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A CONCEPT FOR INFLIGHT CREW RESCUE

FROM DISABLED COMBAT HELICOPTERS

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1. ABSTRACT

No rescue system exists for helicopters which offers a chance of successful escape and survival comparable to the ejection seat of a fighter aircraft. There are several reasons why the development of a special rescue system for helicopters has not been undertaken for a long time.

This paper reviews the activities at the DFVLR Research Center in Braunschweig in the field of inflight rescue from combat/attack helicopters in case of emergency in the last years. The solution which has been selected consists in separating the rotor blades and extracting the crew members upwards by means of individual rescue systems.

For this purpose theoretical investigations and tests have been carried out using a new method to sever the rotor blades by means of a pyrotechnic bolt extraction system (PBAS) and in addition successful work has been done on designing and testing an individual rescue system (IRIS) based on the principle of the well-known YANKEE-system.

Both aspects - rotor blade severance and pilot extraction - have been tested simultaneously in a helicopter ground test facility (SARAH). The test results have been compared with theoretical outcomes.

The configuration of the rescue system and its components are outlined here and some aspects of the behavior of the separated rotor blades are discussed in detail.

The test series which DFVLR has been carried out show that there are no great difficulties to be overcome in the development and installation of rescue systems and its integration into different types of helicopter.

2. INTRODUCTION

First, autorotation was thought to be a universal possibility of rescue for most emergency cases. However statistics have shown (1,2) that autorotation can only be applied in about 30% of emergency cases, since certain preconditions have to be fulfilled, such as an intact rotor, intact control and sufficient height and visibility. A number of accidents even occur after a successfully executed autorotation when landing on uneven ground, as a result of the helicopter tilting over.

When rescue measures were eventually considered, the existence of the rotor was the great obstacle which prohibited the simple application of the approved ejection seats. A further handicap proved to be the additional weight of the rescue system reducing the payload, an already critical factor for a helicopter.

Studies carried out by the DFVLR (5) have shown that a practicable rescue system for helicopters with a wide range of performance requires the separation of the rotor blades and an upward extraction with a YANKEE-like system.

As a first step the DFVLR has developed in various ground test series a concept that requires the development of methods and testing of components for

- severance of helicopter rotor blades, and
- upward extraction of the crew members.

PBAS - Pyrotechnisches Bolzen-Auszieh-System (Pyrotechnical Bolt Extraction System)

IRIS - Integriertes Rettungs-Inflight-System (Integrated Rescue Inflight System)

SARAH - Stationäre Anlage zur Rotorblatt-Abtrennung bei Hubschraubern (Stationary Test Facility for Rotor Blade Severance from Helicopter)

3. TEST SET-UP

The basis of the ground test station SARAH is a tethered Alouette II helicopter powered by a 300 kW turbo engine (Fig.1).

The three-blade rotor has a diameter of 10.2 m. The rotor tip speed is 186 m/s for a nominal speed of rotation of 345 RPM. The rotor blade (profile NACA 0012), with a mass of 28.3 kg, consists of an aluminum cross-beam and of aluminum sheet metal filled with moltoprene foam. Each blade is fastened with two conical bolts to the blade connection beam. Collective pitch control is available. The whole rig is remotely controlled by wire at a distance of 100 m from the test shelter.

The rotor head was modified to permit an accurate blade severance in a predetermined direction. This was necessitated by certain conditions at the test field.

4. MEASURES FOR ROTOR BLADE REMOVAL

Tests for rotor blade severance have been carried out using two different methods.

4.1 Pyrotechnical Cutting System (PCS)

This method will cut the metal fitting of the rotor blade with the aid of a Blade Severance Assembly (BSA) developed by Teledyne McCormick Selph (8,3). The PCS is activated by an electrical detonator. This detonator immediately fires the Flexible Confined Detonating Cord (FCDC) and activates the Cam Thruster, which extends and locks the cam head into the rotation plane of the Firing Pin Assembly (FPA).

The cam depresses the plunger of the Firing Pin Assembly by means of which a detonator fires the FCDC lines which carry the detonation signal to the BSA on the clevices of the rotor blades. For financial reasons we have carried out only one test at 345 RPM. This is the nominal speed of rotation.

4.2 Pyrotechnical Bolt Extraction System (PBAS)

This system has been developed by DFVLR. Here the two bolts connecting each rotor blade with its blade connection beam are extracted pyrotechnically. Essentially the device consists of a bar or bridge which connects the two bolts, and a piston which presses the bar, together with the bolts, out of the fittings with the aid of a pyrotechnical charge (4,7). The initiation of the system is executed electrically. This is useful because many tests were planned and for this reason it is much cheaper than a pyrotechnical control. A pure pyrotechnical control combined with detonating cords and a contactless switch from the stationary plane to the rotation plane is under development.

In a series of 10 tests the rotor blade severance in connection with the PBA system has been investigated and analysed. In these tests the rotation speed of the rotor has been increased from 170 RPM (corresponding to a centrifugal load of 25 kN for each rotor blade) to 345 RPM (100 kN centrifugal load per rotor blade). The pitch angle of the blades has been changed by the collective pitch control from zero to maximum lift force (10 kN for each rotor blade at 345 RPM).

5. RESCUE SYSTEM

The starting-point for the development of an appropriate rescue system for attack helicopters was the well-known YANKEE-734 system. By virtue of the manner in which it functions its low total weight and its compact design this system is, in conjunction with rotor blade severance, suitable for inflight rescue from helicopter unlike the traditional ejection seat.

However tests have shown (6) that essential improvements in its performance are necessary before applying the system to helicopters.

As a result DFVLR has evaluated and improved this system and called it IRIS (Integrated Rescue Inflight System). Like the YANKEE-System it consists of the following components:

- o Catapult system (Stanley Aviation),
- o Rocket (Talley Industries),
- o Pendant line (Edelmann & Ridder),
- o Combined harness/seat harness (DFVLR), and
- o Parachute System (DFVLR).

The main changes and the investigations that have been carried out can be summarized as follows:

- o Seat/torso harness design, release, and pendant line link,
- o Optimization of pendant line,
- o Positioning and functioning of the parachute system incl. packing change,
- o Construction of the main parachute canopy, and
- o Release and clear of a/c.

To evaluate the performance of the rescue system with regard to human tolerances like acceleration etc., a dummy was instrumented with sensors and telemetry. In the present configuration the following data are measured:

- Force/time histories for the pendant line and for the risers during parachute deployment and filling phase,

- Rocket acceleration,

- Acceleration in the three body axis directions, and

- Angular rates about three axes.

Additionally the following data have been plotted:

- Force/time history of the catapult reaction force,

- Velocity of the unignited launched rocket shortly after leaving the catapult, and

- Flight path recording by means of cinetheodolite.

The performance investigations of the extraction system was started with tests under zero/zero conditions.

6. TEST RESULTS AND DISCUSSION

Fig. 2 shows the results and measurements comparing the flight path of the model rotor blades and the original rotor blades of the Alouette helicopter with different rotor speeds.

It shows clearly that the motion of a rotor blade is composed of a translation movement of the center of gravity and of a rotation motion around the cg. In the process the rotor blade moves with the same angle velocity ω_{BL} as around the rotor axis with ω_{RO} before. As a result of the equations of motion the relation between x_s and α is constant for a given blade and independent of the mass and the rotation speed of this rotor blade. The influence of the aerodynamic forces is small shortly after the separation, because the centrifugal forces are ten times as large as the lifting forces.

Fig. 3 shows a comparison between the different methods of rotor blade separation prior to, during and after the test. Unlike the Teledyne System, the DFVLR-PBAS was controlled electrically during these tests for financial reasons but a control by detonating cords is planned for later.

Fig. 3 shows that during the ignition of the charges and the separation of the rotor blades the PCS entails a considerable risk to the turbo engine (inlets and the engine itself), the cockpit, the rescue system and the crew as a result of the dispersion of particles from the Blade Severance Assembly (BSA). Besides this the detonation bang itself seems to be a problem.

This is not the case with the PBAS. Here three masses are ejected simultaneously upwards and outwards (due to linear motion immediately after separation) without impeding the rescue procedure. The flight paths of the masses can be determined precisely. The pictures after the test clearly show once more the different methods of separation. For test purposes the PBAS can be used several times. Only the rotor blades have to be replaced. The only proviso for this method is that the rotor blade must be connected to the rotor head by means of bolts. What kind of material is used in the rotor blade and fittings (metal or a composite material like carbon fiber) is not important.

To demonstrate the feasibility and to validate the performance predictions of the IRIS rescue system a series of four o/o tests was conducted.

Fig. 4 shows such a o/o-test. To interpret test results correctly and to correlate the results with the theory the chronological sequence of the events which occur during extraction must be considered. For this purpose the ejection trajectory is divided into characteristic phases:

- Catapult phase with
  - acceleration phase,
  - freeflight phase, and
  - intermediate phase,
- Rocket phase,
- Free flight phase, and
- Parachute descent phase.

Here the opening of the main parachute can be initiated immediately by the force of the pilot chute (as seen in fig.4) or later on at rocket release.

A very important phase is the transition from the intermediate phase to the rocket phase and its optimization (9).

Fig. 5 shows the force history of the pendant line during these two phases (10). Besides the force due to the kinetic energy of the catapult phase, the increase in the force due to the rocket thrust is shown. The different point of time of rocket ignition leads to individual curves.

The following realistic assuptions have been made:

mass of the rocket	m_R = 9 kg
mass of the dummy	m_D = 114 kg
apparent mass	$\overline{m}$ = 8.341 kg
elasticity modulus	E = 80,000 to 215,000 N
damping factor	δ = 8 to 21.5 1/s
lenght of pendant	l = 3 m
launch velocity	v_o = 30 m/s
thrust of the rocket	F_R = 8,900 N

The figure shows that the force in the pendant is very high in the case of a preignition of the rocket (curve 2, about 500 g/s rate of onset for 35 ms).

If a later ignition point has been selected (at the maximum of curve 1) the maximum force is much lower (curve 4).

Now that the rotor blade severance and the rescue system have been discussed the whole concept will now be described briefly.

Fig. 6 describes the main events for in-flight rescue from a helicopter and Fig. 7 represents the sequence of optic actions from a high-speed camera. The complete sequence consists of three interconnected phases

- o Rotor blade removal
- o Seat harness release
- o Extraction of the dummy

Dummy clear of a/c takes place about half a second after rotor blade ignition.

7. CONCLUSION

The test series which the DFVLR has carried out in the field of rescue from disabled helicopters show that there are no great difficulties to be overcome in the development and installation of rescue systems.

The tests already conducted should be complemented by the following test series:

- o Expansion to flight test with a radio-controlled helicopter to investigate the behavior of the airframe after separation of the rotor blades,
- o Tests of the IRIS rescue system under extreme initial conditions to define the performance envelope, and
- o Accommodation of the rotor severance assembly to actual rotor heads.

With the development of a new method for separating the rotor blades - independent of the rotor blade material - and with the optimization of the YANKEE system and its further development into the IRIS system, the technical fundamentals are now available to design a fully efficient rescue system for particular types of helicopter.

8. REFERENCES

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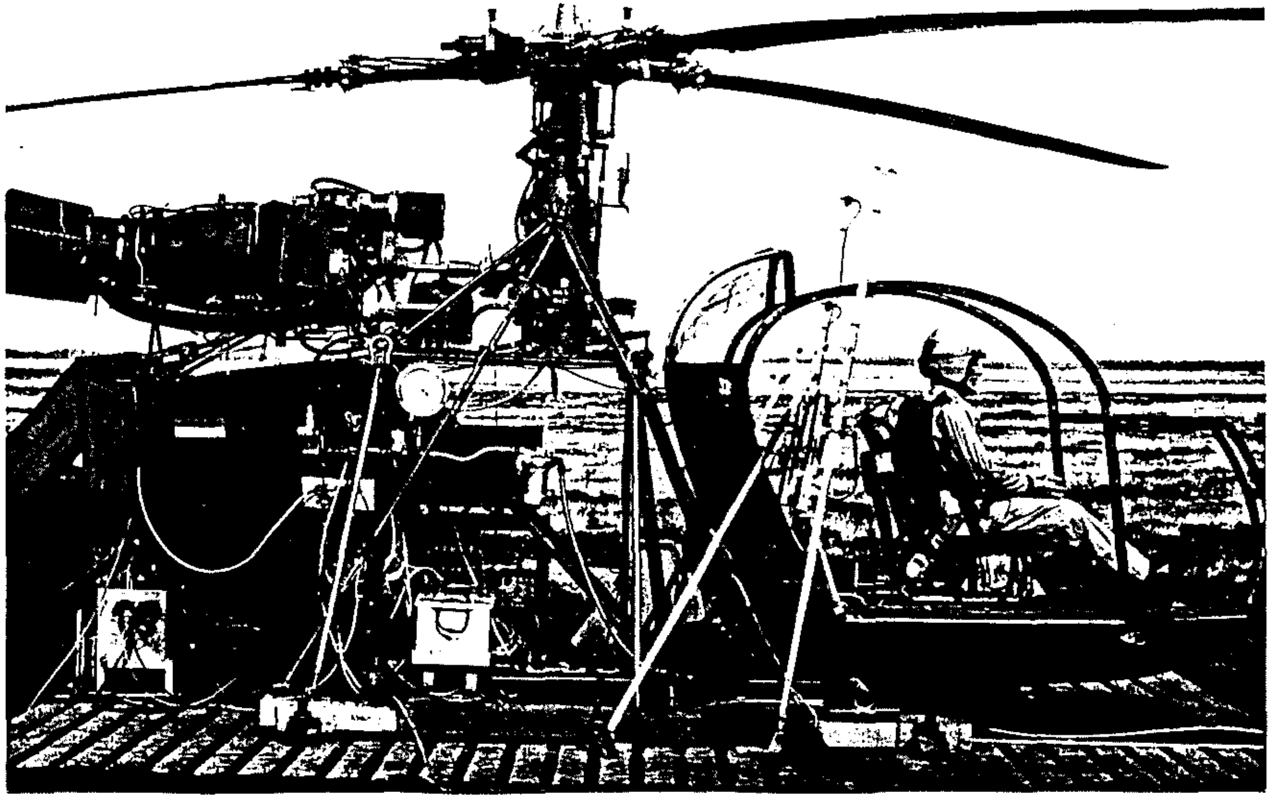
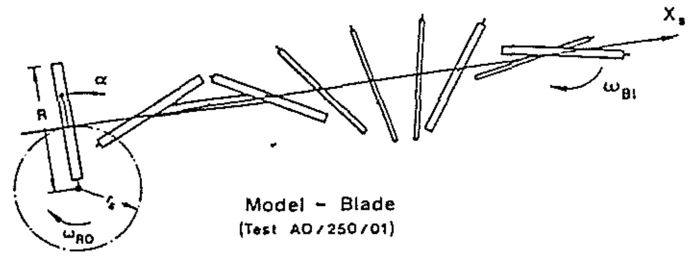


Figure 1. Stationary Test Facility (SARAH)



$$\alpha = \omega t = \frac{x_s}{r_s}$$

$$\omega_{Ro} = \omega_{Bl}$$

	Model	Alouette
R	0,825 m	5,10 m
r_s	0,405 m	2,70 m
ω_{Ro}	26 s^{-1}	36 s^{-1}
m	0,7 kg	28,3 kg

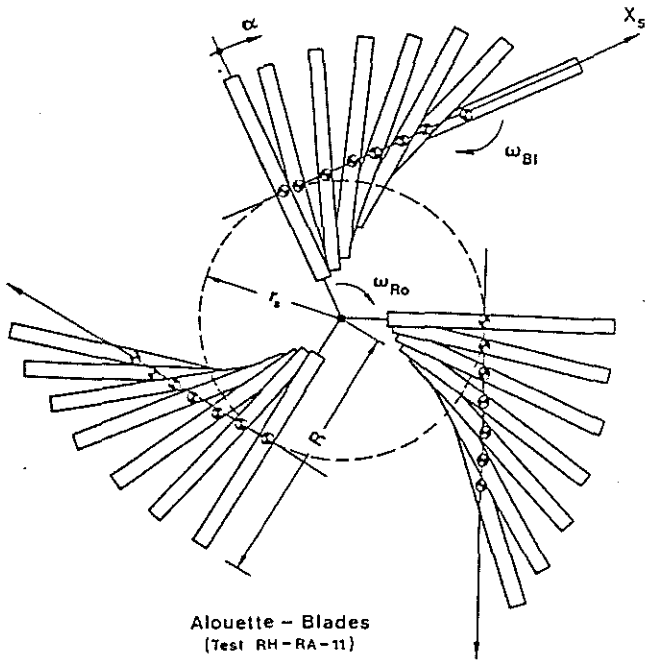


Figure 2. Rotor Blade Removal from Tethered Helicopter (Comparison Model Helicopter-Alouette Helicopter)

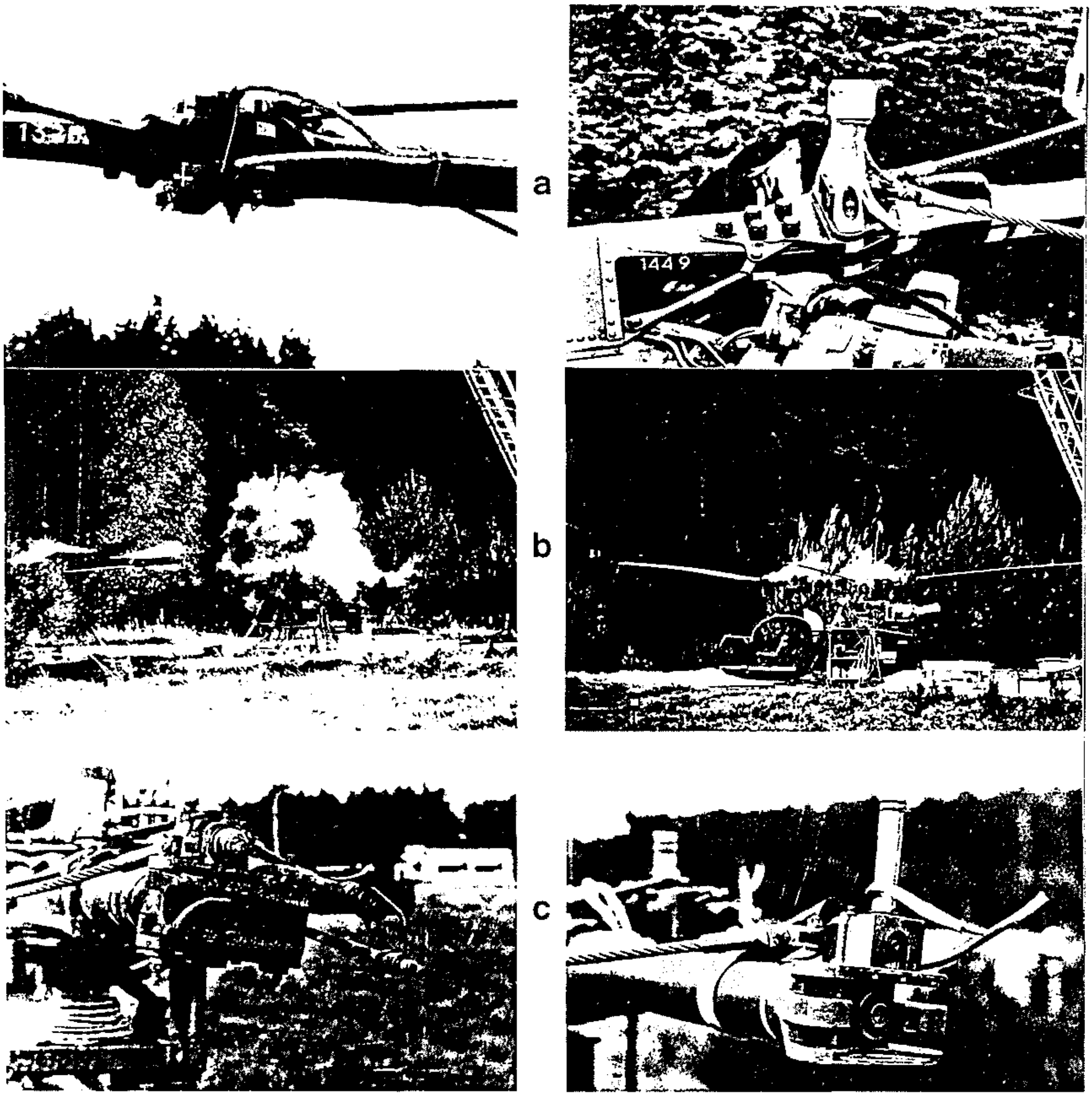


Figure 3. Rotor Blade Separation. Comparison Teledyne (left) - DFVLR.
a. prior to test, b. during test, c. after test

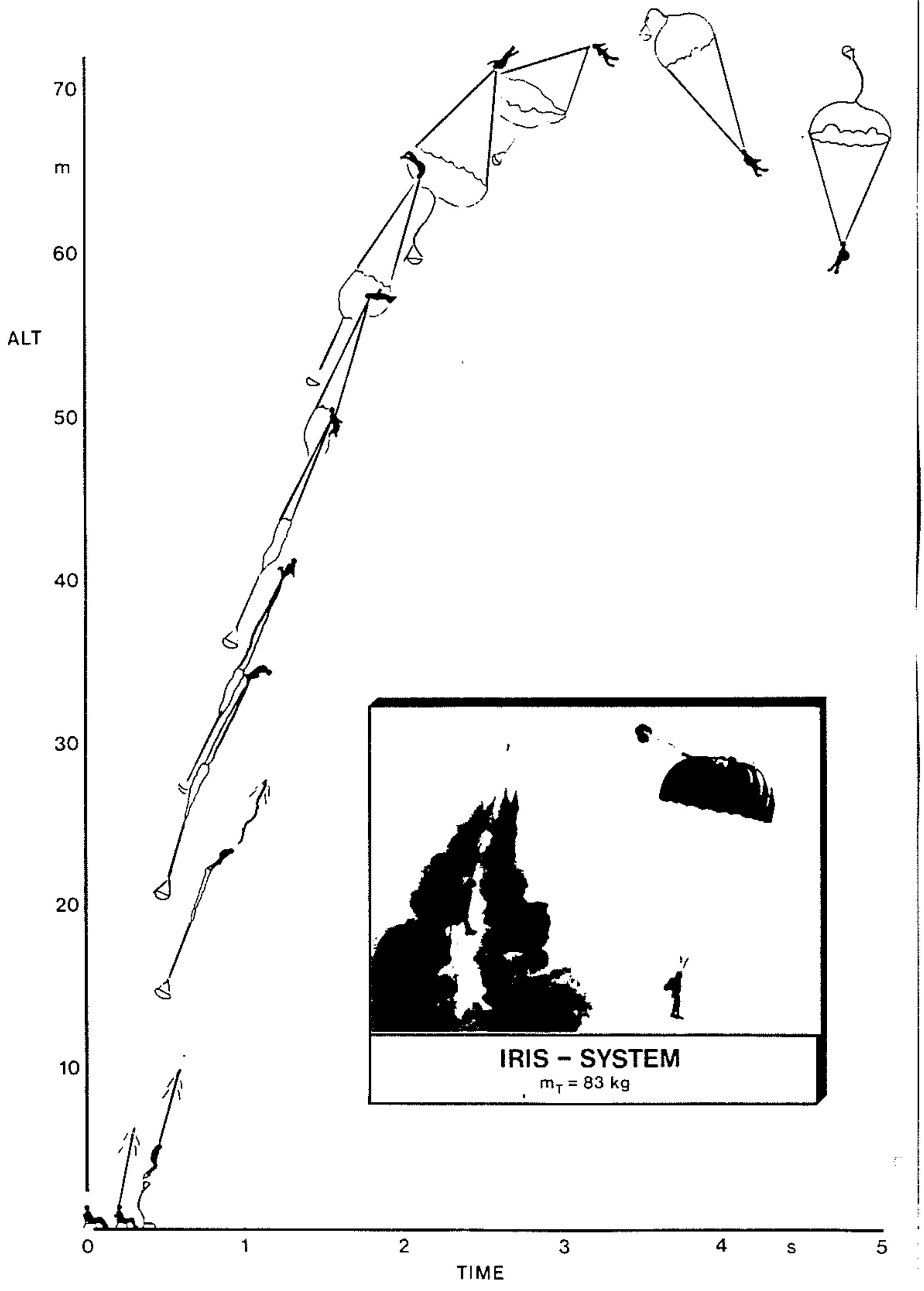


Figure 4. IRIS: Altitude vs. Time during o/o-Test

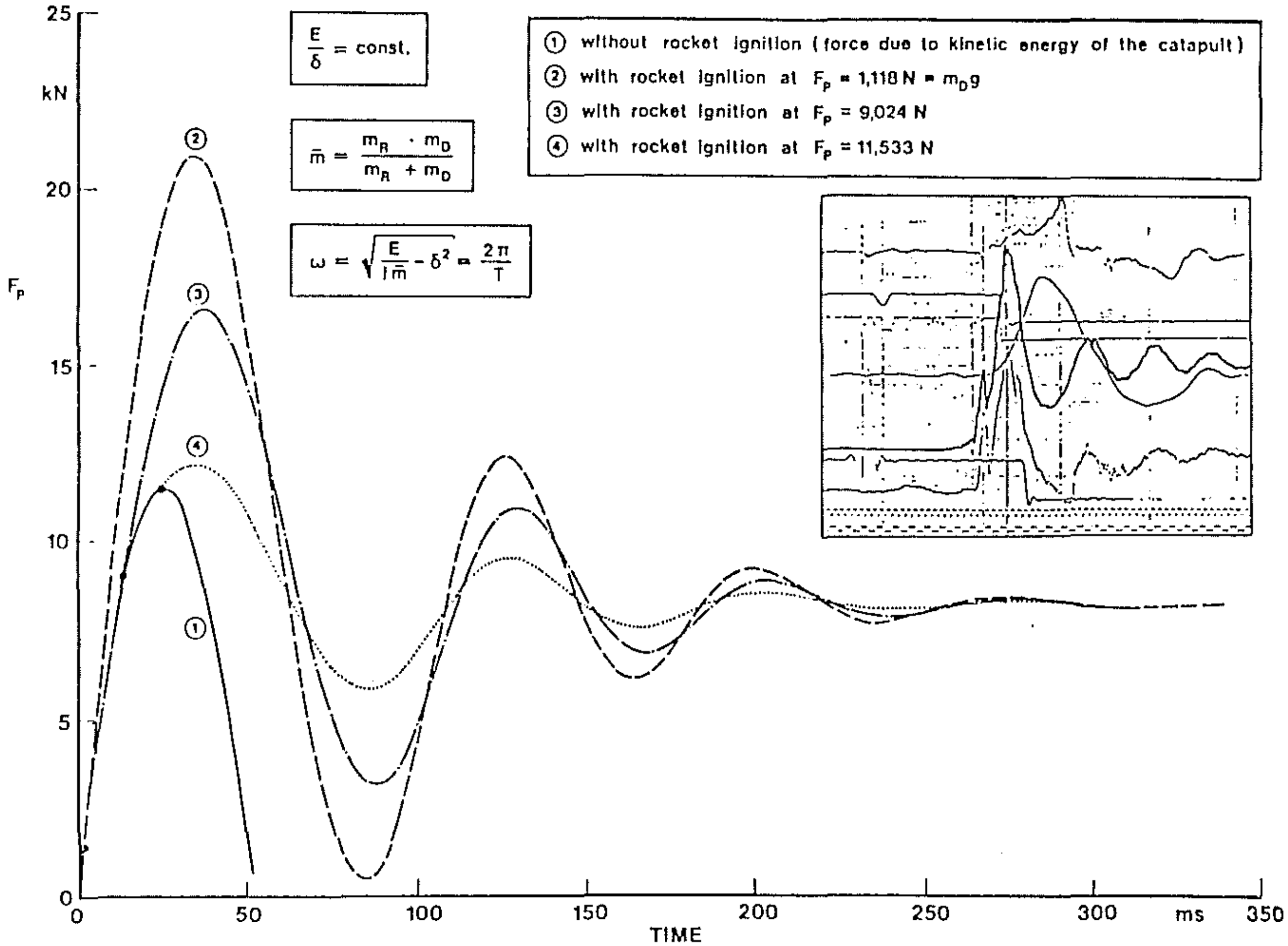


Figure 5. Force vs. Time for Pendant Line

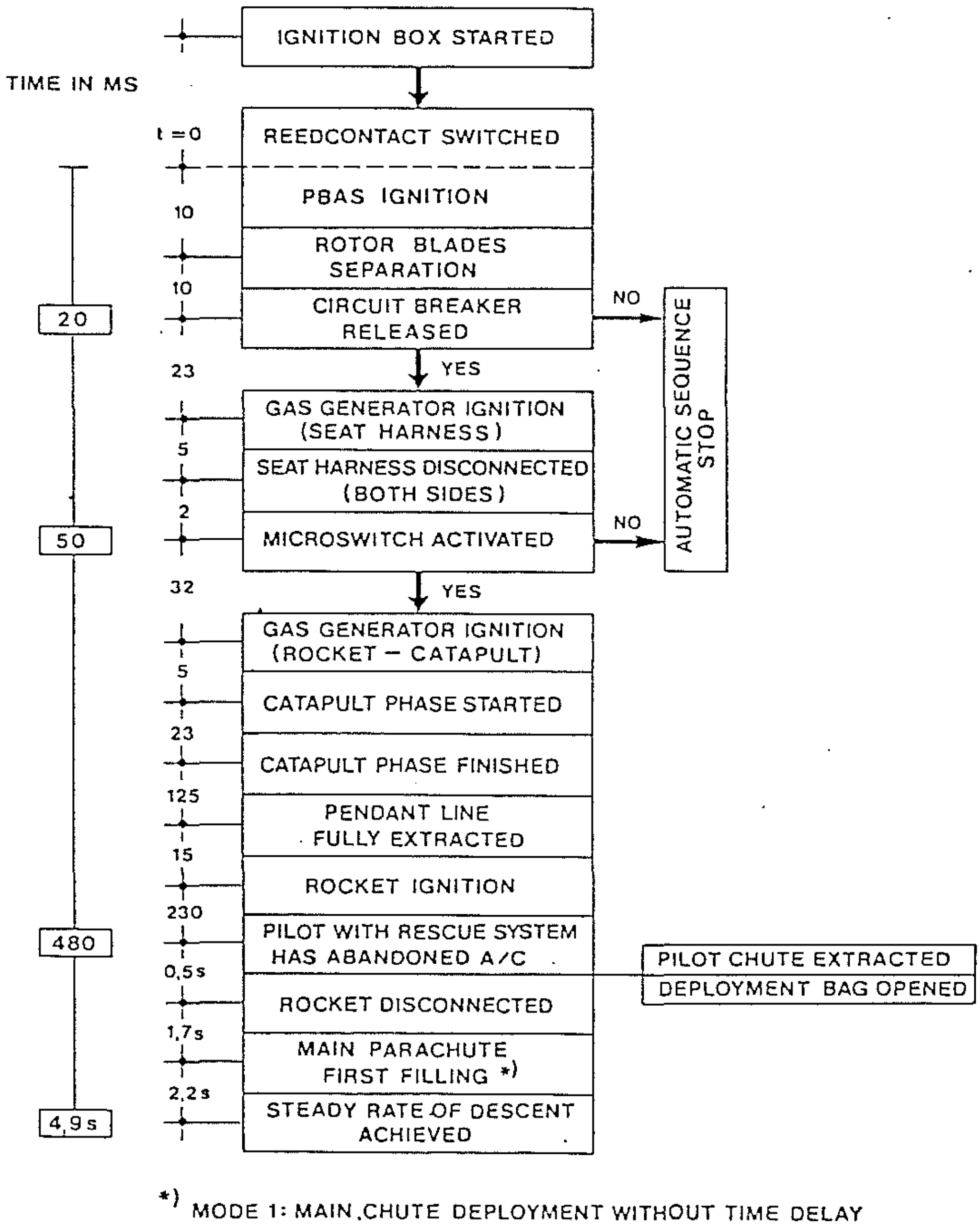


Figure 6. Main Events for In-Flight Rescue from Helicopte:

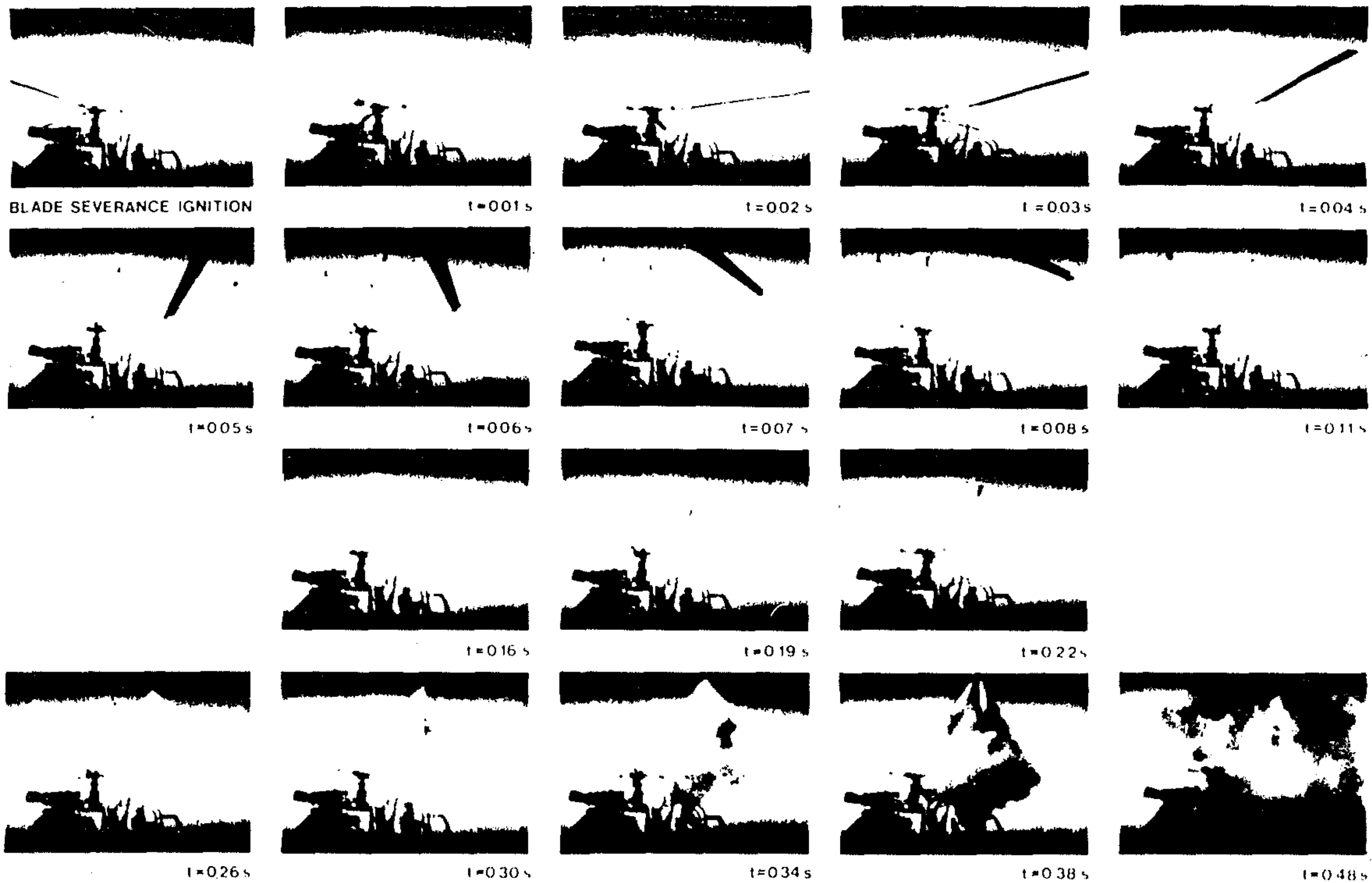


Figure 7. In-Flight Rescue from Helicopter (Groundtest)