor the NHI had experience on dropping static line parachutists from the NH90, especially with the T-10 or a similar system. Thus the analysis results (concerning static line behaviour in helicopter slipstream) were taken only as initial guesses for the flight test planning.

The U.S Army Field Manual [32, p. 17-1–18-14] provided solutions for several comparable helicopters, UH-1 and UH-60 for example. However, the dimensioning principles were not provided, hence the solutions could not be taken as such without complementary analysis.

The NHI's test plan draft was very general and not inspected by flight testing professionals. This was compensated by the test team's own experience and by consultation from Eurocopter's highly experienced experimental test pilot Didier Delsalle.

Finally, the flight test results' applicability and completeness needed to be kept in mind while writing any final conclusions. The number of test points (repetitions) was selected based on the test team's judgment. The random variations were, by experience, believed to have been covered with sufficient reliability. The test team consisted of a team of experienced test pilots and jumpmasters with thousands of flight hours and parachute jumps, respectively. Considering the long experience of the military organisation to utilise the NH90 T-10 static line system, this was believed to provide a sufficient certainty for the conclusions.

Keeping in mind the aforementioned considerations and as the final conclusions are based on full scale test results, the outcome of the research is considered reliable and fully applicable within the scope of the research (see Chapter 1.1).

2. TEST ITEMS

This chapter presents the main components relevant for the research. The main components are the T-10 parachute system (Chapter 2.1), the NH90 TTH IOC+ helicopter (Chapter 2.2), the NHI's Parachuting Kit for the NH90 helicopter (Chapter 2.3) and the specifically designed "PASI" prototype floor mounted anchor line (Chapter 2.4).

2.1 The T-10 static line parachute system

The T-10-series and MC1-series parachutes are made by the Mills Manufacturing Corporation, USA, for military static line airborne operations – see example in Figure 1. The T-10-series includes a non-steerable parabolic canopy and the MC1-series a similar but steerable canopy. Both have a nominal canopy diameter of 35ft (10.7m). The T-10 system was designed in the early 1950's for the US government for demanding military use and has been widely used since with few modifications. [6; 8]

The T-10 main parachute consists of five major components – the harness assembly, the riser assembly, the deployment bag, the pack tray, and the canopy: assembly (Figure 3). A reserve parachute is used in conjunction with the main parachute and fitted in front of the jumper [32, p. 2–1]. The Figure 4 shows the T-10 system as worn by a paratrooper.

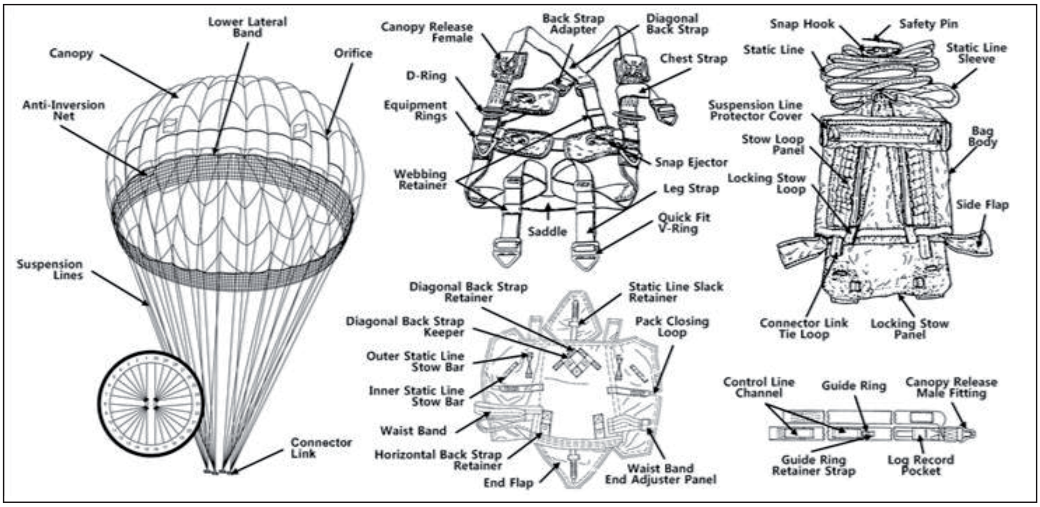

Figure 3. Steerable MC1 version of the T-10 parachute system. The components clockwise from the left: canopy assembly, harness assembly, the deployment bag (including static line), the riser assembly and the pack tray in the bottom middle. The T-10 system is identical but without orifices in the canopy [24]

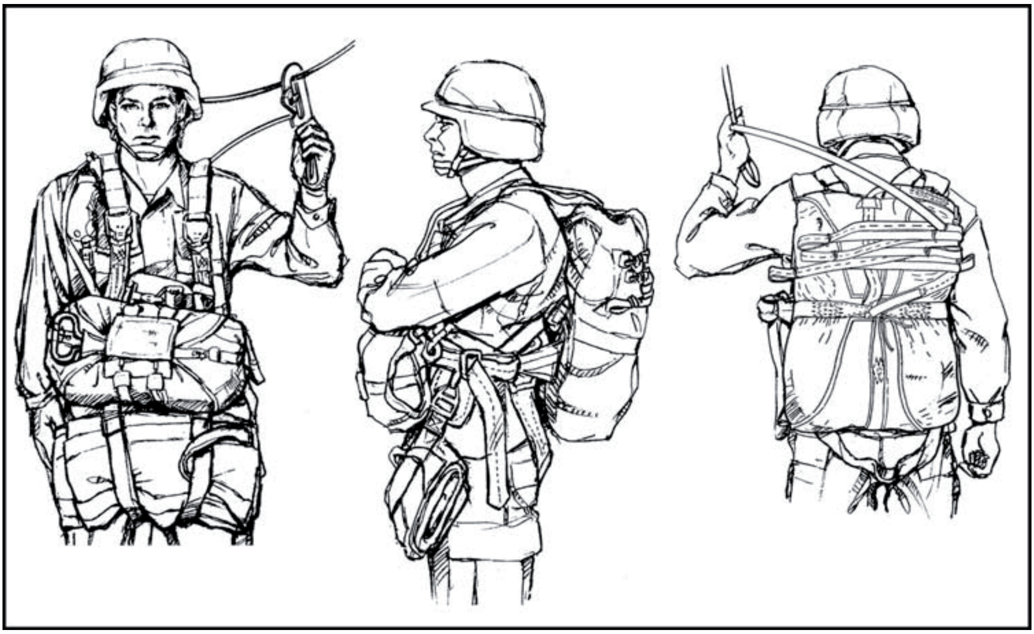

Figure 4. T-10 parachute harness fitted on a paratrooper. The main canopy is on the jumper's back and the reserve canopy on his front. On the left the static line's snap hook is attached to the aircraft via an anchor cable and on the right the static line's folding on the main parachute container is shown [32, p. 2–18]

The T-10B version used by the Finnish Defence Forces originates from the year 1976. The T-10B features an anti-inversion net at the edge of the canopy (Figure 3) intended to eliminate the so called "line-over" malfunctions. The FDF also uses the steerable T-10 variant: the MC1-1C. The MC1-1C's canopy is made from F111 fabric, which provides a smaller rate of descent than the T-10B canopy. Otherwise these two – T-10B and MC1-1C – are functionally identical from the research point of view, with the exception of static line snap hooks. Details of these parachute types are provided in Appendix 4's Table 6, Table 7 and Figure 31. The T-10B snap hook connected to the PASI-1 anchor line is shown in Figure 11.

The static line assembly including all the components shown in Figure 5 is the only part of the T-10 system which remains attached to the aircraft after the jumper has exited. The T-10 deployment bag (D-bag), which is connected to the end of the static line, is constructed of an 8.8-ounce cotton sateen cloth and its dimensions are 46 x 30 x 13 cm (18 x 12 x 5 in). The static line is made of Type VIII yellow nylon and is permanently attached to the D-bag. The static line is 4.6 meters (15 feet) long and has a tensile strength of 16.0 kN (3600 lb / 1633 kg). [32, p. 2-3]. The effective length, up to the pack opening loop is 3.85 meters and the total length of the static line assembly up to the end of the deployment bag (locking stow panel) is 5.3 meters. For static line assembly parts' nomenclature, see Figure 3 and Figure 5.

Concerning the use of the static line assembly with a composite-build airframe it is important to notice that there are no exposed or hidden metal parts in the T-10 static line, other than the snap hook. It is common that the deployment bag hits the aircraft's fuselage after a jumper has exited and the parachute has separated from the bag. However, the lack of metal parts in the T-10 static line assembly – as exposed in the airstream – virtually eliminates the risk of impact damage to the NH90 helicopter's carbon fibre fuselage.

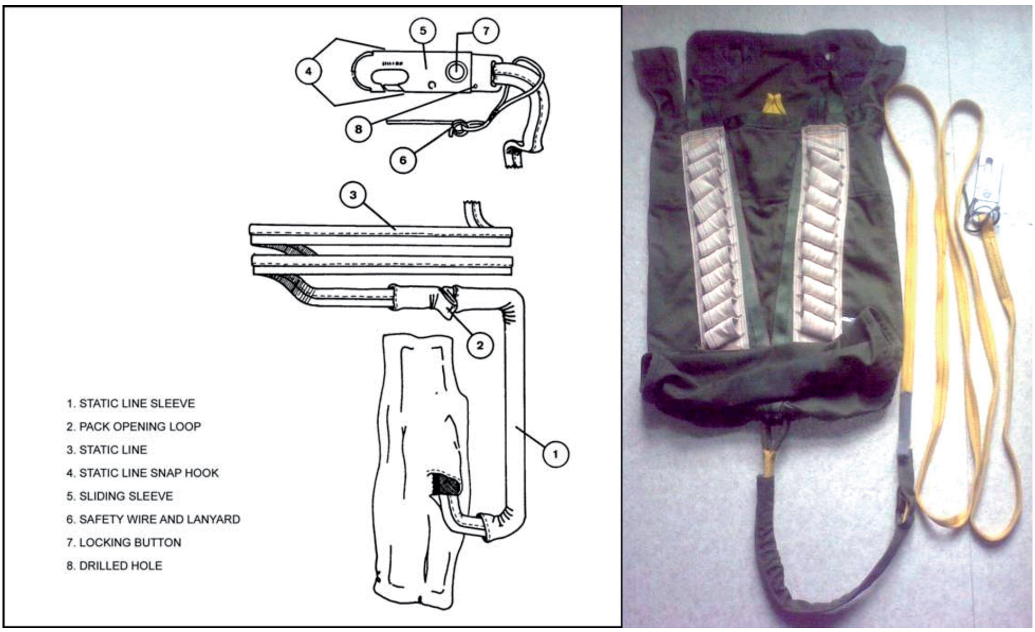

Figure 5. Static line and nomenclature on the left [32, p. 2-3]. On the right the static line assembly is shown with the green deployment bag (bag body) attached to it. The total length of the assembly from the tip of the metallic snap hook until the end of the deployment bag (locking stow panel) is 5.3 meters

2.2 The NH90 helicopter

The NH90 is a medium sized, twin engine, multi-role military helicopter manufactured by the NHIndustries, NHI, which is a consortium owned by three major European aerospace companies: Eurocopter, AgustaWestland and Stork Fokker Aerospace. The first NH90 prototype flew in 1995 and since 2001 the helicopter has been sold to 13 countries worldwide.

The NH90 is technically very modern. It is the world's first serial production helicopter with a full fly-by-wire flight control system and a full-composite structure. The NH90 fuselage is mostly assembled from carbon fibre sandwich structure, but includes also aramid and glass fibre parts with titanium and steel reinforcements.

The Finnish NH90 variant is specified as TTH TFIA (Figure 6). The abbreviation TTH describes the army version "Tactical Transport Helicopter". TFIA identifies the national variant: "Transport, FInnish Army". The Finnish NH90 variant is primarily intended for carrying 16 troops or more than 2500 kg of cargo or conducting search and rescue operations, fire fighting and medical/casualty evacuation missions. The TTH variant's maximum normal take-off weight is 10600 kg and the maximum cruise speed 300 km/h. [36] The main characteristics, performance values and dimensioning of the helicopter are presented in Appendix 4's Table 8, Figure 32 and Figure 33.

The IOC+ (Improved Operational Configuration) is the latest model delivered to FDF by the end of 2012 and is also the version used in this study. The IOC+ lacks some equipment and capabilities, but in terms of suitability for parachuting operations it is fully representative of the final contracted version, the FOC (Final Operational Configuration).

Figure 6. NH90 TTH TFIA IOC+ (tail number NH-215) in hovering flight. The right cabin door is open with the black Parachuting Kit deflector bar installed aft of the door on the outside. Some other test relevant items are also pointed out

Comparing to other helicopters and relevant for this study, the only significant new design feature of the NH90 is the composite structure. A composite structure can be made very efficient both structurally and aerodynamically, but it is sensitive to any sharp impacts. The composite structure is in this respect problematic in that a major internal structural damage might look small and insignificant on the surface. For test planning and execution the integrity of both the external surface and the internal floor had to be considered. The relevant risks and their mitigation are covered in Chapter 4.1.4. and in Appendix 10.

2.3 The NHI's Parachuting Kit for the NH90 helicopter

The NH90 Parachuting Kit, as introduced by the manufacturer, is specifically intended for static line parachuting from the right cabin door. The Parachuting Kit's main components are shown in Figure 7. The other components are the Parachuting Drop Light (PDL) in the cabin and cabin signal panel in the cockpit, see Figure 8. The only item not part of the basic TTH configuration is the deflector bar (Figure 7), which is for protecting both the door frame and the static line from excessive wear. The "anchor lines" in the cabin's ceiling are for attaching the static line snap hook but also the loadmaster's safety strap. [14] See Appendix 4, Figure 33 for a detailed diagram of the ceiling cable location.

The boarding and maintenance steps in Figure 7 are part of the normal NH90 configuration, but they are mentioned in conjunction with the Parachuting Kit as they help the jumpers to exit the helicopter. The boarding step also bears loads caused by the static line, see Figure 24.

The strength substantiation for dynamic loads has been presented in references [11; 13] and [15]. The behaviour of the attached T-10 static line in slipstream after jumper separation has been estimated by analysis in [10]. The part numbers and weight breakdown of the Parachuting Kit is in Table 9 of Appendix 4.

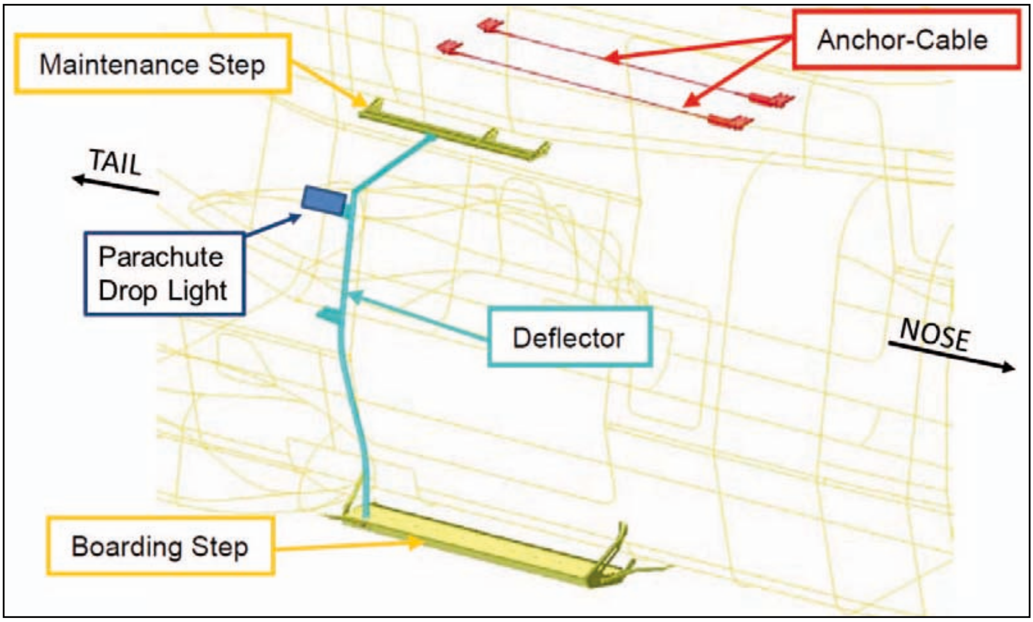

Figure 7. Parachuting Kit main components as viewed from the forward right side of the fuselage (H/C nose on the right) [15, p. 8]. Not shown component is the Parachuting Drop Light control panel in the cockpit. The deflector bar (Static Line Protection Kit) exists to prevent static lines getting caught by outboard installations or getting damaged by any sharp edges [13, p. 4]

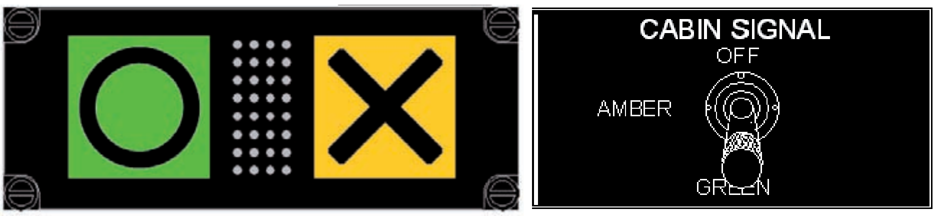

Figure 8. Parachuting Drop Light (PDL) panel is on the left and its control panel (in cockpit) on the right. The green ("JUMP") and yellow ("STAND-BY"/ "STOP") lights have been symbol coded to be readily readable even if operating with NVGs. [14, p. 13] When approaching the jump site the cockpit crew selects CABIN SIGNAL switch to AMBER illuminating amber light on the cabin PDL, meaning "STAND-BY" (or "STOP/ABORT" if lit after GREEN light). At the exit point GREEN position is selected, which illuminates green light on PDL and initiates an audio tone

When using the T-10 system the major challenge with the NHI's Parachuting Kit is illustrated in Figure 9. In the Figure 9 a T-10B static line, visible in the middle, is attached to the cabin ceiling anchor lines. The static line, including the deployment bag extends approximately 4 meters out of the door. There are several potential items – marked with circles – which might get damaged by the tightening ("start"), up-swinging ("max") or trailing static line ("trim"). See the respective calculated positions of the static line in Figure 10. According to the analysis 80 knots would be the most critical case in terms of main rotor clearance whereas 40 knots would provide the safest outcome. However, 80 knots is much more desirable from the parachutists' point of view than 40 knots: the faster the airspeed, the faster the parachute opening. The slipstream "feel" during exit is then also more comparable to fixed wing aircraft.

Before the start of the tests, the item most probably damaged was thought to be the right position light at the forward-right edge of the sponson. The most dangerous contact possibility was with the main rotor blades. The main rotor has a strong structure and an enormous inertia. Therefore the main rotor blades would probably not be much affected by a tangled static line. However, if the tangled static line would rip out of the door the anchor cables (lines) including all the other static lines, that would be a very dangerous situation. This risk could be avoided by attaching the static lines to the cabin floor as in many other jump aircraft, including US Army's UH-1 and UH-60 Blackhawk [32, p. 17–4 & 17–8]. As a method of risk mitigation and in accordance with the incremental approach philosophy, the floor anchor line was implemented for the first drops during the flight tests. This is further elaborated in Chapter 2.4.

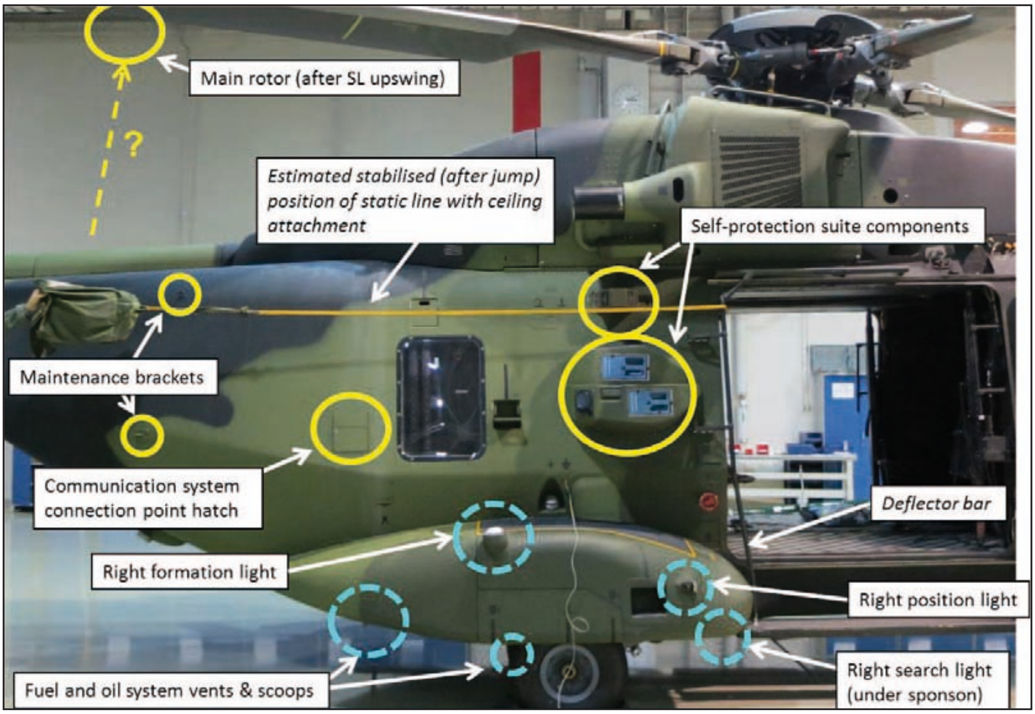

Figure 9. The potential damaging aircraft items (circled, solid and dashed) due to static line dynamic behaviour during and after parachutist exit. The light blue dash line circles indicate items that might be damaged if the static line would be attached to the floor

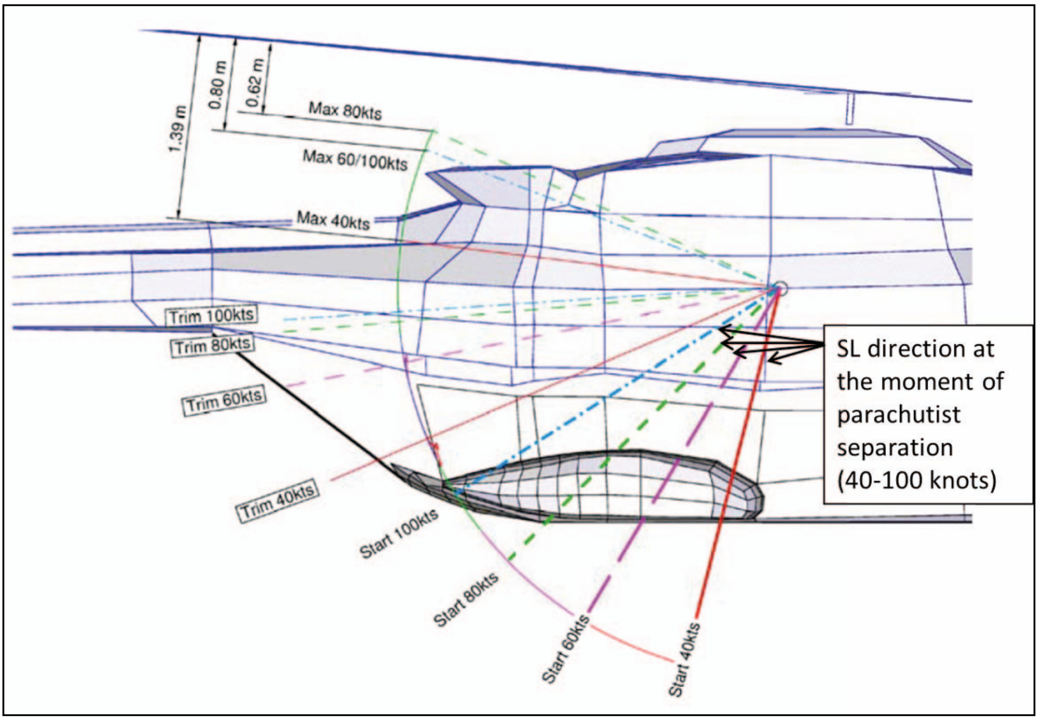

Figure 10. The static line (SL) positions at **Start** (parachutist separates), **Max** (highest point of static line and bag) and **Trim** (final position in slipstream) for 40, 60, 80 and 100 knots according to NHI's calculations [10, p. 8]

2.4 "PASI"–Prototype Anchor for Static line Implementation

The attachment of the static line to the standard anchor line in the ceiling was analysed to cause a risk of inadequate static line deployment bag – main rotor clearance at airspeeds between 63 and 97 KIAS (knots, indicated airspeed) [10, p. 9]. The risk of a static line vs. main rotor contact was eliminated by the test team by manufacturing a prototype anchor line, to be mounted onto the cabin floor at least for the first drops. A greatly increased safe static line vs. main rotor separation could then be achieved. The Prototype Anchor for Static line Implementation (PASI, Figure 11 and Figure 12) provided also a safe mean to validate the analysed results of static line upswing Figure 10. After the first observations an entry into the more risky regime (ceiling anchor attachment) could then be made, as feasible.

The prototype anchor line was designed and manufactured in Utti Jaeger Regiment in cooperation with the author and an FAA Master Rigger certified FDF jumpmaster. Prototype anchor's installation was authorised by the Finnish Air Force Material Command (FINAF AMC) with the TMT installation order AM/132/NH, 12.9.2012, see Appendix 5's Figure 35.

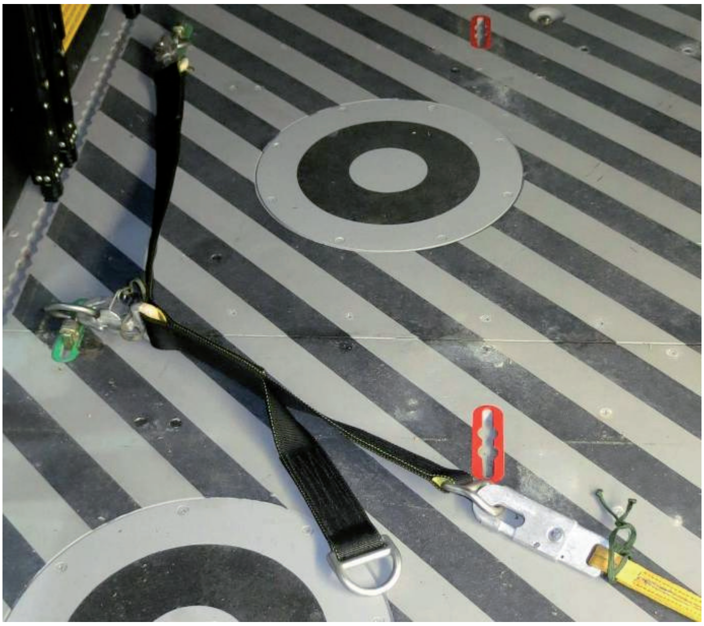

Figure 11. Prototype Anchor for Static line Implementation, version 1 (PASI-1) attached to the front left part of the cabin, onto two "green" attachment points below the row of troop seats. In bottom right, a T-10B static line's snap hook is shown

The prototype anchor line and its method of attachment are dimensioned for the worst loading case in parachuting operations as presented in the NHI's analysis. This scenario assumes a malfunction, where an exiting jumper weighing 150 kg would get tangled to the static line at 4.2 meters, between the pack opening loop and the deployment bag. Then the jumper's velocity would be 9.78 m/s and the resulting peak pulling force on the static line when stopping the jumper's fall 11.76 kN (equalling ~1200 kg). [11, p. 15]

This kind of a malfunction is considered possible in theory and taken as the design loading case also for the FDF tests, even though its probability of occurrence is very small. For example: in Finland no such case is known during the history of military or civilian parachuting, while hundreds of thousands of static line jumps have been made.

The PASI's attachment onto the floor has a coefficient of safety (CoS) of 1.4 against the limit load of the tie-down points (see Figure 34 of Appendix 4). By definition, up to the limit load no deformation of structure is expected. The minimum coefficient of safety against the ultimate load ("break load") of the floor attachment is 2.1. The ultimate strength of the cabin floor's attachment points is 25kN.

The prototype anchor's design is simple. It provides the lowest possible loading on the floor attachment points, has little risk for tangling due to its positioning and can easily be stored away from the middle of the cabin floor. The minimum tensile strength of the anchor and any of its components is 22.3 kN (2270 kg, 5000 lbs), resulting in the minimum CoS of 1.9 for the "PASI" in the design load case. Two versions of the prototype anchor were made for the tests: a shorter one (PASI-1) and a 50 cm longer one (PASI-2). The length of the PASI-1 anchor was designed based on judgment by experience so that only the minimum reasonable length of the static line would be exposed out of the door. This was balanced with the requirement of having a sufficient length for safe canopy vs. fuselage separation. The two anchors could then be used to quickly modify the trailing deployment bag's location in slipstream during the tests if problems were encountered. The prototype anchor components are listed in Table 10 (Appendix 4).

Figure 12. The PASI-1 anchor line and two separate Quick Release Cargo Rings, commonly used in transport aircraft. See list of components and their specifications in Table 10 (Appendix 4). The total length of PASI-1 is approximately 1 metre.

3. REQUIREMENTS FOR THE SPECIFIC PARACHUTING SYSTEM

The applicable requirements are divided in two categories: user and authority requirements. The user requirements cover mostly the functional and maintenance aspects whereas the authority requirements cover the airworthiness aspects. There is however some overlap between the two categories.

In this chapter the word *shall* is used to denote an essential, mandatory requirement that must be fulfilled. The word *should* is used to indicate an optional requirement, where fulfilment is desired but not mandatory.

3.1 User requirements

The end user for the NH90 TFIA's parachuting system is Utti Jaeger Regiment. Operating the parachuting system is always a joint task for the Special Jaeger Battalion's paratroopers and the Helicopter Battalion's aircrew. The user requirements – combining both the paratrooper and the helicopter operator's point of view – can be formalized from the test plan as follows [29]:

1. The NH90 parachuting system **shall** allow dropping static line parachutists equipped with T-10B or MC1-1B parachute systems at an airspeed of at least 60 knots (110 km/h), with a desired minimum airspeed of 80 knots (150 km/h)

2. The jump procedure **shall** be suitable (simple, robust) for the training of conscript paratroopers

3. The jump procedure **shall** enable jumping with rucksacks and similar, up to a maximum paratrooper exit weight of 150 kg.

4. The jump procedure **shall** enable adequate working facilities in the cabin for two jumpmasters and one loadmaster in addition to the paratroopers

5. The jump procedure **shall** not mandate any structural or other significant modifications (like shortening of the static line) to the standard parachute system

6. The jump procedure **shall** not compromise the helicopter's structural integrity, or cause significant additional maintenance burden on either the helicopter parts or the parachute static lines or other parts due to excessive wear and tear

7. The jump procedure **should** enable loads of at least eight and stick of at least four paratroopers and the procedure **should** not set any additional weather constraints compared to those generally regulating parachuting operations.

These user's requirements apply for "Phase I" clearance of the T-10 system. Later phases include tactical items and other equipment. However, the foreseen updates due to later tests concern only the aforementioned requirements number 1 and potentially 3.

3.2 Authority requirements

The approval of any system to be installed in a Finnish military aircraft is governed by the military airworthiness requirements and advisories established by the Finnish Military Aviation Authority, FIMAA. In airworthiness issues it is assisted by the Quality and Airworthiness department (LLOS) of the Finnish Air Force Material Command.

In leading principles the Finnish military airworthiness regulations are rather similar to civilian airworthiness regulations like the FAR-29 commonly used as reference for large civilian transport helicopters. For the scope of this study the relevant FIMAA requirement documents are the Military Aviation Advisory SIO-Ma-Lt-005: "Airworthiness requirements for military aircraft" [30] and Military Aviation Regulation SIM-Ma-Yl-013: "The approval and maintenance of parachutes and safety equipment used in military aviation" [31]. The requirements of the latter document are in practice covered by SIO-Ma-Lt-005. Therefore SIM-Ma-Yl-013 is not referenced in the list below. Both document headers are translated from Finnish as no official English translations were found.

In brief, the relevant authority requirements for the static line parachuting system used in this research are as follows (translated from Finnish):

1. The NH90 parachuting system **shall** be airworthy, i.e. it must be so designed, manufactured, equipped and maintained that it can be safely used for aviation (Chapter 2.2 of [30]);

2. The system **shall** meet its specification. The safety relevant and essential characteristics and features have to be substantiated empirically (Chapter 6.2 of [30]);

3. The system **shall** be type inspected and approved for its intended use (Chapter. 2.3 and 6.1 of [30]. *Author's note: The responsible for managing and controlling the type inspection and approval is the aircraft type certificate holder – in this case the Finnish Air Force Air Material Command*).

4. The qualification **shall** cover and present, as applicable, the following items (Chapter 6.2.1 of [30]):

    - Type marking (name, type number etc.) and modification state;
    - Effect on weight, centre of gravity, moment of inertia;
    - Main dimensions;
    - Structure and components;
    - Method of operation;
    - Performance characteristics;
    - Requirements for installation;
    - Effects on other aircraft systems;
    - Reliability;
    - Safety;
    - Inspection, maintenance, repair, transport and storage requirements;
    - Instruction, training and user competence requirements.

5. If flight testing is required for substantiation, a test plan **shall** be made. It must include among others the test limitations and safety instructions (Chapter 8.2 of [30]).

The authority approval process goes – in brief – as follows: After it has been substantiated and shown that NH90 static line parachuting system fulfills the listed airworthiness requirements and the user requirements in the previous chapter, a type inspection certificate or another applicable documents (for small changes) is issued by the FINAF Air Material Command, usually by its Quality and Airworthiness Division (LLOS). The system is then normally released to line service using the FDF's TMT system. The TMT can be explained as "airborne systems related technical change and information data system", which manages airborne systems related documents between the type certificate holder and the end users.

4. CONDUCT OF THE TEST AND TEST RESULTS

4.1 Test setup

The draft test plan delivered by the NHI on 9 May 2012 [22] was complemented and finalized by the UTJR flight test office, with valuable consultation from experimental test pilot Didier Delsalle of the Eurocopter Flight Test Department [2]. As the planned tests included many unknown and potentially hazardous factors, the final test plan [29] incorporated an incremental approach (Chapter 1.2) to minimise the risks for personnel, helicopter and equipment. Parachuting experience with the FDF's earlier Mi-8 transport helicopter [41] as well as already developed free fall jumping methods for the NH90 [40] were also utilised in the planning.

4.1.1 General arrangement and test conditions

All testing took place on Utti airfield, Finland on 17–20 September 2012. The standard ground preparations for static line jumping as per the FDF rules and regulations were observed. The airfield emergency rescue service was available in normal readiness. One UTJR's MD500 helicopter was used as a chase aircraft to assist the test aircraft's crew as additional eyes and for documenting the test using a video camera. Emergency landing pad was prepared (but not assembled) for the unlikely case of landing gear extension failure due to static line entanglement. Other general test conditions are shown in Table 11 (Appendix 6).

Complementing to what is mentioned in Table 11, for each test the aircraft configuration included:

- A fully operational Parachuting Kit, see Chapter 2.3;
- 15 standard TTH troop seats configured as shown in Figure 19;
- Patria cabin floor protection panels (to avoid dents due to static line hooks slamming the floor after exit), Figure 13;
- "PASI" anchor line (1 and/or 2 as applicable) and the tape protections in accordance with AM/132/NH, Appendix 5;
- Protective tape as shown in Figure 13 and Figure 14 and a video camera at the cabin door, see Figure 15.

The flight tests were documented using simultaneously four video cameras: one fixed at the forward edge of the right cabin door (Figure 15), one in the cabin used either by the flight test engineer (FTE) or the loadmaster (LM), one in the chase helicopter and one on the ground. Part numbers of the test relevant aircraft items are presented in Table 12 of Appendix 6.

4.1.2 Test equipment and assisting devices

The following modifications and installations were done to the test helicopter. The standard composite floor was protected by plywood protection panels (P/N PNH252300010) made by Patria Aviation, Halli. The total weight of the panels was 40–45 kg and the total thickness 8 mm (4 mm plywood + 4 mm padding). [5] As the protection panels had coarse anti-slip strips, the door side edge of the panels was covered with a combination of aluminum tape and duct tape, Figure 13. This abrasion layer prevented damage to the static lines during jumps.

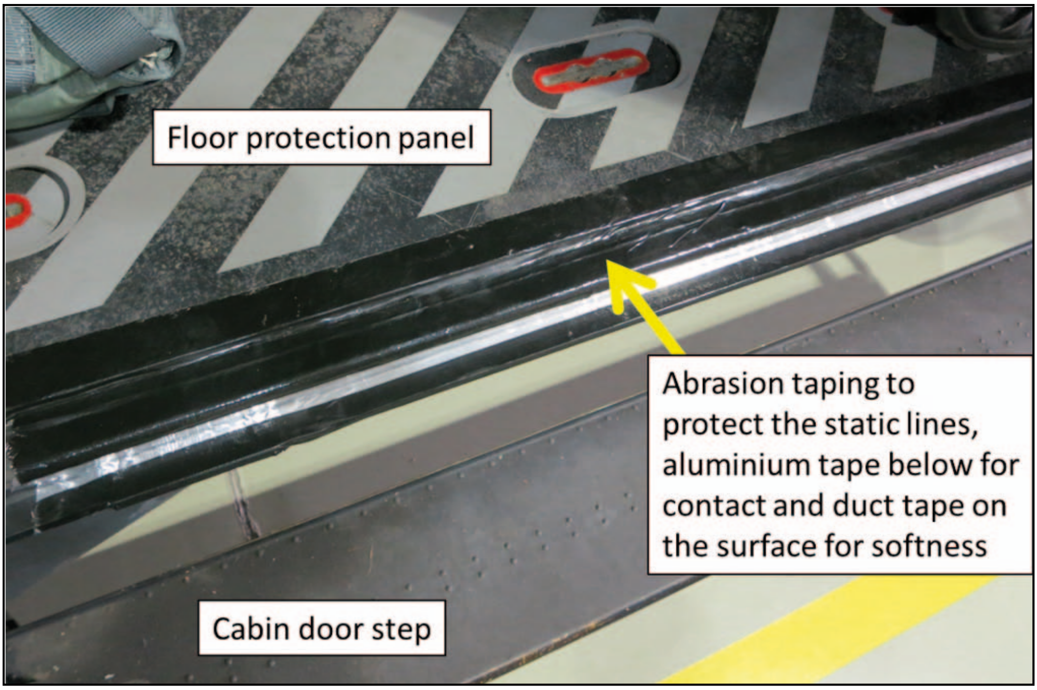

Figure 13. The right side cabin boarding step with Patria's floor protection panels and the abrasion taping installed. The aluminium or "high-speed" tape was of the following type: 3M, width 50 mm, P/N 425 BWB 1194–38. The duct tape type was Würth 50 mm x 50 m SUPERBLACK, P/N 1985 505 05

Some aluminium tape was also added to round up other sharp features as the front edge of the search light below the right sponson and the hatch of the SSU3 access door on the right aft fuselage, see Figure 14.

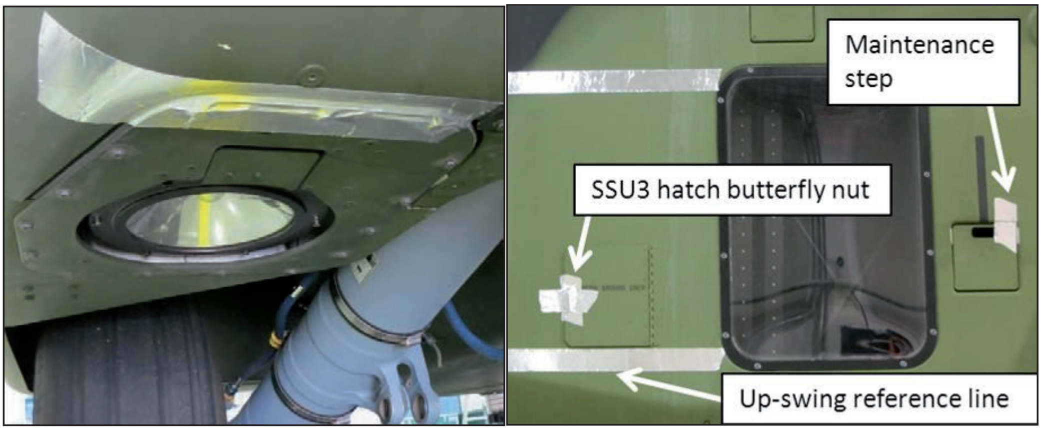

Figure 14. Test setup with aluminium tape: right search light assembly front edge (rounding), SSU3 hatch's butterfly nut (rounding) and maintenance step (securing). Two reference lines were also added to the right aft fuselage to ease the monitoring of static lines' vertical position from the chase A/C

For documenting all the exits and the static lines' behaviour after jumps, a video camera was temporarily installed below the winch man trim (WTR) unit at the forward edge of the right cabin door, see Figure 15. The camera was attached with three cable ties and secured with one safety wire to the WTR. The camera was set up at the smallest possible resolution of 640x480 pixels, which provided continuous recording for 55 min. Installation sideways provided maximum viewing angle along the fuselage in horizontal direction, which was of main interest due to the estimated static line movement path.

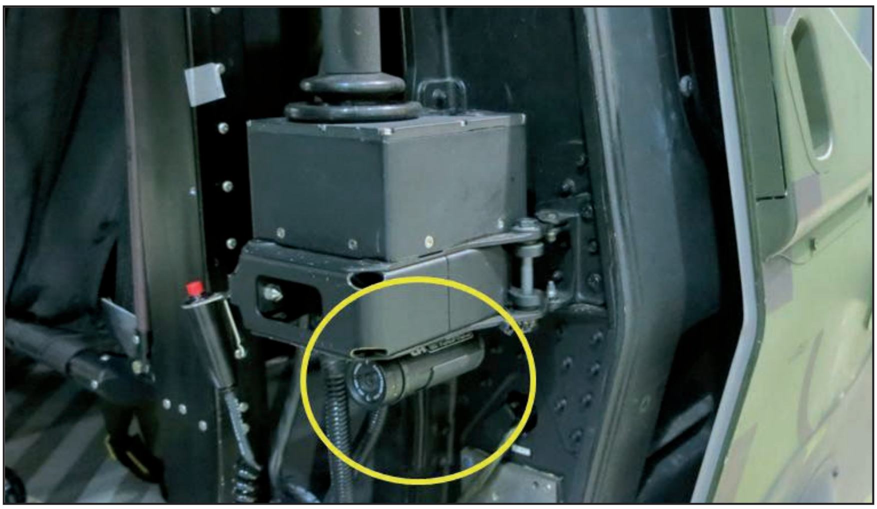

Figure 15. Contour HD 1080p digital video camera, facing towards the tail of the helicopter, installed with cable ties below the Winch Man Trim (WTR) unit

The parachutist test dummies used by FDF are shown in Figure 16. The size of the dummies is as follows: height 102cm, width 50cm and thickness 30cm. The weight of one dummy is 100 kg.

Figure 16. The parachutist test dummies used by the FDF. On the right a dummy is shown at the cabin door with the T-10 harness on. Two people are normally required to handle the 100 kg dummy and push it from the door

The jumpmasters, loadmaster and the flight test engineer as well as the cockpit crew were all connected to the helicopter's intercommunication system (ICS) with NH90 compatible Alpha helmets (Figure 17). The ICS connection points for the cabin personnel were as follows: the loadmaster used Master Station Unit 3 (MSU3), the jumpmaster 1 (JM1) MSU6 and the jumpmaster 2 (JM2) used Secondary Station Unit 1 (SSU1). Both the loadmaster and the two jumpmasters used loadmaster harnesses. LM was secured at the right side guidance cable (anchor line), JM2 was secured to the left side guidance cable and the JM1 to floor cargo attachment point at the LM seat position. For the occupants' positioning on the cabin during flight, see Figure 19. The aircrew used emergency parachutes in combination with life vests, Figure 17. This parachute could also be worn in combination with the Cabin Safety Harness, CSH 2-1560 (Airsafe Sweden Ab), see Figure 18. The installation orders for the use of the emergency parachutes and the safety harnesses are in Appendix 5's Figure 36 and Figure 37, respectively.

Figure 17. Helmet Integrated System Ltd's Alpha-helmet (P/N: SCA0079946), Pioneer Aerospace Corporation's emergency parachute (P/N 2711-519) and Beaufort Ltd's Helicopter Flight Jacket (P/N: A356800A01/2/3) worn by a crew member

Figure 18. Emergency parachute worn with Airsafe Sweden ab's Cabin Safety Harness CSH 2-1560. The connection point for the attachment strap is visible at the back below the parachute container

4.1.3 Flight envelope and test limitations

All tests were done in day time visual flight rules (VFR) conditions in straight and level flight, with the exception of side slipping during the test item #2 (Chapter 4.2.2). The jumps with dummies and jumpers were flown with the slip ball centred (without side slip). All tests were flown with the ATT flight control mode.

The following envelope was covered by the tests:

- Airspeed range: 40…80 KIAS;
- Sideslip: -2/3…+2/3 ball (for static line tow test, item #2, Appendix 6's Table 11);
- Altitude: between 1000 ft AGL (dummy drops) and 3000 ft AGL (approximately 1050 and 3050 ft respectively with the standard pressure setting 1013 mbar);
- Ground wind and turbulence: up to 15 knots (8 knots during jumps), no turbulence;
- Outside air temperature: +13°C…+15°C.

The NH90 flight manual limitations were observed, except for the Parachuting kit / Guidance cable limitation: "*Parachute jumping using the parachute kit is not allowed*" [20, p. O-86]. This limitation existed because the system was not yet qualified by the NHI. The test plan authorised ignoring this limitation [29].

The complete list of the test limitations is presented in Appendix 7.

Based on the risk analysis (Appendix 10) it was also decided that parachutes were worn by test aircraft crew during the first drops with dummies and personnel. During these first drops the jump altitude was 3000 ft AGL to facilitate reasonable possibilities for emergency egress for the crew.

4.1.4 Aircraft loading

Flight Manual weight and centre-of-gravity (CoG) envelope were observed during the tests. Figure 19 illustrates a typical loading case for the initial climb and on the jump run. The figure also shows the jumpers' exit order, movement directions and other personnel's positioning in the cabin. These all were defined by the test team during the ground test phase. Figure 20 from an early test session visualises the exit position and the static lines' routing in the cabin.

Example calculations for mass and centre-of-gravity are provided in Appendix 8. As a summary, no CoG limitations existed for jumpers' seating order or exit positioning in any practical combination, assuming a jumper's average maximum weight of 100 kg. When the jumpers would be equipped with heavy rucksacks (assumed exit weight 150 kg), the longitudinal and lateral CoG could in theory be exceeded in some cases. These cases are taken into account in the test limitations, listed in Appendix 7.

For repeatability of the results, the height and weight of the jumpmasters, loadmaster and the maximum and minimum height of the paratroopers is documented in Appendix 6, Table 13.

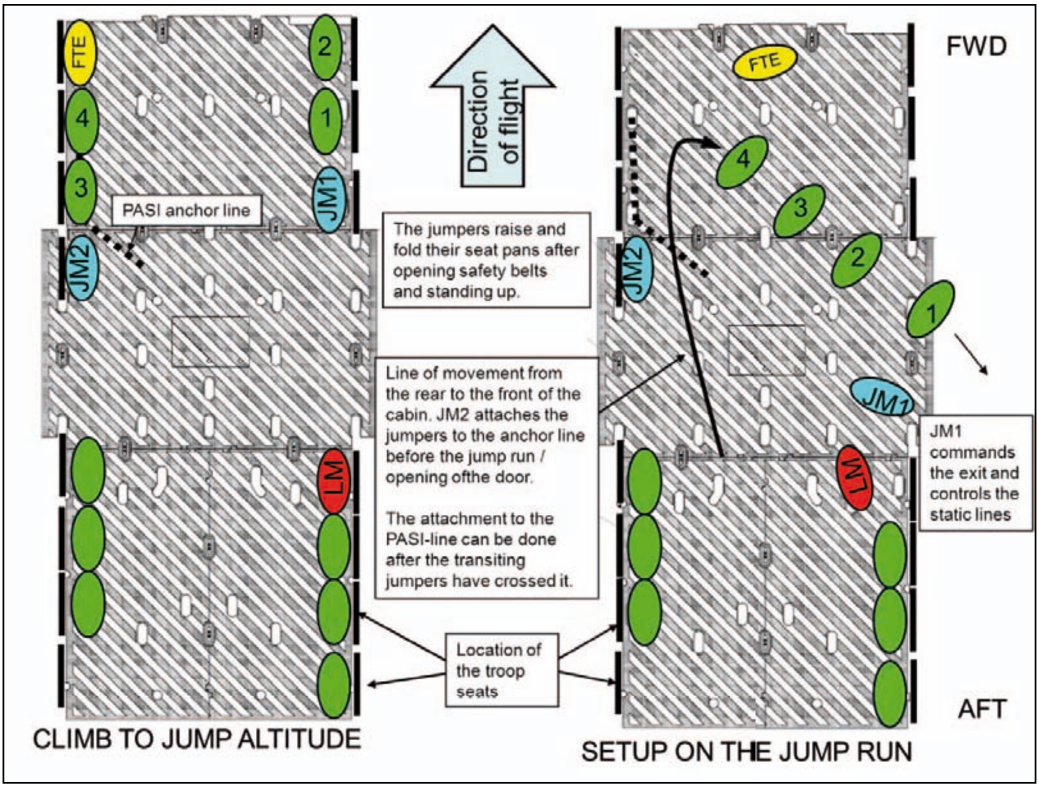

Figure 19. The seat configurations for 15 troop seats and an example of positioning in the cabin during the flight. The example load includes 10 parachutists, two jumpmasters, a loadmaster and the test conductor (FTE). JM = Jumpmaster, LM = Loadmaster, FTE = test conductor / videographer. Floor drawings are from [5]

Figure 20. Ground demonstration of a four-man stick exit. Note that the static lines have too much slack in this test situation. On the right is the estimated positioning of the static lines after parachutist separation – there is no interference with the exiting jumpers

4.1.5 Text matrix and risk assessment

The master test matrix is in Appendix 9. The aircrew – an experimental test pilot, a co-pilot, an FTE and a loadmaster – participated in all the tests. A chase helicopter with a videographer took part in all the flight tests. The jumping took place from the right cabin door only. All other doors and hatches were closed on the jump runs.

The risk analysis summary is presented here. Its details and the description of the hazard level determination and residual risk classification is presented in Appendix 10. The three most important unknown hazard factors were:

1. Static line up-swing at different airspeeds, especially the minimum vertical clearance with the main rotor;

2. Static line contact with the fuselage after parachute separation and the potential subsequent damage;

3. Static line or deployment bag entanglement in helicopter lower fuselage projections during jump or when being pulled in by the jumpmaster.

The risk mitigation concentrated especially on these three cases. The first point was managed by starting the tests with the safest airspeeds as indicated by the Industry analysis [10], using the floor anchor line at least for the first drops and by attaching only one static line to the anchor for the first tests. The second point was managed by starting with the lowest airspeeds (the least energy for up-swing), using the floor mounted anchor line for the first tests and taping any hazardous extruding aircraft parts. The third point was covered by first flying the static lines only, checking their behaviour in the slipstream for various possible end-state positions and by a careful JM/LM cooperation during the static lines' retraction phase. Finally, if a static line would have gotten entangled, the crew could have aborted the testing and landed.

After the risk mitigation actions, the worst residual risk consisted of a small probability for aircraft damage and/or personnel injury (risk category B). This meant that the risk level was higher than in normal flight service but acceptable.

4.2 Test results

The following chapters – 4.2.1 through 4.2.4 – present the test results in writing and with sets of video snap shots. The video recordings are available on request from the flight test office of Utti Jaeger Regiment's Helicopter Battalion. The comparison between the calculated and the actual static line dynamic behaviour is presented in Appendix 11.

4.2.1 Test #1: Ground assessment

The test is outlined in master test matrix item #1 in Appendix 9. The main outcome from test the item #1 (Ground assessment) was verifying the occupants' positioning and movement routes in the cabin as well as the test equipment installation, personnel actions and communication during all phases of the flight, including emergencies. During ground tests also the methodology for dropping the dummies was checked and practised. For example the setup presented in Figure 19 was consolidated during Test #1.

Concerning the test items, the fit of the Parachuting Kit's deflector bar's two middle attachment points were excessively tight, possibly due to paint layers. When installing the deflector bar with a standard 200g maintenance hammer it was considered questionable whether the attachment points' integrity would endure repeated removals and installations. This feature was however acceptable for further testing.

4.2.2 Test #2: Static lines' behaviour in slipstream

The test is outlined in the master test matrix item #2 (Appendix 9). The testing was initiated with assessing the behaviour of the T-10 static lines in slipstream with all the three anchor line versions: PASI-1, PASI-2 and NHI's guidance cables. The airspeed range was 40–80 KIAS. The loadmaster released the static lines manually and incrementally into the airstream, monitoring their behaviour during various amounts of side slip induced by the pilot. See examples of the side slip tests at 40–50 knots in Figure 21 and in Figure 22. The test results for PASI-1, the shorter floor anchor line are in Table 1 and Table 2, the results for PASI-2 (50 cm longer floor anchor line) are in Table 3 and the results for the NHI's anchor line are in Table 4.

Table 1. Test results for PASI-1 (short, floor mounting) with one static line

Test case	Airspeed (KIAS)	Observations
One static line below the sponson	40	Slip ball centred: The static line circled clockwise (looking aft from the door) with a diameter of 2 m so that the D-bag slightly contacted the sponson-fuselage junction's lower surface at the top of the rotation. With the slip ball 2/3 to the left, the D-bag moved to circle below the sponson and with slip ball 2/3 to the right, the D-bag moved below the fuselage.
	50	Compared to 40 KIAS, the D-bag stabilised and the circle diameter diminished to 0.5 meters. With slip ball ½ to the left, the static line slightly touched the main landing gear (MLG).
	60	At 60 KIAS the circling was slow and basically just small sideways movement between the MLG and the fuselage-sponson junction, amplitude 20 cm. With slip ball ½ to left, the D-bag just crossed the MLG tyre line. With ball ½ to the right, the D-bag moved at the fuseage-sponson junction.
	70	The D-bag circled in an ellipse: width 1.5 m, height 0.5 m.
	80	The D-bag circle diameter diminished to 0.5 m, but the frequency increased. Slip ball ± 2/3 moved the D-bag between MLG tyre and sponson-fuselage junction.
One static line above the sponson	40-50	The D-bag reached just over the sponson in longitudinal direction, at the RWR sensor level. The static line rested without motion above the sponson's coarse strips and flapped against the end of the sponson. With slip ball ½ to left, the bag moved against the fuselage. With ½ to right, the SL moved 5 cm inwards from the formation light.
	60->80	Accelerating from 60 KIAS, the flapping increased. With slip ball ± ½ the D-bag remained between the fuselage and RWR sensor. When reeling in, the bag started to circle rapidly and violently at Chaff and Flare Dispenser (CFD) level.

Figure 21. One static line + D-bag below the sponson at 40–50 KIAS with PASI-1. On the left the situation with slip ball on the left (side slipping to the left) and on the right with slip ball on the right (side slipping to the right)

Figure 22. One static line + D-bag above the sponson at 40–50 KIAS with PASI-1. On the left is the situation during side slip to the left (i.e. slip ball on the left). The static line is leaning onto the formation light. On the right is the static line's position during side slip to the right.

Table 2. Test results for PASI-1 (short, floor mounting) with four static lines

Test case	Airspeed (KIAS)	Observations
4 static lines below the sponson	40	The static lines were reeled out one by one. A group of 2 lines made a circle of 2 m in diam. A bundle of 3 and 4 lines flied calmly, remaining together. With slip ball ½ to the left, the bags stabilised at 1 m outside of the sponson and 1.5 m below it.
	50	The bags oscillated vertically, contacting the sponson occasionally.
	60–80	At 60 KIAS the oscillation was reduced. By increased airspeed the bags started rising towards the sponson, making a slight contact with it.
	80	With slip ball 2/3 to the right, the bags rose to the junction of the sponson and the fuselage.
4 static lines above the sponson	40–80	The same observations as with one static line, see Table 1.

Table 3. Test results for PASI-2 (long, floor mounting) with one or four static lines

Test case	Airspeed (KIAS)	Observations
One static line below the sponson	40	The circling amplitude of the bag was greater than with PASI-1: the diameter was vertically 4–5 m (estimated).
	60	Circling diminished with airspeed, being 1 m in diameter at 60 KIAS .
	80	The D-bag circled at 0.5 m diameter and could be seen above the sponson.
One static line above the sponson	40	The D-bag reached beyond the sponson longitudinally and flew at the intersection of the sponson and the fuselage.
	80	With increased airspeed the flapping amplitude increased and the D-bag started pounding the fuselage. At 80 KIAS the sideways amplitude of flapping was 0.5 m.
4 static lines below the sponson	40	Four SLs were reeled below the sponson. The bags circled with a large diameter as a bundle.
	60	With increased airspeed the bundle rose up and aligned with the fuselage. At 60 KIAS the D-bag bundle could be seen above the sponson.
	80	The bundle made a slow circle with a diameter of 0.5 m.
4 static lines above the sponson	N/A	Not tested as the static lines' behaviour with PASI-1 was generally better at the previous test points → Testing with PASI-2 was discontinued.

Table 4. Test results for the NHI anchor line (ceiling mounting)

Test case	Airspeed (KIAS)	Observations
One static line below the sponson	40 80	The behaviour and positioning was similar than with PASI-2.
One static line above the sponson	40 80	The line had a tendency to rise along the deflector bar. This was controlled manually so that the SL did not rise above the lower edge of CFD. At 70 KIAS the D-bag reached up to the aft cabin window and swung vertically ± 1m about the window's lower frame. The D-bag was reeled in at 40 KIAS and it dragged along the top surface of the sponson, getting briefly stuck somewhere. When passing the CFD, it started circling violently, as with previous times.
One static line at door upper edge level (vertically)	40 60	When reeling out the SL it was observed that a side slip affected the SL very strongly. **With ½ slip ball to the left, the D-bag suddenly swung upwards towards the engine cowlings and the main rotor. The out-reeling and testing was discontinued as unsafe.** Thus the effect of side slip for the max length of static line was not tested. It was also concluded that reeling in the D-bag from its full length at door upper frame level would not be safe. On the next flight (test #3) this was re tested: a single static line was secured so (shortened) that it could in no case reach the main rotor. **When reeling out the SL, the D-bag occasionally made a circle hitting the ASF's lower part** (video archived in UTJR flight test office). **This, in combination with the previous observation in sideslip, was considered unacceptable**. Furthermore, the ASF has plastic air scoops, which would probably have been damaged in repeated operations. After this the **testing with NHI's anchor line was discontinued**. No benefit was foreseen from its usage, but the static line behaviour became unpredictable and the risks were elevated compared to the floor attachment.
4 static lines below the sponson	N/A	Not tested due to a single static line's unacceptable behaviour.
4 static lines above the sponson	N/A	Not tested due to a single static line's unacceptable behaviour.

During one of the static line retractions at 80 KIAS, the D-bag got stuck to the engine #2's start fuel drain pipe in the right MLG wheel bay. The drain pipe bent forward approximately 15°. This very minor incident was reported to the NHI with Service Request SR 1-7914270. As a solution it was concluded that if the D-bags got stuck during retraction, the JM should give some slack and try again. The fluttering movement would most probably guide the D-bag via another route and prevent bending of the drain pipe. Since this first occurrence, no entanglements occurred.

As a conclusion of the test item number 2, the testing with NHI's anchor line was discontinued as potentially unsafe and because it did not provide any benefits for the T-10 system usage compared to the floor mounted anchor line. The PASI-2 anchor line was also rejected as it did not provide any benefits compared to PASI-1 and increased the unrest of the static lines in slipstream. The behaviour of the static lines was satisfactory with the PASI-1 anchor and the testing was continued with it. The airspeed regime was limited to 50–80 KIAS (~90–150 km/h). Any lower airspeed increased the static lines instability. Low airspeeds were not desirable for the jumpers due to longer parachute opening times, increasing risks for a given exit height.

4.2.3 Test #3: Dummy drops

A total of 16 dummy drops were made during a single sortie consisting of four loads, i.e. four take-offs and landings. For test details, see Appendix 6 (Table 11, item #3) and master test matrix test points #3 and #4 in Appendix 9. The first eight dummy drops were made one by one, reeling the SL in after each drop. The airspeeds were 50, 60, 70 and 80 KIAS and the altitude 3000ft AGL. Two drops were made from each of the airspeeds. The last eight drops were made in sticks of four dummies, airspeeds being 60 and 80 KIAS and the drop altitude 1000 ft AGL.

Working with the 100 kg dummies was quite hard in the cabin of only 158 cm ceiling height even for two jumpmasters. Possibly due to this, the second dummy hit the cabin boarding step, causing a 30x50mm dent and buckling of the step's longitudinal outer frame (Service Request reference: SR 1–7914270). This was however a minor incident and purely test setup related. All the dummies behaved in a stable manner after exit. The minimum separation with the right sponson during exits was 20 cm. All the static lines stabilised below the sponson and behaved well as on the previous sortie with PASI-1 anchor line.

As a conclusion, the test item was successfully passed and the campaign continued with paratroopers, maintaining the test airspeed range of 50–80 KIAS.

4.2.4 Test #4: Paratrooper jumps

A total of 28 paratrooper jumps were made on one sortie consisting of three loads. For sortie details, see Appendix 6 (Table 11, item #4) and the master test matrix test points #7 and #8 in Appendix 9. The cabin loading with a total of 13 cabin occupants, parachutes on is illustrated with Figure 23 as an example.

The first four jumps were made individually from a seated position and only one jumper connected to the anchor line at a time in accordance with the incremental approach principle and the risk mitigation. The seated exit position reduced variables and made it more probable that the static lines would safely stabilise under the sponson instead of above it. In the seated exit position the jumper was sitting in the left (forward) side of the cabin door edge, facing directly to the side, feet hanging outside the cabin boarding step and hands beside thighs (Figure 24, step 1). The subsequent jumps were made from a standing position from the left side of the door, with left foot on the door edge and left hand taking support of the left door frame (Figure 25). The first ten jumps were made individually, one per jump run (Table 5, test points 1–10) and with only one jumper connected to the anchor line at a time. The subsequent jumps were made in sticks of two or four jumpers (Table 5, test points 11–15). Figure 26 visualises the exit procedure.

The parachuting drop light (PDL, Figure 8) was used from the cockpit as per its design and purpose, but for information only. The jump orders were given via the intercom.

The test points and the observations for the three loads are listed in Table 5.

Figure 23. The loading of 13 cabin occupants including: 9 jumpers, 2 jumpmasters, an FTE and the loadmaster (behind the camera). Situation forward of the cabin door is seen on the left aft of the cabin door on the right

Table 5. Test points and observations for the paratrooper jumps (test item #4)

Test point #	# of load	Airspeed (KIAS)	Number of jumpers	Method of exit	Observations
1	1	50	1	sitting	OK
2		60	1	sitting	OK. See Figure 24
3		70	1	sitting	OK
4		80	1	sitting	OK
5		50	1	standing	OK. See Figure 25
6		60	1	standing	OK
7		65	1	standing	OK.
8		80	1	standing	OK. Static line contacted the front edge of the sponson.
9		80	1	standing	OK.
10	2	60	1	standing	OK.
11		70	4	standing	OK. H/C climbed briefly at +100 fpm (ALT hold on)
12		80	4	standing	OK
13	3	60	2	standing	OK
14		50	4	standing	OK. One static line stabilized against the right POS light –> no issues with retraction of static lines.
15		60	4	standing	See Figure 26

Figure 24. A jumper's exit at 60 KIAS from a seated position. In the readiness position (step 1) the jumper was sitting on the cabin floor facing directly to the side. The feet were hanging outside and hands beside thighs on the door edge. After exit the static line first contacted the middle of the boarding step, then stabilised against the bar between the step and the sponson as seen in step #6 on the bottom right

Figure 25. A jumper's exit at 50 KIAS from a standing position. In the readiness position (step 1) the jumper was standing on the left side of the door left foot forward. After jump the static line stabilised against the bar between the step and the sponson, contacting also the deflector bar

Figure 26. A stick of four jumpers exit at 60 KIAS from a standing position. The top-left picture shows the crowded readiness position. The series from top-middle to bottom-right (steps 2–6) shows the exit of the last jumper of the stick and how the four static lines stabilise below the sponson, contacting also the deflector bar

Figure 27. Retraction of four static lines by jumpmaster #1 at 60 KIAS

In addition to what is noted in Table 5, the following observations were made (collected from the Post Flight Report 6/2012 [3]:

- All the planned jumps could be made fluently and in a controlled manner. The jumpers did not report anything that would restrict the normal paratrooper exit procedure. The jumpers were aware of the sponson behind the door, but at these airspeeds (50–80 knots) it did not create a need for any specific exit technique. It was also reported that the NH90 did not induce a non-conventional or adverse slipstream that would have affected the exits.

- The MC1-1C static lines had slightly larger snap hooks than those of the T-10Bs (see Appendix 4's Figure 31). Connecting and disconnecting the MC1-1C snap hooks to the PASI-1's angled D-ring (Capewell 101406, NPF 61A665) was awkward and slow for the jumpmaster. For the T-10Bs this was not a problem due to smaller snap hooks.

- With four jumper sticks the exit positioning was somewhat tight, making it difficult but possible for the JM2 to inspect the gear of the last jumper. This was already indicated by the ground tests. In spite of this, the jumpmasters commented that it would be feasible to conduct T-10 operations from the NH90 with one jumpmaster only. That would also provide more room for the jumpers in the cabin.

- The cabin occupants reported that from the cabin space point of view it was not necessary to turn the loadmaster's seat against the wall (as all the other seats) from its normal position, which is facing forward.

- The ICS leads and harness attachment straps got easily entangled with each other. The LMs and the JMs required an ICS extension lead, which should be connected to the MSUs behind the door line. The MSUs are preferred for the LM and JMs to hear the external radio traffic (not possible via the SSUs). The LM shall in any case be connected to the MSU3's hardwired back-up connector in case of an ICS malfunction.

- The 44 drops made during the test items #3 and #4 abraded one layer of duct tape partly away from the boarding step. The static lines' contact points are seen in Figure 24's steps 5 and 6. The static lines also slightly abraded the sponson's and boarding step's paint which was acceptable. No observable abrasion of the static lines was noted.

- At these airspeeds the occasional contact between the static lines and the right position light was very benign. This did not raise any concerns as of the position lights integrity during T-10 parachuting operations.

- Retraction of the static lines was straightforward and easy for the jumpmaster. The procedure is illustrated in Figure 27.

- The Parachuting Drop Light "jump" tone with green light was not audible inside the cabin in flight.

- No testing with weapons or rucksacks was made due to time constraints.

- The right side Chaff and Flare Dispenser is located so that if operated during parachuting operations, it would endanger the exiting jumpers.

The static lines' good behaviour was substantiated already during the dummy drops (Chapter 4.2.3). However, as the static lines' dynamic behaviour was the main unknown during the test planning, a limited comparison between the analytical predictions and the actual flight test observations was made. These results can potentially be utilised in future planning of similar tests. The static line's dynamic behaviour during and after parachutist separation is discussed in Appendix 11.

5. CONCLUSIONS AND RECOMMENDATIONS

As a conclusion, parachuting from the NH90 right cabin door at 50–80 KIAS using the T-10B/MC1-1C static line parachute systems was easy for the paratroopers, safe for the helicopter and readily controllable for the jumpmasters. With the used setup, the dynamic behaviour of the T-10 static lines was predictable and uneventful. The NH90 TTH TFIA helicopter equipped with the deflector bar, Patria's floor protection panels, PASI-1 anchor line and tape protection at the right cabin door edge was found suitable for T-10 static line parachuting operations within the scope of the test (Chapter 1.1).

For the configuration mentioned in the paragraph above, the following aircraft related operating limitations are proposed by the test team:

1. Allowed exit airspeed range: 50–80 KIAS;

2. Maximum jumper weight: 150 kg;

3. Landing gear shall be retracted during jumping;

4. The right search light shall be retracted during jumping;

5. With rucksacks the last group of four jumpers to exit shall not sit in the last two rows of seats in the cabin;

6. With rucksacks only two jumpers shall be sitting or standing at the cabin door edge at the same time;

7. Parachuting is not allowed with static lines connected to the ceiling anchor cables.

The first limitation is based on the observed static line behaviour in slipstream (Chapter 4.2.2). The second is based on the maximum design load used to dimension the parachuting kit and the PASI-anchor (Chapter 2.4). The third and fourth limitations are based on the risk analysis to avoid the static line entanglement and damage to H/C (Appendix 10). The fifth and the sixth limitation are deducted from centre-of-gravity calculations (Appendix 8). The last limitation comes from the test results (Chapter 4.2.2).

The test team's recommendation for the exit airspeed is 65 KIAS (120 km/h) as the best compromise between the parachute opening speed and the static lines' behaviour. The recommended exit method is to leap out from the left (nose) side of the right cabin door to minimise risks for contact with the sponson.

The Prototype Anchor for Static line Implementation, version 1 (PASI-1) installed in accordance with Figure 11 and Appendix 4's Figure 34 was found suitable for its intended purpose. However, the small size of the snap hook attachment ring should be rectified by changing bigger D-rings to PASI-1 instead of Ring D, angled (Capewell 101406, NPF 61A665). The load bearing capability of the new D rings shall be at least 5000 lbs and the total functional length of the PASI-1 shall not change.

The used method of taping the door edge with a combination of aluminium and duct tape was found as a suitable mean to protect the static lines from excessive abrasion. This kind of method was also instructed in [32, p. 17–9]. This was finally the only tape protection considered necessary for routine static line operations with the Finnish variant NH90.

The fit of the parachuting system's deflector bar's two middle attachment points were excessively tight, possibly due to paint layers. It was considered questionable whether the attachment points' integrity would endure repeated removals and installations with a standard 200g maintenance hammer. Until this issue has been rectified, the number of removals and installations of the bar should obviously be kept to the minimum.

No specific recommendation concerning the seating configuration was made. The only important point was to leave the right cabin door area clear, which was self-evident and can only be realised with a maximum of 15 installed troop seats (in the Finnish configuration). By the test team's judgment the occasional contact of the static lines with the right position light was so benign that it did not cause any real structural risk for the integrity of the position light. Thus no further actions concerning this are foreseen when using the PASI-1 anchor.

The effect of atmospheric turbulence was considered not a factor from the safety point of view. In any case the wind limitation of 7 m/s for static line parachuting training prevent any significant turbulence at the jump altitudes.

It was concluded that if the D-bags got stuck during retraction (for example to the start fuel drain pipe), the JM should give some slack and try again. The fluttering movement would most probably guide the D-bag via another route and prevent bending of the drain pipe.

The Parachuting Drop Light (PDL) was not necessary for static line operations at least during day time, as the relevant information between cockpit and cabin could be conveniently transferred by ICS and hand signals. The operation logic of PDL's audio tone is in contradiction with other FDF aircraft, but as the audio tone was not audible in flight, this did not have a significant effect.

Even though the need to use chaff and flares for self-protection during parachuting operations is unlikely, it needs to be instructed that the use of Chaff and Flare Dispenser is not possible from the right side during jumping.

The risk analysis and mitigation actions predicted well the actual outcome. Especially the introduction of the floor attached anchor line proved to be a good decision for testing and operation with the T-10 system. With another parachute system with much shorter static lines the use of the NHI's ceiling mounted anchor lines could be possible. However, with the T-10 system the use of the ceiling mounted anchor lines was considered unsafe.

T-10 parachuting operations with personal weapons or rucksacks were not tested due to time constraints. The use of the NH90 helicopter with the T-10 parachuting system in combination with personal weapons and rucksacks as well as material dropping should be investigated. Also the use of other types of parachutes than the T-10 should be tested. Discussions with the authority are required to define what kind of substantiation is needed for operational release.

The use of the NH90's rear ramp for static line operations should be investigated as soon as the complete removal-installation instructions for the rear ramp and hatch are available. This could potentially enable using greater exit airspeeds and make moving in the cabin and material dropping easier than with the right cabin door exit solution.

The NHI' calculated estimations of the static lines' behaviour seemed to predict well the real characteristics in flight for airspeed range of 50 to 80 knots, as detailed in Appendix 11. However, the calculations could not predict all the details of the static lines dynamics, such as the trim position high amplitude rotation at 40 knots and the flutter in trim position at all airspeeds. Only the "Start" and "Trim" positions could be verified, as the "Max" or highest up-swing position was in limited by the sponson in the test setup. Due to different initial conditions in the calculation and the actual test, some assumptions had to be made. These are detailed in Appendix 11.

As a final conclusion the test team considered the NH90, equipped as mentioned above, to meet both the user and the authority requirements (see Chapter 3) concerning the T-10 static line parachuting operations. However, the official approval process needs to address and decide on the completeness of the presented substantiation before the capability is released to service.

6. SUMMARY

This study summarises the analyses and tests conducted to introduce the T-10 static line parachuting capability to the Finnish Defence Forces' NH90 helicopter. The main research question "*By which procedures and limitations can the NH90 helicopter be used for static line parachutist training with T-10B/MC1-1C parachutes?*" can now be answered. By flight testing, supported by analysis and literary study it is shown that the NH90 can safely be used for static line parachuting training with T-10B/MC1-1C equipment, taking into account the scope mentioned in Chapter 1.1 and the procedures and limitations presented in Chapter

5. Most importantly, the static lines anchor point should be on the cabin floor level and the airspeed range 50–80 knots for safe parachuting operations from the right cabin door.

The first sub question: *"What are the NH90 helicopter and the T-10B/MC1-1C parachute systems?"* is answered in Chapter 2. The chapter also describes the modifications for the helicopter and the manufacturer's Parachuting Kit to enable safe and controlled conduct of operations.

The second sub question: *"What are the relevant user and authority requirements for the NH90 static line parachuting system and capability?"* is answered in Chapter 3. User requirements are defined by the end user Utti Jaeger Regiment. Airworthiness aspects are governed by the Finnish Military Aviation Authority via regulations and advisories, of which the relevant items are presented in Chapter 3.

The third sub question: *"How does the static line parachuting system, as incorporated in the NH90 helicopter, behave during flight tests and what are the possible areas requiring further development?"* is answered in Chapter 4.2. In short, the NHI's standard Parachuting Kit's cabin ceiling mounted guidance cables were considered as unsafe anchor lines for the T-10 system. This was due to the ceiling attached static lines' unacceptable behaviour in slipstream. However, the floor mounted PASI prototype anchor line was a usable solution for the T-10 static line operations. In the flight test setup the only items requiring modification were the PASI-1 prototype anchor's D-rings for static lines' attachment. The D-rings needed to be changed to larger ones to facilitate use of the MC1-1C snap hooks.

Some proposals for future testing are presented in Chapter 5. One of the most important points is the usability of the rear ramp for parachuting operations, with the ramp and hatch removed.

REFERENCES

[1] *Aviation Act (1194/2009)*, Finnish Transport Safety Agency [quoted on 30 Dec 2012]. Available at: http://www.finlex.fi/fi/laki/kaannokset/2009/en20091194.pdf

[2] Delsalle, D. Experimental test pilot, Flight Test Department, Eurocopter, Marignane, France. Interview concerning the best approach to static line testing concerning the NH90 helicopter, 10 May 2012. Notes held by the author.

[3] Heinonen A, Koivisto J. *NH90 pakkolaukaisuhypyt*, MI31984, 6 Nov 2012, flight test office, Utti Jaeger Regiment. Post Flight Report # 6/2012, 15 pages. Held in FDF's Hallnet database.

[4] *Insinöörikapteeni Ville Siiropään EUK65 tutkimustyön tekeminen englannin kielellä*, AI20478, 24 Oct 2012, National Defence University. A document permitting to use English in captain(eng) Siiropää's SSOC study. Held in FDF's Hallnet database.

[5] Laatikainen Y. *Esitys NH90-lattiasuojalevyjen asennus-, huolto- ja vauriokorjausohjeeksi*, Patria Aviation 16 Feb 2011. Instruction document, 11 pages. Held in Finnish Air Force Material Command's Helonet database.

[6] Mills Manufacturing Corporation, *Airborne Troop Parachutes* [quoted on 11 Jan 2013]. Available at: http://www.millsmanufacturing.com/products/airborne-troop-parachutes

[7] Mills Manufacturing Corporation, *MC1-1C/D Parachute Assembly*, [quoted on 11 Jan 2013]. Available at: http://www.millsmanufacturing.com/files/MC-1C-D%20 Tech%20Data%20Sheet-09-27-11.pdf

[8] Mills Manufacturing Corporation, *T-10 Parachute Assembly* [quoted on 30 Dec 2012]. Available at: http://www.millsmanufacturing.com/files/T-10%20Tech%20 Data%20Sheet.pdf

[9] *NH90 huoltokoelento-ohje*, MI28280, 24 Sept 2012, flight test office, Utti Jaeger Regiment. National maintenance flight test instructions for the NH90. Held in FDF's Hallnet database.

[10] NHIndustries (Eurocopter Deutschland), *Determination of trajectories of static line and bag of standard NH90 H/C in horizontal flight after parachuting*, Technical Note TN S252M1527E01, issue A, 1 Apr 2008. An NH90 qualification document, 9 pages. Held in Finnish Air Force Material Command's Helonet database.

[11] NHIndustries (Eurocopter Deutschland), *Dynamic Loads and Behaviour of the Parachuting Kit during Malfunction of the Parachute Deployment*, Technical Note TN S259M0548E01, issue B, 3 Dec 2008. An NH90 qualification document, 16 pages. Held in Finnish Air Force Material Command's Helonet database.

[12] NHIndustries (Eurocopter Deutschland), *NH90 Qualification Sheet for the Troop Seat*, QS S252M0608E01, issue D, 20 Jan 2006. An NH90 qualification document, 60 pages. Held in Finnish Air Force Material Command's Helonet database.

[13] NHIndustries (Eurocopter Deutschland), *Strength Substantiation of Parachuting Kit Anchor Cable and Deflector*, Technical Note TN S259M0556E01, issue C, 3 Dec 2008. An NH90 qualification document, 21 pages. Held in Finnish Air Force Material Command's Helonet database.

[14] NHIndustries (Eurocopter Deutschland), *System Description for Parachuting Kit*, Technical Note TN S259M0512E01, issue G, 19 Jan 2011. An NH90 qualification document, 26 pages. Held in Finnish Air Force Material Command's Helonet database.

[15] NHIndustries (Eurocopter Deutschland), *System Hazard Analysis (SHA) for Parachuting Kit and Cabin Safety Belt*, Technical Note TN S252M0534E01, Issue F, 12 Jan 2009. An NH90 qualification document, 18 pages. Held in Finnish Air Force Material Command's Helonet database.

[16] NHIndustries (Eurocopter), *NH90 – Finish of the production variant TFIA*, Technical Note TN S112A0501E02 Issue D, 9 Jan 2012. An NH90 qualification document, 72 pages. Held in Finnish Air Force Material Command's Helonet database.

[17] NHIndustries, *Cargo and stores limitation – Description (for aircrew)*, DMC-JA-A-15-11-30-00A-043A-A, issue 028-07, 19 Mar 2012. An NH90 FOC IETP data module. Held in FDF's Hallnet database.

[18] NHIndustries, *Draft Test Plan updated.pdf*, received 9 May 2012 via email as attachment to action sheet IOC+ QR4-32. Industry draft test plan for static line parachuting system, 2 pages. Held in Finnish Air Force Material Command's Helonet database.

[19] NHIndustries, *NH90 Helicopter Aircrew Information, TTH TFIA IOC+, Volume 1: General Description*, IETP 3.0, JA-A-FM_GD-00-V1-P-SX-TFIA, Edition 01, Rev 005.00, 10 Feb 2009. An NH90 FOC IETP data module for the aircrew. Held in FDF's Hallnet database.

[20] NHIndustries, *NH90 TTH-TFIA IOC+ Pilot's Abbreviated Flight Crew Checklist*, JA-A-FCC-00-V1-P-SX-TFIAA02-V3.2-ED, 25 Mar 2011, revised 27 Aug 2012. An abbreviated flight manual for the NH90 aircrew. Held in Finnish Air Force Material Command's Library.

[21] NHIndustries, *Static line jumping*, TFIA IOC+ QR2_3-04 as signed and closed on 19 Jan 2009. An NH90 qualification action sheet. Held in Finnish Air Force Material Command's Helonet database.

[22] NHIndustries, TFIA IOC+ QR4-32 *Parachuting system*, as signed and closed on 10 May 2012. An NH90 qualification action sheet. Held in Finnish Air Force Material Command's Helonet database.

[23] NHIndustries, *VCDD for NH90 TFIA IOC+*, TN S000A1547E02, issue D, 15 Jan 2009. An NH90 qualification document, 90 pages. Held in Finnish Air Force Material Command's Helonet database.

[24] Parachute Factory, *Military Parachutes, MC1 Troop Pack* [quoted on 31 Dec 2012]. Available at: http://www.parachutefactory.com/01_par/par.php?num=79

[25] *Parachute Rigger Handbook*, FAA-H-8083-17, U.S Department of Transportation, Federal Aviation Administration (USA), Flight Standard Service, 2005. 344 pages. Available at: https://www.faa.gov/library/manuals/aircraft/media/FAA-H-8083-17.pdf

[26] Poynter D. *The Parachute Manual*, Volume II, Fourth Edition, Para Publishing, Santa Barbara, California, 1991, ISBN 0-915516-80-2.

[27] *Project Test Plan Policy and Process for Testing Air Vehicles, Weapons, and Installed Systems*, NAVAIRINST 3960.4A, AIR-4.11, Department of the Navy, Naval Air Systems Command, 8 Jun 1999. 91 pages. Document held by the author.

[28] *Security Classification Guide*, Attachment 1 for the NH90 PI/P Contract's Annex K. PI/P0001, ALN27, 12 pages. Held in Finnish Air Force Material Command's Helonet database.

[29] Siiropää V, Heinonen A, Tuomisalo T. *NH90 Static Line Parachuting System Flight Tests – Phase I*, MI27801, 13 Sept 2012, flight test office, Utti Jaeger Regiment. Test Plan # 6/2012, 52 pages. Held in FDF's Hallnet database.

[30] *Sotilasilma-aluksen lentokelpoisuusvaatimukset*, SIO-Ma-Lt-005, Finnish Military Aviation Authority, 18 Apr 2011 [quoted on 2 Jan 2013]. Available at: http://www.puolustusvoimat.fi/wcm/76d8ac00468d1e3980d4cb2bcc0c25fc/Sotilasilma-aluksen+lentokelpoisuusvaatimukset.pdf?MOD=AJPERES

[31] *Sotilasilmailussa käytettävien laskuvarjojen ja pelastautumisvarusteiden hyväksyntä ja ylläpito*, SIM-Ma-Yl-013, Finnish Military Aviation Authority, 10 Jan 2011 [quoted on 3 Feb 2013]. Available at: http://www.finlex.fi/data/normit/36728-SIM_Ma_Yl_013SUOMI.pdf

[32] *Static Line Parachuting System Techniques and Training*, Field Manual FM 3-21.220(FM 57-220)/MCWP 3-15.7/AFMAN11-420/NAVSEA SS400-AF-MMO-010, US Army Headquarters, 23 Sept 2003. 436 pages. Available at: http://armypubs.army.mil/doctrine/DR_pubs/dr_a/pdf/fm3_21x220.pdf

[33] *Type Specification – Appendix 1 to FDF NH90 Contract (between FDF and NHI)*, Contract Amendment 6, 28 Oct 2008. 392 pages. Held in Finnish Air Force Material Command's Helonet database.

[34] Vuori, P. FAA Master Rigger, Utti Jaeger Regiment, Utti, Finland. Interview on his experiences on jumping from UH-1 with a T-10 static line system, 3–5 Aug and 4–6 Sept 2012. Notes held by the author.

[35] Wikipedia, *Aircraft* [quoted on 8 Jan 2013]. Available at: http://en.wikipedia.org/wiki/Aircraft

[36] Wikipedia, *NHIndustries NH90* [quoted on 30 Dec 2012]. Available at: http://en.wikipedia.org/wiki/NHIndustries_NH90

[37] Wikipedia, *Paratrooper*. [quoted on 22 Jan 2013]. Available at: http://en.wiktionary.org/wiki/paratrooper

[38] Wikipedia, *T-10 Parachute.* [quoted on 31 Jan 2012]. Available at:http :// en.wikipedia.org/wiki/T-10_parachute

[39] Wikipedia, *Turn and balance indicator* [quoted on 8 Jan 2013]. Available at: http://en.wikipedia.org/wiki/Aircraft

[40] *Yhteistoimintaohje itseaukaisuhyppytoiminnasta NH90-helikopterista*, MF31082, 17 Sept 2009, Finnish Army Command. A document containing the procedures for free fall parachuting operations from the FDF's NH90 helicopters. Held in FDF's Hallnet database.

[41] *Yhteistoimintaohje laskuvarjohyppytoiminnasta Mi-8-helikopterista*, R1689/12.1.1/D/IV, 16 Sept 1997, Finnish Air Force Command. A document containing the procedures for parachuting operations from the FDF's Mi-8 helicopters. Held in FDF's Esikuntajärjestelmä database.

APPENDICES

The list of appendices:

Appendix 1:	TERMS AND ABBREVIATIONS
Appendix 2:	EXTRACT FROM THE NH90 ACQUISITION CONTRACT
Appendix 3:	EXTRACT FROM THE NH90 SECURITY CLASSIFICATION GUIDE
Appendix 4:	TECHNICAL DETAILS OF THE TEST ITEMS
Appendix 5:	FINAF AMC's INSTALLATION ORDERS FOR FLIGHT TESTS
Appendix 6:	GENERAL TEST CONDITIONS
Appendix 7:	TEST LIMITATIONS
Appendix 8:	MASS AND BALANCE CALCULATIONS
Appendix 9:	MASTER TEST MATRIX
Appendix 10:	HAZARD LEVEL DETERMINATION
Appendix 11:	STATIC LINE UP-SWING WITH AIRSPEED

TERMS AND ABBREVIATIONS

@	"at"
#	"number"
°C	Degrees Celsius
A/C	Aircraft
AGL	Above Ground Level
Aircraft	A machine that is able to fly by gaining support from the air. [35] The word aircraft can mean for example a fixed wing aeroplane, a helicopter or a hot air balloon.
ALT (hold)	An autopilot mode for automatic barometric flight altitude hold.
AM	Asennusmääräys ("Installation order" for temporary solutions)
ASF	Anti-sand filter (of the engine air intake)
ATT	Attitude hold based flight control mode of the NH90 Flight Control system Authority In this case the Finnish Military Aviation Authority (FIMAA), a military aviation regulatory unit associated with the Air Force Headquarters [1].
CFD	Chaff and Flare Dispenser or Computational fluid dynamics
CGx	Longitudinal centre of gravity
CGy	Lateral centre of gravity
Conscript	A person undergoing his/her compulsory national military service
CoG	Centre of Gravity
CoS	Coefficient of Safety, number given by break-up or limit load divided by the maximum applied load (the design load)
CP	Control Panel
D-bag	Deployment bag
e.g.	For example (in Latin: "exemplī grātiā")
EDA	European Defence Agency
Exit weight	The all-up-weight of the jumper including all personal equipment and the parachute assembly
F_AL	Force on the anchor line
F_RING	Force on the floor attachment ring
F_SL	Force on the static line
FAA	Federal Aviation Administration
FAR-29	Federal Aviation Regulation, part 29 (for transport category rotorcraft)
FDF	Finnish Defence Forces
FIMAA	Finnish Military Aviation Authority
FINAF	Finnish Air Force
FINAF AMC	Finnish Air Force Air Materiel Command
FM	Field Manual (US) or Flight Manual
FOC	Final Operational Configuration
ft	Foot/feet, 1 ft = 0.3048m
FTE	Flight Test Engineer
FWD	Forward
H/C	helicopter

HD	High Definition
hPa	Hecto-Pascals, 1 hPa = 100 Pascals or 0.001 bars
IAS	Indicated airspeed (seen on cockpit instruments)
ICS	Intercom system
ID	Identification (number/code)
IETP	Interactive Electronic Technical Publication
in	Inch = 2.54 cm
IOC+	Improved Operational Configuration
IR	Infra-red
JM	Jumpmaster
KIAS	Indicated airspeed in knots
kN	Kilo-Newton = 1000 Newtons
kt (or kts)	Knot(s), 1 knot = 1.852 km/h
kW	kilo-Watt
lb (or lbs)	Pounds, 1 lb = 0.4536 kg
LG	Landing Gear
LH	Left hand side
LLOS	Laatu- ja lentokelpoisuusosasto / Quality and Airworthiness Division of the FINAF AMC
LM	Loadmaster
local	Local time, in this case the Finnish summer time, UTC+3, unless otherwise indicated
MAUW	Max All-up weight
mi	Statute mile(s). 1 mi = 1.609 km
MLG	Main Landing Gear
MOD	Ministry of Defence
mph	Miles per hour. 1 mph = 1.609 km/h
MPKK	Maanpuolustuskorkeakoulu
MR	Main rotor (of a helicopter)
MSU	Master Station Unit, control box of the NH90 intercom system
NAHEMA	Nato Helicopter Management Agency
NATO	North Atlantic Treaty Organization
NDU	National Defence University
NHI	NHIndustries, NH90 supplier
NH90	"Nato Helicopter for the 90s"
OAT	Outside Air Temperature
OHCP	Overhead control panel (in the NH90 cockpit)
P/N	Part Number
Paratrooper	A soldier who is trained to enter combat zones by parachuting from aircraft [37]
PASI	Prototype Anchor for Static line Implementation (designed and manufactured by UTJR)
PDL	Parachuting Drop Light
PFR	Post Flight Report
PI/P	Product Investment / Production
POS	Position
QNH	Pressure setting for altitude above mean sea level

RBL	Requirement of Type Specification
RFQ	Request for Quotation
RH	Right hand (side)
RWR	Radar Warning Receiver
SCT	Scattered clouds, 4/8 of the sky or less
SL	Static Line
Slipstream	The region of airflow close to the helicopter's fuselage affected by its movement or rotor's wake
Sponson	(for the NH90) A projection from the side of the fuselage, housing primarily the main landing gear
SR	Service Request (to the NHI support organisation)
SSOC	Senior Staff Officer Course
SSU	Secondary Station Unit, the passengers interface to the NH90's intercom system
Stick	A group of paratroopers to exit with short intervals on the same jump run
SX16	A powerful external search light
T-10 / MC1	Round troop military parachute. MC1 is the steerable version of the T-10
TBC	To Be Confirmed (later)
TFIA	Transport Finnish Army (an NH90 TTH variant)
TMT	"Lentoteknillinen muutos- ja tiedotusjärjestelmä" – FDF's airborne systems related technical change and information data system
TN	Technical Note
TOW	Take-off weight
TPSA	Requirement of Type Specification
TS	Type Specification
TTH	Tactical Transport Helicopter
UH	Utility Helicopter
US	United States (of America)
UTJR	Utti Jaeger Regiment
VFR	Visual Flight Rules
Vis	Visibility
VM	Verification Method
WTR	Winch Man Trim
XTP	Experimental Test Pilot
YT-ohje	Yhteistoimintaohje, a procedure for co-operation (here between the aircrew and the parachutists)

APPENDIX 2

EXTRACT FORM THE NH90 ACQUISITION CONTRACT

ID	TPSA	RFQ Obj. ID No.	Finnish Contractual Requirement	Contractual Commitment for Finland	Contractual Verification Method	Contractual Remarks for VMs	Classification
RBL-925	TPSA660	TS3929	A2/A6 Requirement The helicopter shall have complete provisions for equipment providing the possibility to perform static line jumping.	The helicopter shall have complete provisions for equipment providing the possibility to perform static line jumping.	9(3c)		Requirement
RBL-926	TPSA661	TS6860	A2/A6 Requirement The helicopter shall as a removable item have static line jumping equipment.	The helicopter shall] as a removable item have static line jumping equipment.	9(1,7,4)		Requirement

Figure 28. Extract from the FDF NH90 acquisition contract's Appendix 2 [33]: requirements RBL-925 and RBL-926 relating to the parachuting capability. Contractual Verification Method 9 means that the qualification for the Finnish NH90 variant (TFIA) is based on an already existing qualification. In this case the NAHEMA qualification for the TTH. The verification method "9" is specified in brackets with numbers that have the following explanations: 1 = Design documents, 3c = Demonstration on material – Moc-ups, 4 = Flight tests, 7 = Documentation for aircrew (Flight Manual etc). Together the requirement RBL-926 and MOC4 as the verification method indicate that flight testing is required for the contractual substantiation of the requirement (and the capability)

EXTRACT FROM THE NH90 SECURITY CLASSIFICATION GUIDE

Below are two extracts (see Figure 29 and Figure 30) of the NH90 program's Security Classification Guide [28], which is attachment 1 for the annex K (unclassified) of the NH90 PI/P Contract (NH90 acquisition contract) between the NAHEMA and the NHI.

General Note : The classification given in this PSI define the highest possible classification. Lower gradings are allowed according to content, especially if sensitive parts can be separated and removed from a comprehensive documentation / item.

Classification abbreviations:

NU	NATO UNCLASSIFIED
NR	NATO RESTRICTED
NC	NATO CONFIDENTIAL
NS	NATO SECRET

Figure 29. Extract from page 1/12, clarifying the classification abbreviations

6	GENERAL MISSION SYSTEM/EQUIP, TTH					
6.1	CARGO HOOK SYSTEM		NU			
6.2	RESCUE HOIST System		NU			
6.3	REAR RAMP		NU			
6.4	CARGO ROLLING DEVICE		NU			
6.5	HEAVY STORE CARRIER SYSTEM		NU			
6.6	PARACHUTING System		NU			
6.7	MANUAL TAIL FOLDING SYSTEM		NU			
6.8	MANUAL MAIN BLADES FOLDING SYSTEM		NU			
6.9	AUTOMATIC TAIL / BLADE FOLDING SYSTEM		NU			
6.10	CARGO WINCH		NU			

Figure 30. Extract from page 6/12 showing that the parachuting system is classified as "NU" = NATO Unclassified which is the lowest classification possible and in this case corresponds to "JULKINEN" in Finland

TECHNICAL DETAILS OF THE TEST ITEMS

Table 6. T-10B / MC1-1C main characteristics [7; 8]

Parameter	Value
Diameter	35 feet (10.7 m) nominal, 25.7 feet (7.8 m) inflated
Gore (canopy) material	T-10B: 1.1 oz. PIA-C-7020, type I ripstop nylon parachute cloth MC1-1C: 1.12 oz PIA-C-44378, F-111 ripstop parachute nylon
Number of suspension lines	30
Suspension line material	Type II nylon cord, PIA-C-5040, 400 lb (181.8 kg) tensile strength
Length of suspension line	T-10B: 7.8m / MC1-1C: 6.7m connector to lower lateral band
Maximum Weight Capacity	163 kg (360 lbs)
Complete assembly weight	14 kg (31 lbs)
Maximum jump wind speed	14 knots (7 m/s), in Finland, [34]
Descent rate	T-10B: Avg 6.7 m/s (22 ft/sec), MC1-1C: avg. 5.5 m/s (18 ft/sec)
Minimum deployment altitude	500 ft (152 m)
Maximum deployment speed	150 knots (278 km/h)
Service life	16.5 years (in Finland, [34])

Table 7. T-10 main components' part numbers [7; 8; 34]

T-10B	(P/N: 11-1-564-1)	MC1-1C	(P/N: 11-1-900-2)
Canopy	11-1-1501-1	Canopy	11-1-1501-3
Pack	62J434	Pack	62J4342
D-bag	56D6276	D-bag	(the same as for T-10B)
Static line	56D6481	Static line	55D6481
Harness	11-1-2143-1	Harness	(the same as for T-10B)
Riser	11-1-2149-2	Riser	(the same as for T-10B)

Figure 31. The snap hooks used during the tests. On the left the T-10B snap hook (P/N: MS 70120, proof load 1750 lbs/794 kg/7.8 kN) and on the right the MC1-1C snap hook (P/N: 11–1–6991–1, 100% proof load 1750 lbs/794 kg/7.8 kN, tensile strength 8000 lbs/3600 kg/35.6kN) [25, p. 3–21]. The 11–1–6991–1 snap hook is generally simpler to use as it does not need a safety pin, unlike the earlier MS 70120 snap hook. However, the construction makes the 11–1–6991–1 slightly larger in dimensions.

Table 8. NH90 general characteristics and performance values ([36] unless noted otherwise)

Crew	minimum 1 pilot + 1 crew member, normally 2 pilots + 1 loadmaster [20]
Capacity	16 seated troops or 12 medevac stretchers or 2 NATO pallets or approximately 3000 kg internal or external load.
Length	16.13 m (52 ft 11 in)
Rotor diameter	16.30 m (53 ft 6 in)
Height	5.23 m (17 ft 2 in), nominal cabin height 1.58 m (5 ft 2 in)
max take-off weight	11000 kg (24250 lb) [20]
Powerplant	2 × Rolls-Royce Turbomeca RTM322-01/9 turboshaft, approx 1400 kW (1900 shp) each at max continuous power
Maximum speed (cruise)	300 km/h (162 knots, 186 mph)
Range (with internal fuel)	800 km, 497 mi
Service ceiling	6000 m (20000 ft)
Rate of climb (max weight, sea level)	8 m/s (1574 ft/m)

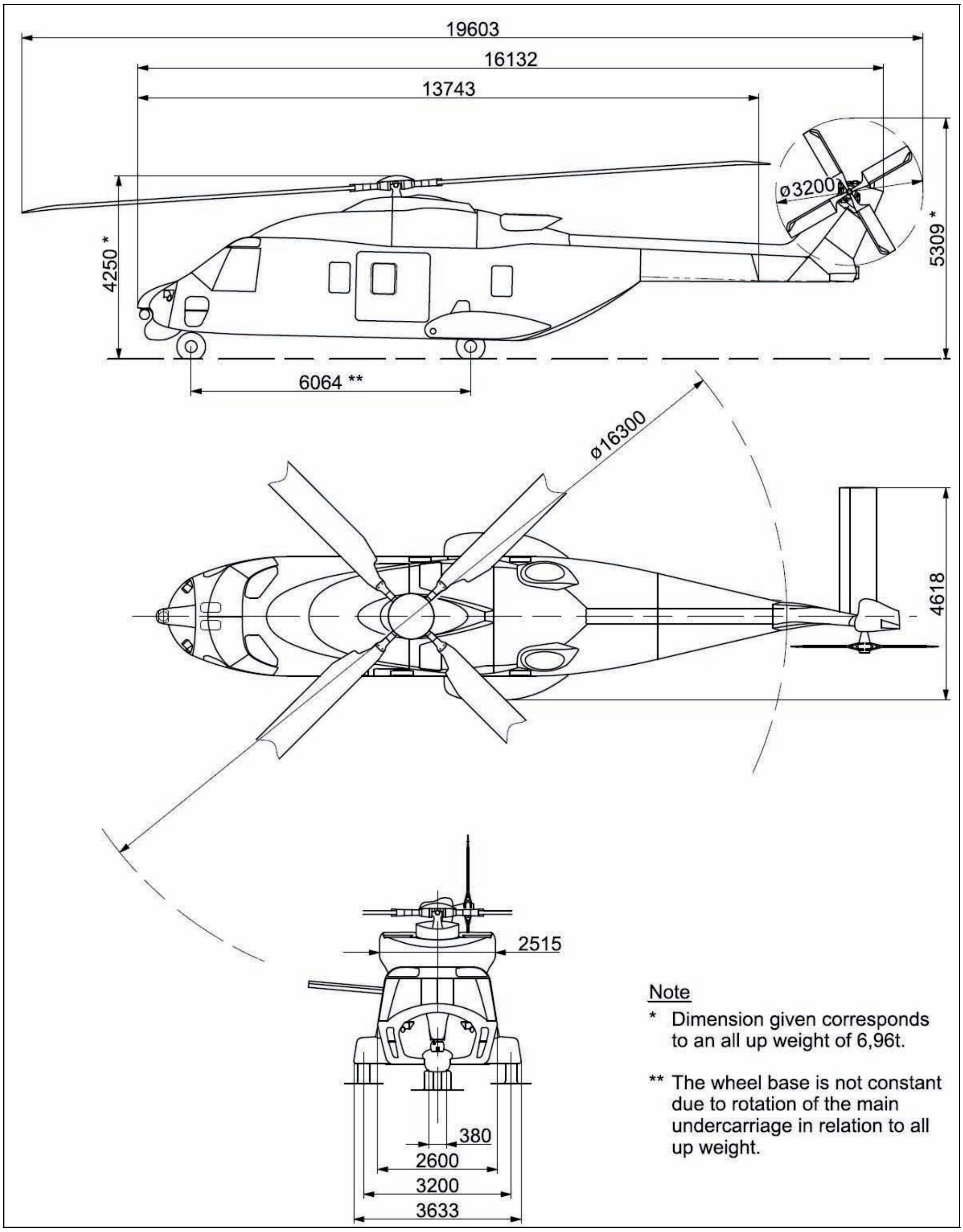

Figure 32. The NH90 TTH three view diagram: principal dimensions in millimetres. The cabin doorway on both sides is 1.6 metres wide and 1.5 metres high [19]

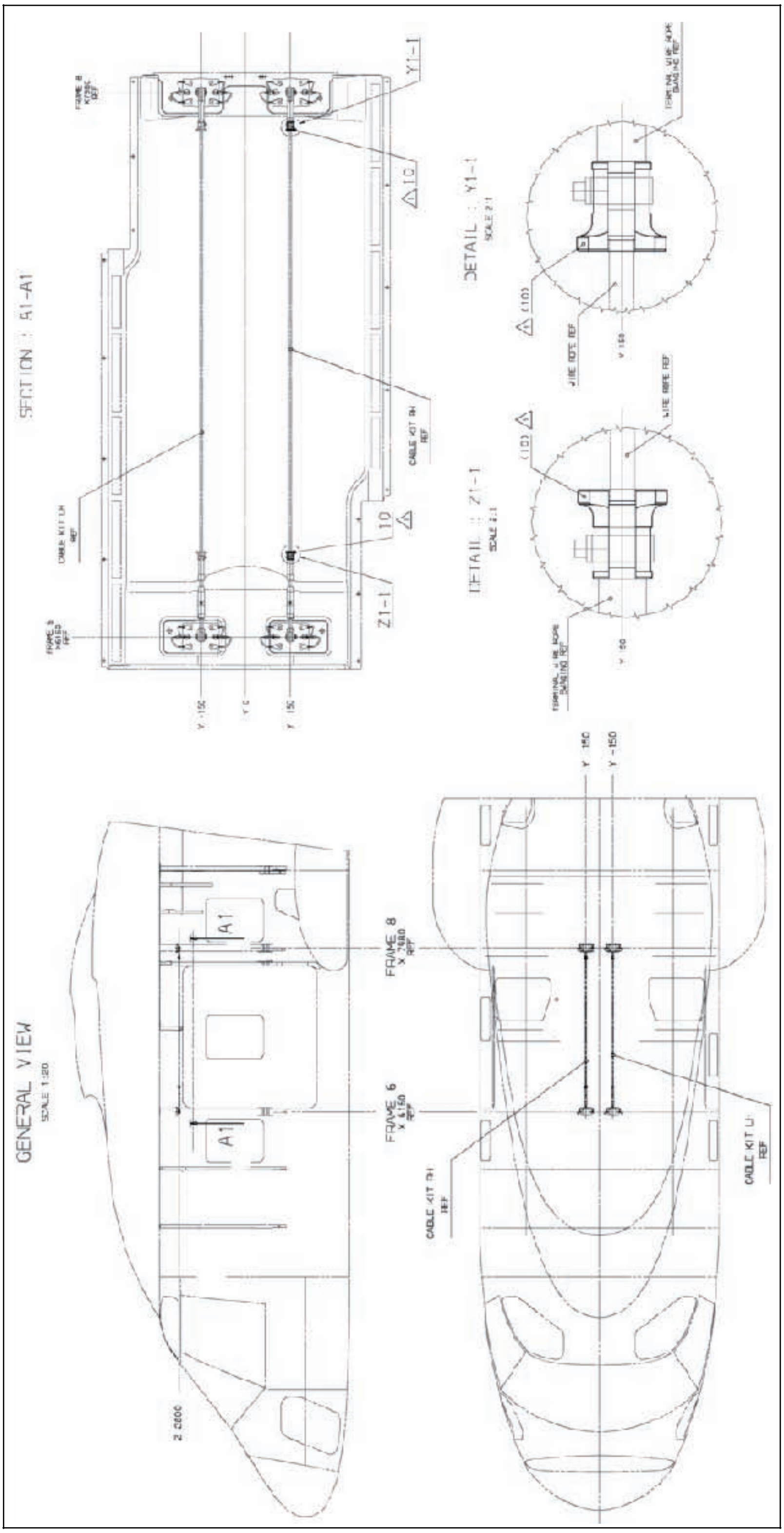

Figure 33. The location of the Cable Kit: Anchor cable, support brackets and optional rubber stops mounted on interface brackets [Ref 1]

Table 9. NH90 Parachuting System part numbers and weights [14]. As an exception to the convention of the study, here commas are used as the decimal separators instead of dots.

Part	Number	Weight	Weight HC
Interface brackets	S259M1045051	1,38kg	1,38kg
Parachute Drop Light panel LH	S333M1004051	0,3kg	0,3kg
Parachute Drop Light panel RH	S333M1001051	0,3kg	0,3kg
Cabin Signal CP (in cockpit OHCP)			
Electrical Cabling of CP		0,4kg	0,4kg
Structural parts for Static Line Protection Kit	S533M0217051	0,8kg	0,8kg
Removable parts			
Cable Kit LH	S259M1008051	3,4kg	3,4kg
Cable Kit RH	S259M1044051	3,4kg	3,4kg
Static Line Protection Kit	S259M1017051	6,42	-
Static Line Protection Kit HCV	S259M1028051	-	6,46kg
Replacement parts			
Para. Drop Light blanking plate LH	S259M1015051	0,03kg	0,03kg
Para. Drop Light blanking plate RH	S259M1013051	0,03kg	0,03kg
Rubber Stop			
Rubber Stop LH	S259M1034051	0,04kg	0,04kg
Rubber Stop RH	S259M1035051	0,04kg	0,04kg
Configurations:			
Full equipped Parachuting Kit (w/o blanking plates)		16,48kg	16,52kg
Parachuting Kit without removable parts		3,18kg	3,18kg
Guidance Cable configuration		8,32kg	8,32kg

Table 10. Prototype anchor line components [25; 26]

Item / name	P/N	Strength (lbs)	Strength (kg)	Purpose	Notes
Quick Release Cargo Ring (double stub ring, for Douglas type rails)	47981-10 NSN: 5340-01-560-3313	5000	2268	Attachment of the anchor line to floor	MFG: ANCRA INTERNATIONAL LLC
Snap, parachute chest type pack	MS70121-1	5000	2268	Connection to cargo rings	
Type-7 webbing ("belt")	Ty-8, PIA-W-4088	6000	2722	Anchor line webbing	1 23/32" width (44 mm). Commonly used in parachute harnesses
Ring, D angled	Capewell 101406, NPF 61A665	5000	2268	attachment of the static line to anchor line	Optionally used instead of Ring, D (as in Figure 12)
Ring, D	11-1-485	5000	2268	attachment of the static line to anchor line	T-10B/MC1-1C harness assembly component Optionally used instead of Ring, D angled
Harness thread		> 6000 lbs	> 2760 kg	Attachment of the components by sewing	The tensile strength of a single thread is 12 kg

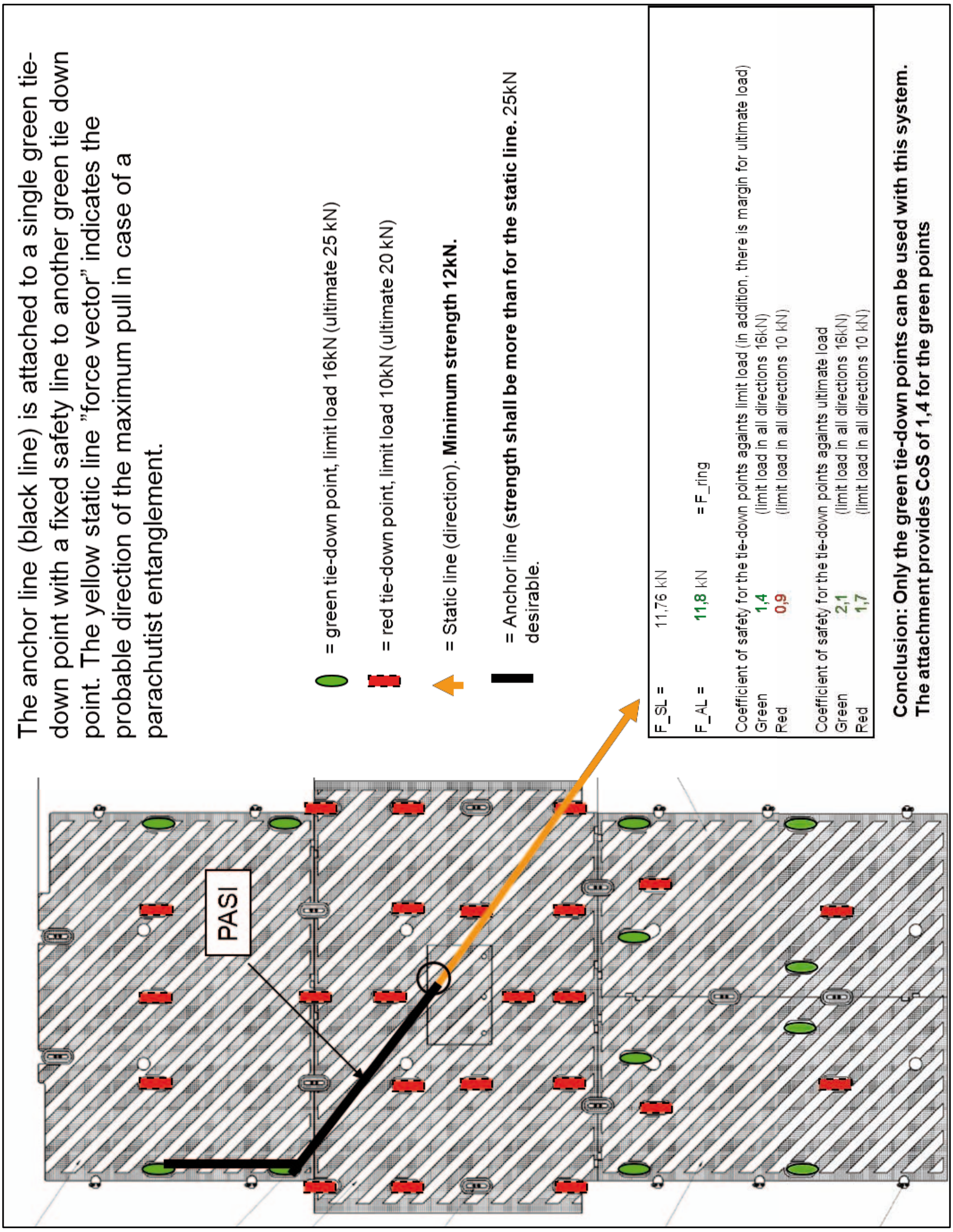

Figure 34. Strength and dimensioning calculations of the "PASI"-belt's attachment to the cabin floor. Load on the SL = load on PASI = load on the floor attachment point = 11.76kN in the worst (design) case. The PASI belt has the minimum ten- sile strength of 22.3 kN, which provides a CoS of at least 1.9 against the design load. Floor drawing is from [5]

APPENDIX 5

FINAF AMC'S INSTALLATION ORDERS FOR FLIGHT TESTS

Hyväksytty Lentotekninen

ASENNUSMÄÄRÄYS (AM)

Julkaisija	AM no	Konetyyppi	Julkaisupvm
Ilmavoimien Materiaalilaitos	AM/132/NH	NH	12.09.2012
Organisaatio	**Viimeinen voimassaolopvm**	**Muu voimassaoloperuste**	
Lntkalos/Helikopterisekt/Runko- ja voimalaitejaos	31.12.2012		
Allekirjoitukset	**Otsikko**		
Sektorin johtaja Insinöörikapteeni Lassi Latvanne Jaosjohtaja Juha Helminen	**Pakkolaukaisuhyppyjen koeasennus NH90 koneeseen** Kumoaa asennusmääräyksen		

Kohde

NH90 IOC+, yksilöt NH-207 - NH-216, UTJR valitsee käytettävän koneyksilön.

Nimikkeet/Yksilöt

Muutoksen vaikutus painoon ja painopisteeseen Merkityksetön

Rajoitukset

Viite

Merkinnät kone- ja laitekirjoihin

Paperijakelu

Sähköinen jakelu teollisuuteen

Huomautus

Asia

Asia:

T-10B –pakkolaukaisuhyppyjärjestelmän prototyyppiankkurihihnan asennus NH90 IOC+ versioon koelentoja varten.

Laajempi selvitys asennuksesta kuvineen on tämän asiakirjan liitteenä.

Asiaan liittyvä koelentosuunnitelma on: UTJR koesuunnitelma 6/2012: "NH90 TFIA Static Line Parachuting System Flight Tests – Phase I"

Asennus:

1. Irrota Static discharge line matkustamon oikean rahtioven taka-yläkulmasta (kuva 3, takertumisen ehkäiseminen, katso liite)
2. Asenna Patrian suunnittelemat lattiasuojalevyt (suojaavat lattiaa PL-hihnan lukkojen iskuilta avausvaiheessa)
3. Kiinnitä PASI-ankkurihihna – joko lyhyempi tai pidempi versio miehistön ohjeiden mukaan - matkustamon lattiaan kuvien 1 ja 2 osoittamalla tavalla. Hihnan saa asentaa vain vihreisiin kiinnityspisteisiin.
4. Varmista että hyppyjärjestelmään kuuluva suojatanko on paikallaan oikean rahtioven takareunassa
5. Teippaa oikean matkustamon oven reuna alumiiniteipillä kuvan 8 osoittamasta kohdasta siten että PL-hihna ei kiristyessään ota kiinni mihinkään karhennuksiin.
6. Teippaa (tue) oikeassa kyljessä olevan SSU3:n luukun avauksessa käytettävä siipimutteri alumiiniteipillä sen vahingoittumisen estämiseksi (kuvissa 3 ja 4 matkustamon oik takaikkunan vasemmalla puolella)
7. Tee huomautus koneen lokikortti A:lle: "AM XXX (<= tämän AM:n numero): (PL-hyppyvalmius)".

HUOM: järjestelmän mahdolliset käyttörajoitukset ja huomautukset ohjeistetaan koelentotoiminnan puitteissa ym. koelentosuunnitelmassa.

Irrotus:

1. Irrota PASI-ankkurihihna
2. Kiinnitä Static discharge line -rulla matkustamon oikean rahtioven taka-yläkulmaan
3. Poista SSU3:n luukun ja oven kynnyksen teippaukset
4. Poista tarpeen mukaan Patrian suunnittelemat lattiasuojalevyt
5. Viivaa yli lokikortti A:ta asiaan liittyvä huomautus.

Raportointi:

Koelentojen tuloksista ja erityisesti mahdollisista koneeseen aiheutuvista vaurioista tulee raportoida mahdollisimman pian Helikopterisektorille. HEKOSEKT tekee päätöksen prototyyppiankkurihihnan hylkäämisestä, modifioimisesta tai sen hyväksyttämisestä palveluskäyttöön.

Jatkotoimenpiteet

Liitetiedostot

NH_AM_ankkurihihna_lattiaan.doc

Laatija

07.09.2012 Jaosjohtaja Juha Helminen Lntkalos/Helikopterisekt/Runko- ja voimalaitejaos

Figure 35. Installation order "AM/132/NH" for PASI and test related modifications

Hyväksytty Lentotekninen

ASENNUSMÄÄRÄYS (AM)

Julkaisija	AM no	Konetyyppi	Julkaisupvm
Ilmavoimien Materiaalilaitos	AM/133/NH	NH	12.09.2012

Organisaatio	Viimeinen voimassaolopvm	Muu voimassaoloperuste
Lntkalos/Lekojärj/Lentovarustejaos	31.12.2013	

Allekirjoitukset	Otsikko
Sektorin johtaja Insinöörimajuri Harri Koskinen Jaana Pihlaja	**VN-pelastautumisvarjojen väliaikainen käyttö NH-kalustossa** Kumoaa asennusmääräyksen

Kohde

NH-202, NH-203, NH-204, NH-205, NH-206, NH-207, NH-208, NH-209, NH-210, NH-211, NH-212, NH-213, NH-214, NH-215, NH-216

Nimikkeet/Yksilöt

Rty/Rekno	Pyt	Nimi	Täsmennys	Valv.tyyppi	Yksilöt
60581	2711-519	PARACHUTE P/N 2711-519 (1)		LL	0241/124357, 0322/124419, 0330/124426, 0354/124453

Muutoksen vaikutus painoon ja painopisteeseen Merkityksetön

Rajoitukset

Viite

Merkinnät kone- ja laitekirjoihin

Paperijakelu

Sähköinen jakelu teollisuuteen

Finnair Oyj
Insta DefSec Oy
Patria Aviation Oy

Huomautus

Asia

Taustaa

MAAVE:n vuosien 2012–2015 toimintasuunnitelman (MH34698) mukaan UTJR:n tulee suorittaa pakkolaukaisuhyppyjärjestelmän koelennot NH90-helikopterista. Liitteessä on taustatietoa pakkolaukaisujärjestelmän koelennoista.

Asia

Tällä asennusmääräyksellä ohjeistetaan Vinka-pelastautumisvarjojen (RNO60581) käyttö UTJR:n NH- kalustossa. Asiaan liittyvä koelentosuunnitelma on UTJR koesuunnitelma 6/2012: "NH90 TFIA Static Line Parachuting System Flight Tests – Phase I". Varjoja käytetään tarvittaessa hätätilanteessa miehistön pelastautumisvarusteena, kun tehdään pakkolaukaisuhyppyjärjestelmätestausta NH-kalustolla. Varjot toimitetaan lainaksi ILMASK:sta testausten ajaksi.

Toimenpide

Varjoja voidaan tarvittaessa käyttää yhdessä Cabin Safety Harness (RNO483074) -valjastyypin kanssa. Liitteen kuvassa valjaat ja varjo on puettuna päällekkäin. Valjaiden laukaisukahva tulee asettaa näkyviin siten, että laukaisu onnistuu varjon alta. Varjojen huolto ja pakkaaminen suoritetaan UTJR:n laskuvarjopakkaamossa. UTJR vastaa siitä, että ennen käyttöönottoa kaikki käyttäjät on perehdytettävä varjojen toimintaan ja käyttöohjeistukseen LJK:n hyppykouluttajan toimesta.

Jatkotoimenpiteet

Liitetiedostot

kuva_valjaista_ja_varjosta_puettuna.doc
pakkolaukaisu.doc

Laatija

22.05.2012 Katja Viitanen Lntkalos/Lekojärj/Lentovarustejaos

Figure 36. Installation order "AM/133/NH" for the use of the rescue parachutes

Hyväksytty Lentotekninen

ASENNUSMÄÄRÄYS (AM)

Julkaisija Ilmavoimien Materiaalilaitos	AM no AM/109/YL	Konetyyppi YL	Julkaisupvm 07.09.2012
Organisaatio Lntkalos/Lekojärj/Lentovarustejaos	Viimeinen voimassaolopvm 30.05.2013	Muu voimassaoloperuste	
Allekirjoitukset Sektorin johtaja Insinöörimajuri Harri Koskinen Jaana Pihlaja	Otsikko **Cabin safety harness- valjaiden kokeilukäyttö** Kumoaa asennusmääräyksen		

Kohde
NH-90 -kalusto

Nimikkeet/Yksilöt

Rty/Rekno	Pyt	Nimi	Täsmennys	Valv.tyyppi	Yksilöt
483074	2-1560	VALJAAT, LENTOTURVA-		EM	

Muutoksen vaikutus painoon ja painopisteeseen Merkityksetön

Rajoitukset

Viite

Merkinnät kone- ja laitekirjoihin

Paperijakelu

Sähköinen jakelu teollisuuteen

Huomautus

Asia

Johdanto

NH90 kuljetushelikopteriin kuormamestarin käyttöön on hankittu käytössä olevaa 2B/K - valjastyyppiä kevyempi malli Cabin Safety Harness (CSH), joka on on ruotsalaisen Airsafe Sweden Ab:n kehittämä ja valmistama. Sama valjastyyppi on käytössä Norjan ilmavoimissa, jossa se on suunniteltu oviasemiehelle. Joten käyttöä voidaan laajentaa jatkossa myös NH90 kalustossa operoivan oviasemiehen käyttöön. Kuormamestari joutuu työskentelemään helikopterin matkustamossa matalassa ja ahtaassa tilassa. Kuormamestarin päällä on tehtävästä riippuen päällään valjaiden lisäksi luotiliivit, meripuku ja pelastus-/varusteliivit. Uusi valjas keventää kuormamestarin varustuksen painoa ja laajentaa sivuttaista liikerataa, mikä parantaa kuormamestarin toimintaedellytyksiä. Uusi valjas mahdollistaa mm laskuvarjon pukemisen koelentotoiminnassa.

Cabin safety harness

Valjaskokonaisuuteen sisältyy seuraavat osat: Harness, Release Strap ja Attachment Strap. Valjaita voidaan käyttää myös ilman Attachment Strapia, joka korvataan Comfort Grip -turvaköydellä (RNO480830). Valjaissa on hätätilannetta varten huomiovärinen pikalaukaisukahva, joka sijaitsee etuosassa vasemman olkapään kohdalla.

Kokeilukäyttö

Tällä Asennusmääräyksellä otetaan koekäyttöön kuormamestarin valjas CSH 2-1560 Utin helikopteripataljoonassa. Ennen valjaiden käyttöönottoa on jokaisen käyttäjän perehdyttävä käyttöohjeeseen "Technical Manual Cabin Sfety Harness 2-1560" (liite 5). Valjaat ovat putoamissuojainten standardien EN 361 ja EN 358 mukaisia. Testausraportti: SP Technical Research Institute of Sweden, 5.1.2011 (kts liite 4)

Turvavaljaat kiinnitetään valjaan selkäosassa olevasta kiinnityshihnasta D-lenkillä turvaköyteen Attachment strapilla tai nykyisin käytössä olevalla Comfort Gripillä (TT/213/NH/95-00). Turvaköysi kiinnitetään koneen runkoon ja säädetään mahdollisimman lyhyeksi, niin ettei vartalon painopiste joudu oviaukon ulkopuolelle.

Kokeilun käyttötarkoitus

Kokeilun aikana selvitetään turvavaljaiden sopivuus lennolla työskennellessä NH-90:ssä. Koekäytöstä raportoidaan ILMAVMATL/LNTKALOS/LENTOKONEJÄRJESTELMÄSEKTORI 30.05.2013 mennessä.

Jatkotoimenpiteet
Raportti

Liitetiedostot
attachment_strap.JPG
Harness.JPG
release_strap.JPG
Report,_Cabin_Safety_Harness.pdf
9-547_A,_Technical_Manual_Cabin_Safety_Harness_2-1560.pdf

Laatija
07.06.2012 Katja Viitanen Lntkalos/Lekojärj/Lentovarustejaos

Figure 37. Installation order "AM/109/YL" for the Gabin Safety Harness.

APPENDIX 6

GENERAL TEST CONDITIONS

Table 11. General test conditions for each sortie

Test #	Date (2012)	A/C (NH)	Config & Equipment	Weight&CoG	Fuel (take-off, kg)	QNH / OAT / Wind / Visibility / Clouds, WX	Landing /Flight Time (hh:mm, local)	Other
1	17.9.	209	Ground test. Anchor lines PASI-1 & 2 and NHI	N/A	N/A	N/A	N/A	
2	18.9.	209	LG UP, ASF, no IR suppressor, RH cabin door open, PASI-1, -2, and NHI	TOW: 9400 kg CGx:7.06 m CGy: 0.02 m	1700	1011 hPa / +11°C, / 190°,5kt, / 16 km / few 300ft	11:16 / 1:57	40 KIAS: pitch +8° 80 KIAS: pitch +2°
3	20.9.	209	LG UP, ASF, no IR suppressor, RH cabin door open, PASI-1	TOW: 9600 kg CoG within FM limits	1500	1011 hPa / +13° / 200°, 8kt / vis 50 km / SCT 3500ft	11:45 / 1:36	4 loads with 4 dummies each = 16 dummy drops total
4	20.9.	209	LG UP, ASF, no IR suppressor, RH cabin door open, PASI-1	TOW:10100kg CGx:7.05 m CGy: 0.02 m	1500	1011 hPa / +13° / 200°, 8kt / vis 50 km / SCT 3500ft	15:47 / 0:54	3 loads, 9+9+10 jumpers = 28 jumps

Table 12. Part numbers for some test relevant aircraft items

Troop seat	P/N: S252M20A1005 [12, p. 4]
Floor protection panels (Patria)	P/N: PNH252300010 [5, p. 2]
Boarding step (group)	P/N: S533M0060051 [23, p. 9]

Table 13. The essential anthropometric data of the test personnel (without any equipment)

Role	Height (cm)	Weight (kg)
Jumpmaster 1	173	75
Jumpmaster 2	180	90
Loadmaster	170	75
The tallest paratrooper	196	90
The shortest paratrooper	175	70
Paratrooper average	180	75

APPENDIX 7

TEST LIMITATIONS

The reason for each limitation is clarified in brackets.

1. Absolute weather minima for flight testing: visibility 3km / cloud base 500ft AGL (FDF's NH90 maintenance flight test guide, [9]);

2. The maximum airspeed for static line jumping:

    - o 80 KIAS for floor attachment (due to design assumptions [15]);

    - o 60 KIAS for ceiling anchor cable attachment (due to analysis results [10]).

3. The minimum airspeed for static line jumping: 40 KIAS (own judgment, less risk for SL bounce up, [2]);

4. Maximum ground wind speed for dropping parachutists: 14 knots (FDF regulations. Also test recommendation for dummy drops);

5. Maximum equipped jumper's all-up-weight: 150 kg (design assumption [15]);

6. Minimum drop altitude for parachutists: 1500 ft AGL [32];

7. Minimum drop altitude for test dummies: 300 ft AGL (own judgment adequate ground clearance for T-10 opening);

8. Landing gear shall be retracted (up) during static line jumping (less risk for SL entanglement);

9. Intentional quick stop, autorotation and hovering manoeuvres at an airspeed less than 30 KIAS are prohibited with static lines out on the door (own judgment, risk for SL vs. rotor contact);

10. The right search light shall be retracted during jumping activity (risk for SL entangle- ment);

11. Turbulence at the exit altitude shall be low (NHI draft test plan limitation);

12. No sideslip when dropping dummies or parachutists (less risk for adverse static line behaviour);

13. With rucksacks the last four jumpers to exit shall not sit in the last two rows of seats in the cabin (CoG calculations, longitudinal aft limit);

14. With rucksacks only two jumpers shall be sitting or standing at the cabin door edge at the same time (CoG calculations, lateral limit);

15. The maximum allowed vertical position for the static line during jumping (up-swing) is the top of the helicopter tail boom (own judgment for safe margin vs. MR).

APPENDIX 8

MASS AND BALANCE CALCULATIONS

Some example results are given below presuming 1700 kg of fuel and all occupants weighing

100 kg (a realistic average value for parachutists without rucksacks). In the following figures, the precise NH90 centre-of-gravity envelopes or CoG limits (longitudinal and lateral) have been omitted due to classification reasons.

- The max loading is 12 jumpers (@ 100 kg), two jumpmasters and a four man crew (Figure 38);
- The aft CoG limit is nearly reached (but not yet crossed) with 1700 kg fuel, if the first three cabin seat rows (six seats) are empty and the remaining seats occupied (Figure 39);
- It is ok to have four jumpers at the most aft four seats and two jumpmasters inspecting them (with loadmaster at the cabin door);
- With one occupant on the left side of the cabin (JM), two on the right (LM+JM) and four sitting in the right cabin door, the lateral CoG is well within limits (Figure 40).

Reducing the amount of fuel provides more marginal to these cases. As a summary, if all occupants weigh on the average 100 kg, there is no practical case where the MAUW and CoG limits would be exceeded during these tests.

Below are some similarly calculated example values presuming 1800 kg of fuel, aircrew and jumpmasters weighing 100 kg <u>and jumpers weighing 150 kg (with rucksacks):</u>

- The max loading is 8 jumpers (@ 150 kg), two jumpmasters and a four man crew;
- The aft CoG is exceeded if the last four remaining jumpers sit at the most aft seats and the JMs walk to inspect them -> with rucksacks the last group of jumpers to exit shall not sit in the last two rows of seats in the cabin;
- The lateral CoG is exceeded with one JM on the left side of the cabin, JM + LM on the right side, two jumpers sitting at the right cabin boarding step and two standing immediately behind them -> not more than two jumpers @ 150 kg shall be sitting or standing at the cabin door edge at the same time.

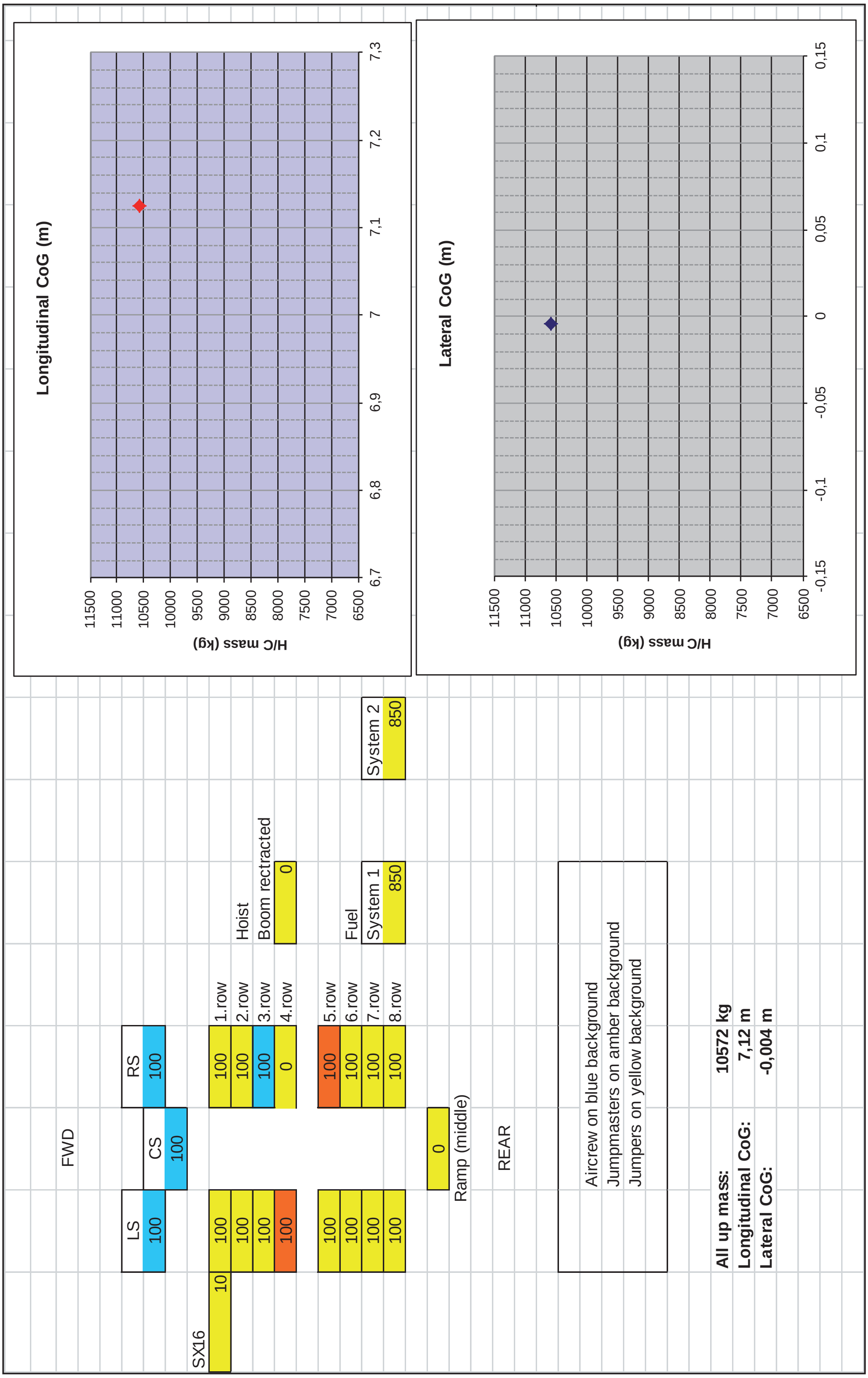

Figure 38. MAUW limiting: 12 jumpers (@ 100 kg), two jumpmasters, a four man crew and 1700 kg (850 kg +850 kg) of fuel. The CoG envelope of the NH90 is omitted from the graphs for classification reasons

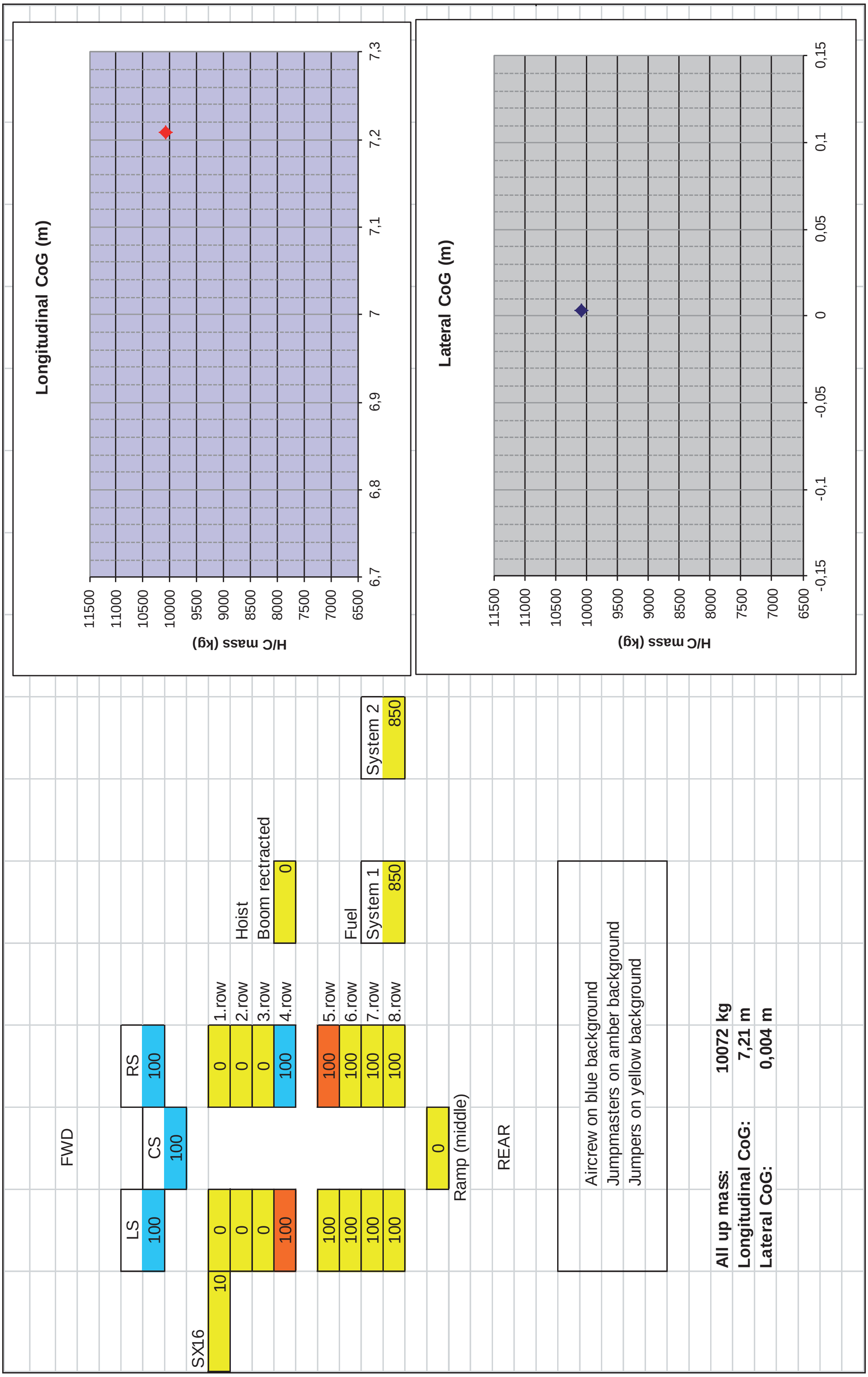

Figure 39. Aft CoG limiting: the first three cabin seat rows (six seats) are empty and the remaining seats occupied. The CoG envelope of the NH90 is omitted from the graphs for classification reasons

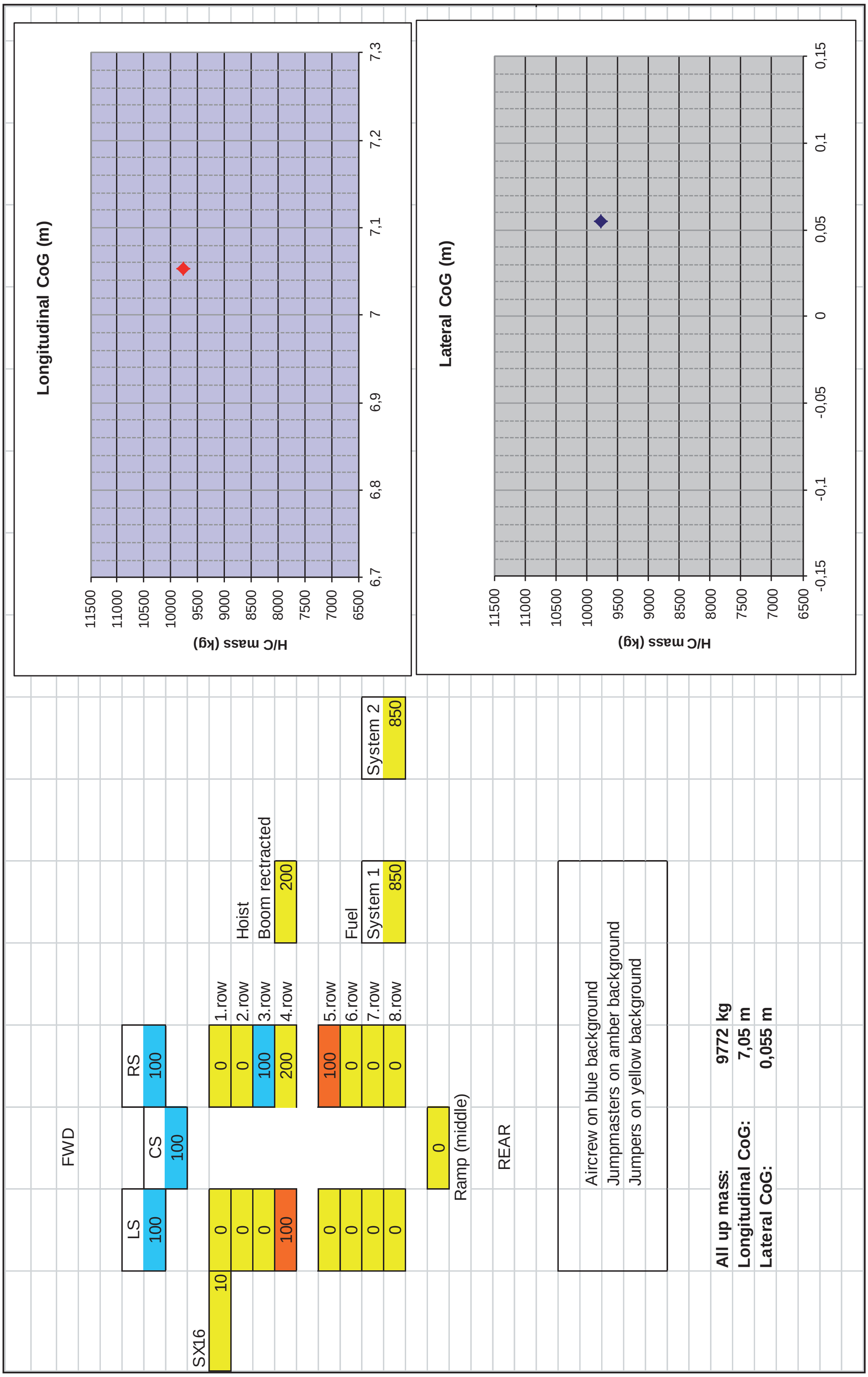

Figure 40. It is also allowed to have the last remaining four jumpers all at the right cabin door edge at the same time. At least one occupant has to sit on the left side of the cabin as a counterweight for lateral CoG

APPENDIX 9

MASTER TEST MATRIX

Table 14. Master test matrix as written in the test plan[29]. The tests #5, #6, #9 and #10 (drops with anchor line in the cabin ceiling) were eventually not done as unsafe with the T-10 static lines

#	Test item	H/C Configuration & cargo	Flight conditions	Altitude (AGL)	Cabin test personnel	# of drops	Pass criteria
1	Occupants' actions: *before and during take off *before exit & during exit *in case of forced landing *in case of emergency jump * in case of chute opening in cabin * Check draft "YT-ohje"	Anchor line on ceiling and on floor. 8 LH + 7 RH seat conf. in the cabin.	Ground test	Ground test	* LM * JM * up to 12 parachutists fully geared up	NA	The positioning and transitions shall be such that: * the JM & LM can control the situation at all times. * There is no inherent risk of accidental chute opening in cabin in flight * H/C's CoG limits are not violated
2	An "empty" static line's behaviour (one and four lines) in slipstream, including pulling it in	* LG UP * Anchor line: 1. on floor. 2. on ceiling At least one T-10 static line with total length of 5.3 m.	* @ 40, 50, 60, 70, 80 KIAS * sideslip -1, 0, +1 ball at each speed	300 ft	*LM * JM * video	NA	SL with either anchor line position: *No objectionable sporadic behaviour * No objectionable contact with H/C structure * No snagging of the SL while pulling in by the JM
3	Dropping dummies with anchor line on the floor one dummy per jump run	* LG UP *FDF anchor line on the floor * 4 dummies with T-10 type parachutes / load	* 40, 60, 70, 80 KIAS Notes: * 2 dummies from each airspeed * only one dummy connected to the anchor line at the time. * Parachutes for test crew	3000ft	* LM * JM1 * JM2 * video	8	*Safe separation of the dummies *No objectionable behaviour of the static line(s) (esp. up swing towards MR) * No objectionable contact with H/C structure * No snagging of the SL while pulling in by the JM * No objectionable behaviour of the anchor line
4	Dropping dummies with anchor line on the floor four dummies per jump run	* LG UP *FDF anchor line on the floor * 4 dummies with T-10 type parachutes / load	* 60, 80 KIAS (TBC by expecience) Notes: * all four dummies dropped on one jump run	1500ft	* LM * JM1 * JM2 * video	8	As above
Items #5 and #6 are only be done if the clearance with the SL and the MR is estimated to be adequate based on tests #3 and #4							
5	Dropping dummies with anchor line on the ceiling one dummy per jump run	* LG UP *Standard NHI anchor line on the ceiling * 4 dummies with T-10 type parachutes / load	* 40, 50, 60 KIAS Notes: * At least 2 dummies from each airspeed Note: only one dummy connected to the anchor line at the time. * Parachutes for test crew	≥ 3000ft	* LM (safety harness + parachute) * JM1 * JM2 * video	8	As above
6	Dropping dummies anchor line on the ceiling four dummies per jump run	* LG UP *Standard NHI anchor line on the ceiling	* 50, 60 KIAS (TBC by expecience) Note: all four dummies dropped	1500 ft	* LM (safety harness + para-	8	As above

		* 4 dummies with T-10 type parachutes / load	on one jump run		chute) * JM1 * JM2 * video		
Select 2 3 most suitable airspeeds for dropping jumpers. Decide on how to proceed with ceiling mounted anchor line – margin to MR.							
7	Dropping parachutists with anchor line on the floor exit position sitting on the cabin door edge one jumper per jump run, different speed for each	* LG UP *FDF anchor line on the floor *4–12 parachutists per load	50, 60, 70, 80 KIAS (based on previous tests) Only those jumpers connected to the anchor line who are about to jump on that run	1500 ft AGL	* LM * JM1 * JM2 * video *at least 4 jumpers	4	*Safe separation of the jumpers *No objectionable behaviour of the SL (esp. up swing towards MR) * No objectionable contact with H/C structure * No snagging of the SL while pulling in by the JM * No objectionable behaviour of the anchor line
8	Dropping parachutists with anchor line on the floor exit position standing on the cabin door edge 2 – 4 jumpers per run. Interval TBD by jumpmaster	* LG UP *FDF anchor line on the floor *4 – 12 para-chutists per load	60 – 80 KIAS (2 – 3 airspeeds based on previous tests) Only those jumpers connected to the anchor line who are about to jump on that run	1500 ft AGL	* LM * JM1 * JM2 * video * 12 jumpers	20	As above
# 9 and #10 – IF CONSIDERED SAFE AFTER DUMMY DROPS:							
9	Dropping parachutists with anchor line on the ceiling exit position sitting on the cabin door edge one jumper per jump run, 4 jumpers	* LG UP *Standard NHI anchor line on the ceiling *4–12 para-chutists per load	40 – 60 KIAS (2 – 3 based on previous tests) Only those jumpers connected to the anchor line who are about to jump on that run	1500ft AGL	* LM * JM1 * JM2 * video * 12 jumpers	4	As above
10	Dropping parachutists with anchor line on the ceiling exit position standing on the cabin door edge/step 2 – 4 jumpers per run. Interval TBD by jumpmaster	* LG UP *Standard NHI anchor line on the ceiling *4–12 para-chutists per load	40 – 60 KIAS (2 – 3 airspeeds based on previous tests) Only those jumpers connected to the anchor line who are about to jump on that run	1500 ft AGL	* LM * JM1 * JM2 * video * 12 jumpers	20	As above

APPENDIX 10

HAZARD LEVEL DETERMINATION

The risk analysis was done in accordance with the "hazard level determination" method originating from the United States Naval Air Systems Command [27]. The hazard levels were rated for severity and probability in accordance with the guidelines identified in Table 15.

Table 15. Test hazard levels

Mishap Probability		Hazard Severity	
A Frequent:	likely to occur immediately or within a short period of time.	**I Catastrophic:**	may cause death or aircraft loss.
B Probable:	probably will occur in time.	**II Critical:**	may cause severe injury or major aircraft damage.
C Occasional:	may occur in time.	**III Marginal:**	may cause minor injury or minor aircraft damage.
D Remote:	unlikely to occur	**IV Negligible:**	will not result in injury or aircraft damage.

Applying the above guidelines to each test event provided the basis for making a risk assessment for each test event defined in the test matrix. Individual element risk categories were assigned using the residual risk matrix specified in Table 16.

Table 16. Residual risk matrix

Mishap Probability	Hazard Severity			
	I Catastrophic	II Critical	III Marginal	IV Negligible
A Frequent	UA	UA	Risk Category C	Risk Category B
B Probable	UA	Risk Category C	Risk Category C	Risk Category A
C Occasional	Note 1	Risk Category C	Risk Category B	Risk Category A
D Remote	Note 2	Note 2	Risk Category A	Risk Category A

Notes: (1) The determination of a test project whose residual risk assessment falls under I/C will require up front discussions with TCT (Test Coordination Team) prior to proceeding with the test program development.

(2) Assignment of Risk Category where residual risk falls under I/D or II/D will require up front discussions with the TCT to determine whether Risk Category A or B is applicable.

UA Unacceptable risk, project residual risk too high to proceed.

Risk Category C - Test or activities which present a significant risk to personnel, equipment or property, even after all precautionary/corrective actions are taken.

Risk Category B Test or activities which present a greater risk to personnel, equipment or property than normal operations.

Risk Category A Test or activities which present no greater risk than normal operations.

HAZARD ANALYSIS SUMMARY

The most significant hazards identified by the test team are summarized as follows:

Damage to H/C due to contact with static line or jumper after exit

Cause & effect: SL dynamics, damage to several possible items

Precautionary Measures: Risk to be minimised by starting at a low airspeed (40 KIAS) and assessing the risk with increased airspeed. In case the POS light or other part disintegrates, abort mission and investigate damages. When pulling in the SLs by the JM, the LM shall be monitoring possible contact with fuselage. The right side search light under the sponson shall be retracted during parachuting.

Residual hazard level: C/III = Risk category B

Damage to composite structure due to D-bag contact after exit

Cause & effect: SL dynamics, up-swing against the fuselage. The inherent risk is considered low as there are no heavy (=metal) objects in that part of the static line or deployment bag that is hung outside the fuselage. Thus the impact pressure on any part of the fuselage is probably small even though the impact speed after up-swing could be high

Precautionary Measures: The use of low airspeeds on the first drops and increasing the airspeed with small steps, continuously monitoring the SL behaviour from inside the cabin and from the chase H/C.

Residual hazard level: C/III = category B

Damage to composite cabin floor due to snap hook contact after exit

Cause & effect: SL dynamics, probable damage to unprotected standard cabin floor with floor mounted anchor line.

Precautionary Measures: As the risk of damage is high due to normal snap hook behaviour (slamming against the floor as the SL tightens), the Patria floor protection panels must be used with the floor mounted anchor line. After this, the risk is very improbable.

Residual hazard level: D/IV = risk category A

Parachutist or dummy entanglement to the SL after exit (a "hang fire")

Cause & effect: Exit in a rolling movement or a packing error. Parachute fails to open, jumper does not separate from the SL.

Precautionary Measures: A knife to cut the SL shall be immediately available to JM and LM. The knife shall be immediately taken for readiness to cut the SL if circumstances so mandate to save the H/C. Communication between the JM and the tangled jumper – it has to be reminded prior test to all jumpers that opening the reserve parachute is absolutely forbidden when tangled to SL! (a standard parachuting procedure). Jumpmaster is to instruct the crew to go for a careful landing, after the situation is stable. If the reserve parachute opens, the SL must be cut immediately (a standard parachuting procedure). The additional static lines have to be pulled into the cabin before entering hover.

Residual hazard level: D/III = Risk category A

Accidental opening of a parachute inside the cabin

Cause & effect: Careless movement in the cabin -> handle extracted and canopy opens. In the worst case the canopy slips out of the door taking the jumper and a considerable part of the fuselage with it. This is a very dangerous situation if let to happen.

Precautionary Measures: The risk is minimised by using experienced parachutists for test jumps and by briefing the procedure on how to move inside the cabin ("protect handles, move slowly, if you get stuck: inform JM etc). It is also briefed (normal parachuting procedure) that in case an opened chute is noticed, the closest person takes control of the chute, immediately warns others and the closest one to the door closes it. After that, no door opening is allowed before landing.

Residual hazard level: D/II = Risk category B

Contact of static line with main rotor

Cause & effect: This risk potentially exists with ceiling attachment of the static lines. If gotten stuck to the MR and if the SL or the snap hook would not fail, the anchor could be torn out from the cabin towards the MR. As such this would probably not be catastrophic, but if the anchor line would pull put other SLs and canopies, that could potentially end up in a loss of aircraft control and lives.

Precautionary Measures: With the first jumps using either attachment, the first drops are made with only with the floor mounted anchor line and only one static line in the anchor at any time. This minimises the damages should the SL tangle with MR. During the first drops from ceiling cable (if declared safe by the previous tests), only one SL attached to the cable at the time -> less risk in case SL gets stuck to the MR. Emergency rescue parachutes for all occupants on board to minimise the risks for personnel. Emergency escape to be practiced before flights.

Residual hazard level: D/II = Risk category B

SL/deployment bag entaglement during retraction after jump

Cause & effect: Although no obvious risk has been identified, it is possible that the static line's deployment bag would get tangled before or during retraction. This risk is considered realistic if the static line stabilises below the sponson

Precautionary Measures: An investigation was made with an NH90 on jacks, whether there were clear points for entanglement. When the landing gear was retracted, the only potential obstructions were the fuel system vent scoop and a thin engine start fuel vent line coming from the upper deck. No potential mechanism for the static line to jam the landing gear was seen.

As precautions: the landing gear has to be retracted when dropping jumpers, the static lines' behaviour in slipstream will be checked during test item #2, before actual jumps, the LM shall monitor the static line behaviour when being retracted by the JM, near the landing site, a set of tyres shall be ready in case the LG extension still fails for some unknown reason. In case the static line anyway gets tangled after a jump, the JM shall try to remove it with all suitable means. Communication with LM is essential. If the static line cannot be retracted, all other lines shall be retracted and the LG extended for landing. The JM shall control the static line(s) until on the ground

Residual hazard level: B/IV = Risk category A

SUMMARY: The biggest risks in the analysis above belong to the risk category B, which is thus the overall test risk category. The risk category B means that the planned tests cause an increased risk which is higher than in normal service. The tests do not cause a considerable risk to materiel or personnel when all the mitigation actions are implemented.

APPENDIX 11

STATIC LINE UP-SWING WITH AIRSPEED

Although the risks related to the static line up-swing after jumper separation were eliminated using the floor attached anchor, a limited comparison of the analysis and results was made as interesting and for future reference. The NHI's analysis of the static line's dynamic behaviour in slipstream is visualised in Figure 10. The analysis has been made using a general aeromechanical simulation code named GENSIM [10].

Airspeeds of 50, 60 and 80 knots were selected for comparison as representative values of the tested airspeed envelope. The jumps were filmed from a chase helicopter located slightly aft of the test helicopter with a 50–100 meter separation. This created some parallax error which was taken into account by the error margins.

Only the "Start" and "Trim" positions of the static line were taken into consideration, as with the floor attachment the sponson prevented the static lines rising above H/C bottom surface level. Thus the comparison concerning the "Max" case would have been erroneous and meaningless.

Even when comparing the "Start" and "Trim" cases, some error may have been be caused by the different setups for the analysis and the tests. In the analysis, the static lines were mounted on the ceiling, whereas in the tests they were mounted on the floor. Based on the author's experience on the flow dynamics around helicopter fuselages, this error was probably insignificant for the "Start" case and small/moderate for the "Trim" case. The only major variable (for a non-sideslip condition) was the downwash of the main rotor, and in forward flight case the downwash would be directed almost horizontally backwards, with a small deviation downwards. However, in hover or at low speeds this would not be the case. The precise effect of the main rotor downwash for the results of this comparison was left open within the scope of the study.

The Figure 41 shows the calculated static line position at the time of the parachutist separation (Start) and Figure 43 the stabilised or trim position of the static line after the jumper has separated and the static line's up-swing ended (Trim). The Figure 42 and Figure 44 show the respective flight test results. The jumper separation point is here defined as the moment when the parachute suspension lines are deployed and the canopy fabric is just starting to extract from the D-bag. In this case the airstream is not yet significantly deflecting the static line-D-bag-parachute –combination backwards.

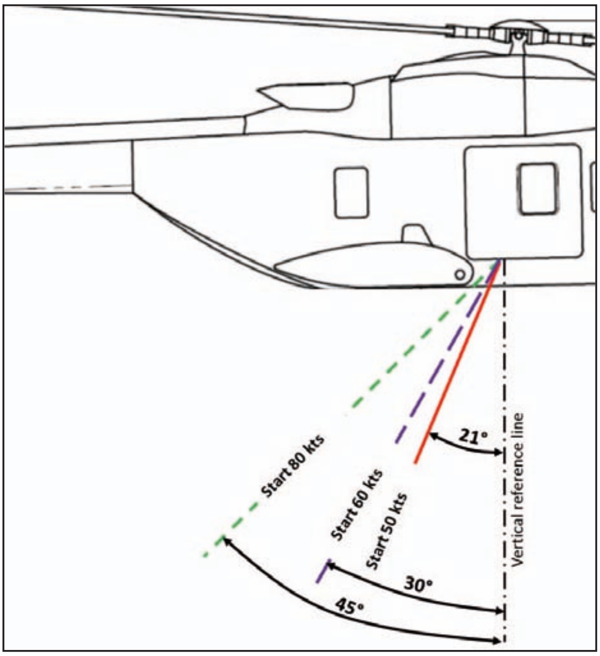

Figure 41. Calculated static line deviation angles at the moment of the parachutist separation (with floor mounted static lines), based on NHI's analysis [10]. Angles for 60 and 80 knots have been measured directly from the Figure 10. The angle for 50 knots was interpolated.

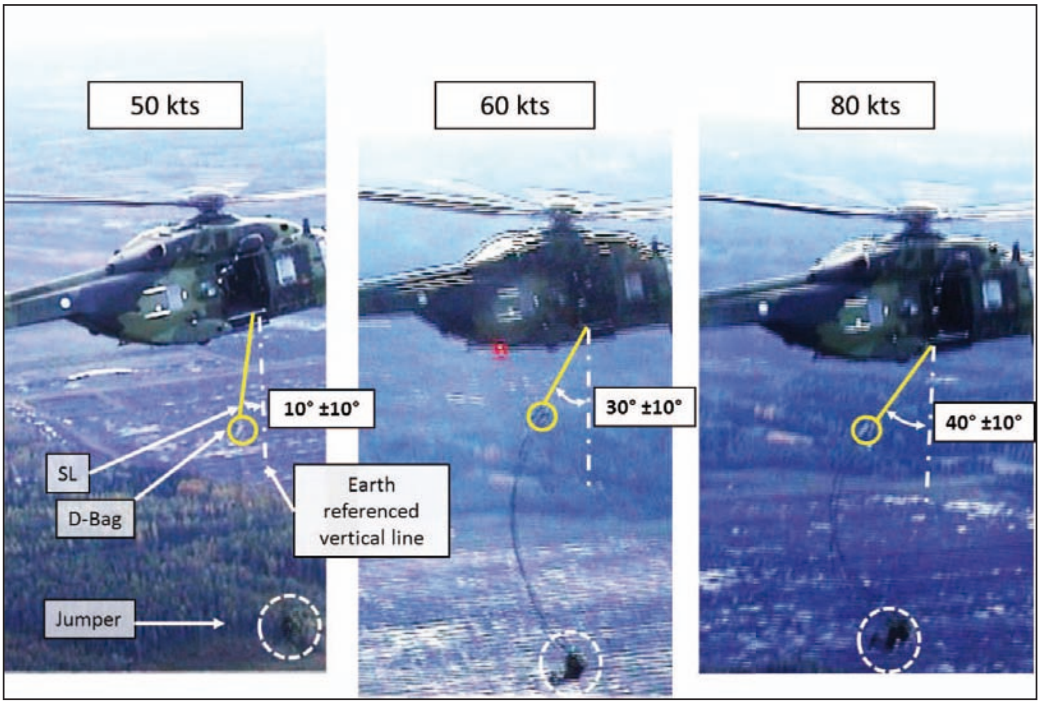

Figure 42. The measured static line deflection angles at the time of the parachutist separation for 50, 60 and 80 knots. All images are from test #4 "Paratrooper jumps". The 50 knots image is of test point #1, the 60 knots of test point #2 and the 80 knots of test point #12 (see Table 5 for details).

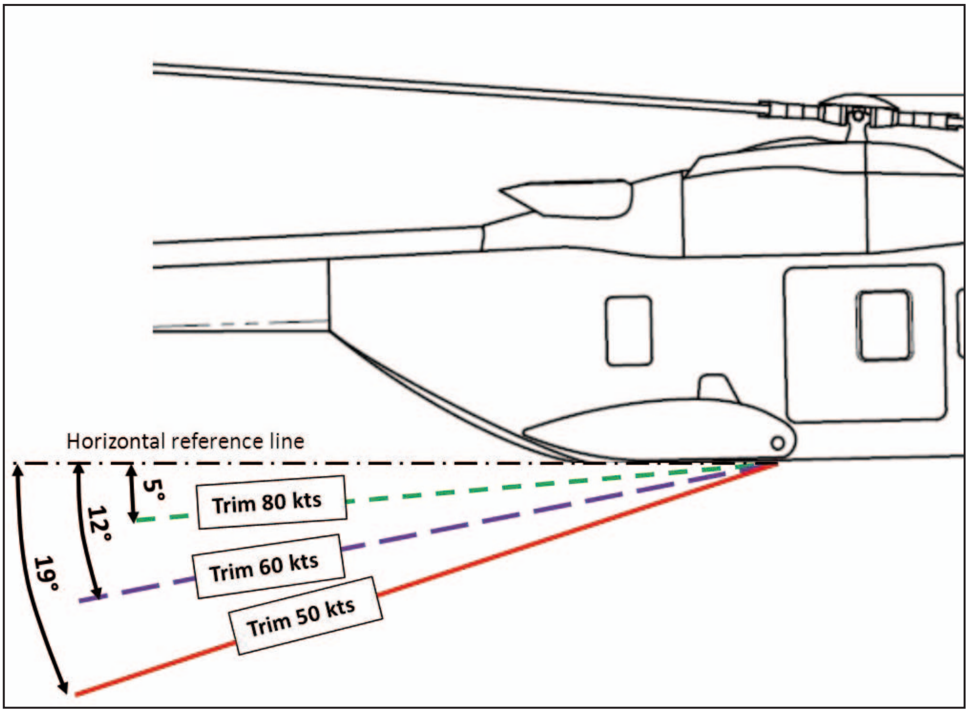

Figure 43. Calculated static line deviation angles in the ultimate or trim position (for floor mounted static lines), based on NHI's analysis [10]. Angles for 60 and 80 knots have been measured directly from the Figure 10. The angle for 50 knots was interpolated.

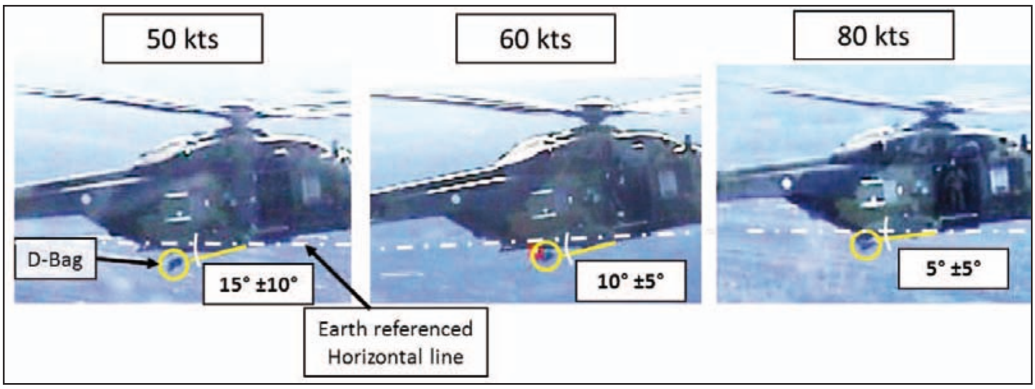

Figure 44. The measured static line deflection angles in the trim case for 50, 60 and 80 knots. All images are from test #4 "Paratrooper jumps". The 50 knots image is of test point #1, the 60 knots of test point #2 and the 80 knots of test point #12 (see Table 5 for details).

In Figure 42 and in Figure 44 the static line deflection angles were measured against the geometrical vertical and horizontal (Earth coordinates), as the ambient airflow affecting the static line was horizontal. The use of Earth referenced coordinates also helped to overcome the fact that the helicopter's longitudinal pitch angle in trimmed flight conditions varied with airspeed up to 6° in the tested regime. Therefore the helicopter's fuselage would not have been a solid and good reference for static line deviation measurements. The Earth referenced horizontal and vertical were defined from the real horizon visible on the video footage.

When the calculated and the flight test results for 50–80 knots were compared, there seemed to be a surprisingly good correlation. All the calculated deflection angles fit inside the test results, considering the error margins. The error margins were rather large (up to ±10°) due to the parallax error caused by the chase H/C position, the sensitivity of the "Start" angle for the parachute deployment phase and the fluttering of the D-bag in the "Trim". In spite of the error margins the comparison was clearly indicative. The ±10 ° accuracy in defining the static line's positions in this kind of an extremely complex scenario seemed sufficient with a sound engineering judgment. Despite the good correlation at 50–80 knots, the calculations could not predict all the details of the static lines dynamics. Such examples were the trim position high amplitude rotation at 40 knots, the flutter in trim position at all airspeeds, the effect of side slip and the effect of the D-bag's longitudinal position along the fuselage (see Chapter 4.2.2).

The most interesting calculated case, the maximum position of the static line during its dynamic up-swing could not be assessed in flight. However, the good correlation of the GENSIM calculation and the flight test results indicated, that the method and assumptions made in the NHI's analysis [10] could be used to model a similar new case with a reasonable confidence, at least for the airspeed range of 50–80 knots. A full substantiation for this claim cannot be achieved until the simulation is done with the same setup (floor mounted anchor etc.) as what was used in these flight tests.

ISSN 1796–4059
ISBN 978–951–25–2504–1 (print)
ISBN 978–951–25–2505–8 (PDF)

National Defence University
Department of Military Technology
P.O. Box 7
00861 Helsinki
Suomi Finland

www.mpkk/mil.fi