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EH101 - THE OPTIMUM NAVAL HELICOPTER

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## 1. Introduction

Following conceptual studies for the UK and Italian Governments for a replacement Naval Helicopter the EH101 was found to also readily fulfil the market requirements for both civil and military use. Thus was born the "Integrated Development Programme" for the design, build and development of a single helicopter to satisfy the future needs of Naval, Civil and Utility customers.

It has been an interesting challenge to direct the design and development activities towards Qualification against the military requirement of Def Stan 00.970 from the UK, Mil Specs from the US and Italy and at the same time achieve Certification against BCAR's and FAR's.

The early configuration to achieve the specified naval requirements together with the experience of Westland and Agusta in design of aircraft for the shipborne application have led to the EH101 being the definitive medium size helicopter for use on both the small frigate and the large aircraft carrier type of ship. See Figure 1.

The features incorporated to provide this Naval capability also endow the aircraft with the facilities and performance parameters to operate from fixed or deep water floating rig platforms in a Civil capacity.

## 2. Air Vehicle Performance

The EH101 was configured to enable landings on small ships to be carried out in severe weather conditions, without traditional ship manoeuvring being involved. Specifically the need for the ship to routinely head into wind before recovery of the aircraft was to be minimised.

Two parameters are paramount in achieving the broadest 'Ship Helicopter Operating Limits', namely vertical thrust margins and tail rotor yaw power.

The thrust margin deemed appropriate was 5% at maximum Take Off Weight whilst the tail rotor is sized to permit left and right sideways flight to be achieved at 35 kts with ten to fifteen per cent pedal margin remaining.

A third parameter was considered during project definition as potentially important in effecting sideways translation of the aircraft while tracking the moving deck, namely main rotor control power. Whilst small aircraft (eg Lynx) achieve this by possessing large control powers through rigid rotor head design, it was considered that an articulated design capable of quickly producing side thrusts without induced fuselage roll would be appropriate to a larger helicopter. Accordingly a 5% hinge offset was chosen as producing satisfactory control power to complement thrust and yaw agility.

Flying to date indicates that the handling qualities and agility achieved at maximum weight compare well with those designed into Lynx and that the EH101 will have no difficulty with performing landing manoeuvres onto moving platforms - be they ships or floating rigs.

This agility is complemented by ensuring that the visibility from the cockpit is unmatched by any comparable large helicopter, and that the landing area visibility and cues to the pilot on approaching the pad are maximised.

### 3. Ship Interface

Having provided the performance and control to approach a deck landing, the correct design of the landing gear to complete the touchdown in the foul weather conditions in say the North Atlantic is clearly essential.

The configuration selected for the EH101 is a wide track tricycle arrangement with a single nose oleo. With high static torque progressive friction brakes on the main wheels and a hydraulic sprag lock on the nose wheels very positive F/A wheel locking is provided to enhance deck stability and still allow progressive braking during taxiing.

To allow for the high side and drag loads transmitted from a rolling pitching deck it is important to maximise bearing overlap and minimise the break out friction of the shock strut bearings. This together with weight and size restraints has led to the adoption of through piston (pogo stick type) oleo-pneumatic struts with a two stage orifice. See Figure 2.

The overall landing performance requirement based on ship trials can be described as being analogous to the 3D surface of a bell, with the height representing the vertical landing velocity component (being a maximum of 12 ft/sec for EH101), one horizontal axis representing Fore and Aft or Lateral drift and the other horizontal axis representing angular misalignment of the aircraft to the ship. See Figure 3.

This empirical envelope, validated by Lynx trials, was used to specify and stress the EH101 landing gear and has subsequently been verified by successful "drop tests" of an EH101 mass and inertia representative Drop Test Vehicle onto both a sliding platform and an inclined plane with representative surface friction.

To minimise roll of the helicopter relative to the ship due to ship motion forces some stability augmentation is essential in high sea states. The EH101 uses a manually engaged gagging valve fitted to the main landing gear. This restricts the recoil orifice of the damping valve to avoid unwanted oleo extensions thus maintaining hangar clearances, easing replenishments, especially rearming, and minimising oleo seal wear.

To further enhance both the landing capability and on-deck stability:-

- a) The EH101 flight control system allows the application of some 3000 kg negative thrust helping the aircraft to "stick to the deck".
- b) the EH101 can be equipped with a "deck lock" actuated by the pilot which engages into a grid, surface mounted on the ship's deck. Having been engaged, the deck lock is automatically tensioned to tie the aircraft to the ship. See Figure 4.
- c) or the EH101 can be equipped with a haul down system located under the rotor which allows the ship to apply a constant restraining force, enabling the pilot to fly the aircraft with assisted hover position and improved landing accuracy followed by rapid securing to the deck.

Other considerations taken into account include:

- a) no mechanical trail on the wheels thus avoiding the tendency to "weather cock" on deck under high side winds.
- b) powered nosewheel steering with closed loop control for taxiing and 0-90° powered castoring for deck rotations about the deck lock located just forward of the main wheels. This allows the aircraft to centralise on deck following a landing or to range into wind if necessary to avoid ship heading changes during take-off.
- c) fatigue loading due to ship motion forces and wind loads - an important factor used in addition to the static design cases, as the loading is generally induced with a period of some 10 seconds giving potential for fatigue damage over the life of the aircraft.
- d) corrosion from the salt mist and green seas over the deck of the ship have required attention to detail design to avoid water traps and the use of ultra high tensile steels with suitable protective treatments or Aluminium Lithium forgings to enhance both corrosion and fatigue resistance at minimum weight.

#### 4. Deck Handling

On a small frigate it is necessary to be able to centralise the aircraft on the deck and traverse the aircraft into the hangar without personnel on the moving deck of the ship.

For the RN aircraft with the deck lock engaged in the deck grid the procedure is for the pilot to castor the nose wheels through 90 deg and using tail rotor power rotate the aircraft about the deck lock until the nosewheels pass over "sleeping policemen" on the centre line of the deck. See Figure 5.

The nose wheels are then aligned with the ship and engaged by a shuttle driven out on a track by the deck officer. The shuttle is then used to pull the aircraft forward until the main wheels are positioned on arcuate plates which can then be moved to port or starboard to swing the aircraft onto the centre line. See Figure 5A.

Shuttles then engage and restrain the main wheels. With the aircraft shut down and folded and deck lock disengaged, the aircraft can be towed into the hangar by the pretensioned shuttles which also constrain the aircraft against ship "g" forces.

The reverse process is employed to range the aircraft from the hangar. The main wheel shuttles can also be used to transport and accurately position armament under the aircraft.

Whether on board large or small ships hangar space and doors dictate the maintenance size of the helicopter. To fit into the hangar of a frigate or down the lift of a carrier EH101 has been designed to automatically fold both the main blades and the tail pylon to give folded dimensions of

16.0m long  
5.2m high  
5.5m wide

Blade fold is achieved by electrically turning the rotor head until No. 1 blade is over the tail, hydraulically driving the flight controls to pre-determined positions and locking the swashplate - these locks eventually react the blade loads. The final part of the sequence is the folding aft of the 4 remaining blades by epicyclicly geared electric drives in each blade attachment, the same drive first withdrawing the blade locking pins.

The tail fold hinge is skewed forward by 18 deg to both shorten and reduce the height of the aircraft during folding. Again electrical power is used to withdraw the lock pins and drive and fold. See Figure 6.

Folding of the blades and tail unit can be completed in 2 1/2 minutes and in 50 knot winds. The whole sequence is computer controlled.

## 5. Maintainability

The maintenance of helicopters in single unit ships presents problems which do not arise in a shore based facility.

The limitation of available space not only for the helicopter but for the stowage of servicing and support equipment plus facilities to perform some off-aircraft tasks requires particular attention to be paid to the need to reduce preventative maintenance requirements and to extend the intervals between those maintenance activities.

The use of MSG-3 logic in developing the maintenance programme for EH101 coupled with the comprehensive Health and Usage Monitoring (HUM) of the aircraft and its systems has greatly reduced the preventative maintenance burden.

The philosophy for preventative maintenance is a minimum periodicity of 200 Flight hours with allowance for safety systems mandatory requirements and calendar based environmentally related tasks.

Continuous operations of 50 hrs flight are possible with one shut down at 25 hrs to monitor fluid levels and replenish if required.

### 5.1 Aircraft Management System (AMS)

The AMS provides the ability to monitor the status of the aircraft systems, including fluids, by manipulation of data generated by installed sensors.

This ability provides the confidence for extending the Flight servicing task intervals providing better aircraft utilisation and availability.

### 5.2 Built-In-Test (BIT)

The inclusion of a comprehensive BIT coverage of avionics coupled with the HUM and AMS reduces at-aircraft replacement times by providing the ability to isolate faults to Line Replacement Unit level. The AMS display, and if necessary downloading through the use of a data transfer device, gives the maintainer added assistance in fault location, rectification and testing.

### 5.3 Preventative Maintenance

Reliability Centred Maintenance (RCM) analysis is employed to determine the preventative maintenance requirements for EH101.

The RCM method employed is Maintenance Steering Group 3 (MSG-3) Logic.

The major difference from previous RCM methods is that MSG-3 employs a "from the top down" approach. This considers the consequences of failure which are placed in two distinct categories:-

- A - Safety
- B - Economics

MSG-3 considers further applicable criteria such as whether the failure is evident to the operating crew or hidden.

All structural functional failures are considered safety consequential.

Such a procedure helps eliminate from the analytical procedure items whose failure have no significant maintenance tasks which have become traditional but have no direct effect on detecting degradation of performance or preventing failure.

## 6. Reliability

In order to achieve the minimum cost of ownership minimum corrective maintenance is required with the implicit attribute of high reliability. This concept becomes even more clear for the aircraft embarked on a small ship with it's restricted maintenance facilities and the need for operational availability.

During the EH101 Development programme any premature failures are accurately reported as they occur on the 9 Pre Production aircraft through a FRACAS process such that a good data base already exists of equipment reliability and required fixes. These fixes will be embodied into the production units and reliability will be a major feature of Production Equipment specifications.

To further drive out unreliability in the real operational environment a funded Maturity and Reliability Enhancement programme is planned to start in 1994. This takes two of the pre production aircraft at the end of their development flying, upgrades them with as many of the production equipments as possible and subjects each aircraft to 3000 hours of intensive flying.

The plan is to operate remote from the factory as a Single Site Operation, both aircraft operative for some 18 months in the cold and wet environment off the North of Scotland and a further 18 months in the hot and dry conditions of Southern Italy. These environments should highlight failure modes which would not previously have been exposed until in-service operation.

The intention is to "fix all failures". This will require a rapid response by EHI and by equipment vendors. The overall aim is to achieve a Mean Time Between Attributable Faults of 4 hours within 7000 flying hours - prior to the start of the Navies formal IFTU.



Other benefits will accrue from the M & RE activity.  
These include:-

- a) Developing all aspects of the Maturity of the aircraft
- b) Establishing and extending the drive system TBO
- c) Developing and proving the use of HUM and
- d) Establishing and improving fatigue damage tolerance.

The M & RE process is seen as a revolutionary change to the way an aircraft is launched into production to minimise the maintenance penalty.

## 7. Synopsis

The above discussion has highlighted just some of the efforts to design an aircraft fit for the Naval environment - the margins and control power together with the landing gear capability for foul weather landing without ship manoeuvring - the ability to fold and manoeuvre the aircraft into small hangars - the facilities to ease maintenance - and the plan to improve the maturity of the aircraft.

Other features not discussed here, included to marinise the aircraft consist of:-

- General protective treatments
- High safety levels from redundant systems
- Multiplexed Flotation System
- An autonomous capability, Etc

These with many other details features have ensured that either a Military or a Civil operator will be provided with an aircraft designed, tested and proven to a degree of capability and reliability in the Naval environment not previously available at any entry into service of any new type.



Figure 1 EH101 NAVAL DEVELOPMENT AIRCRAFT

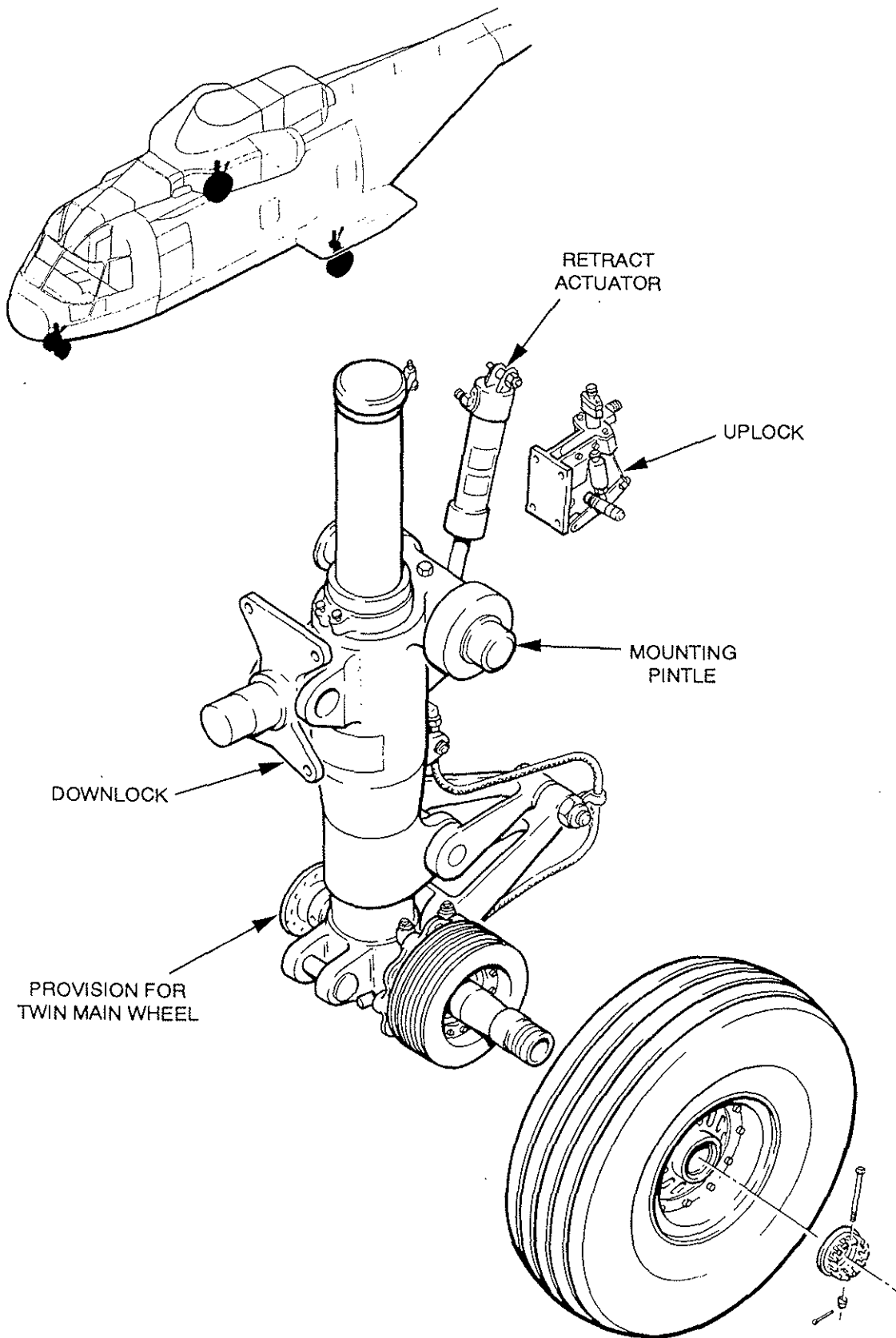


Figure 2 EH101 MAIN LANDING GEAR

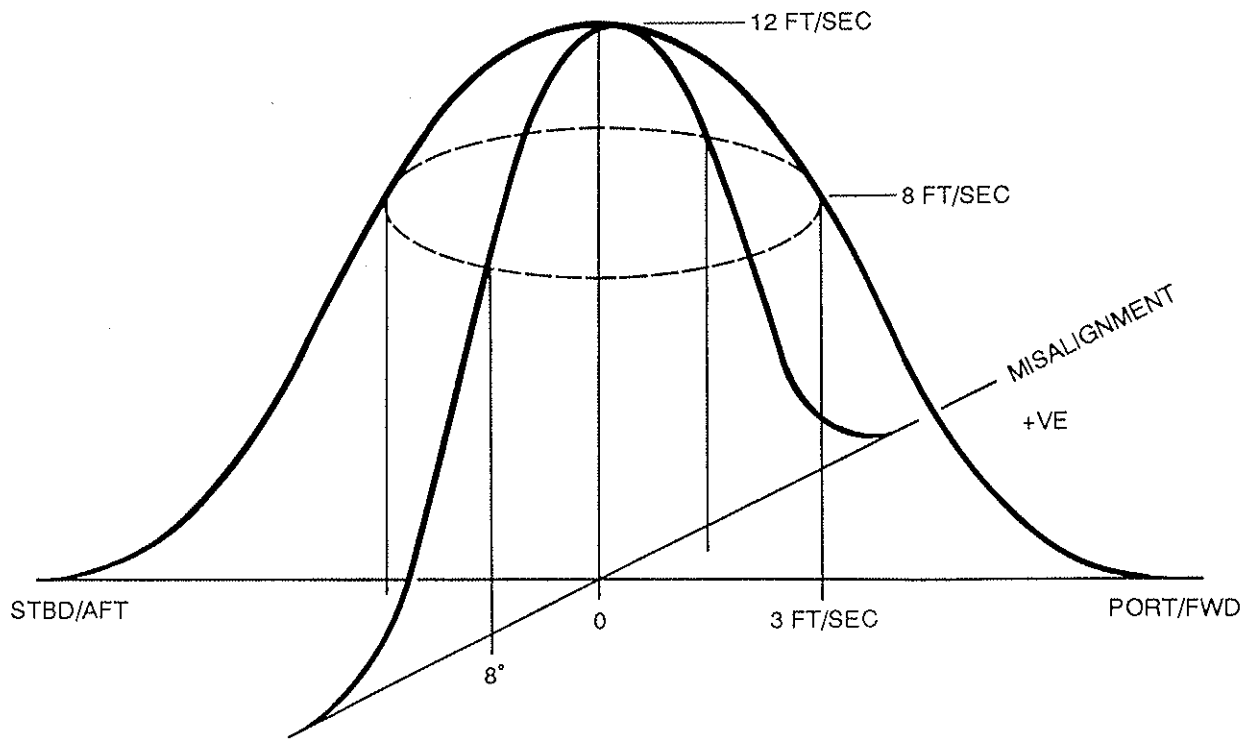


Figure 3 EH101 LIMIT LANDING ENVELOPE

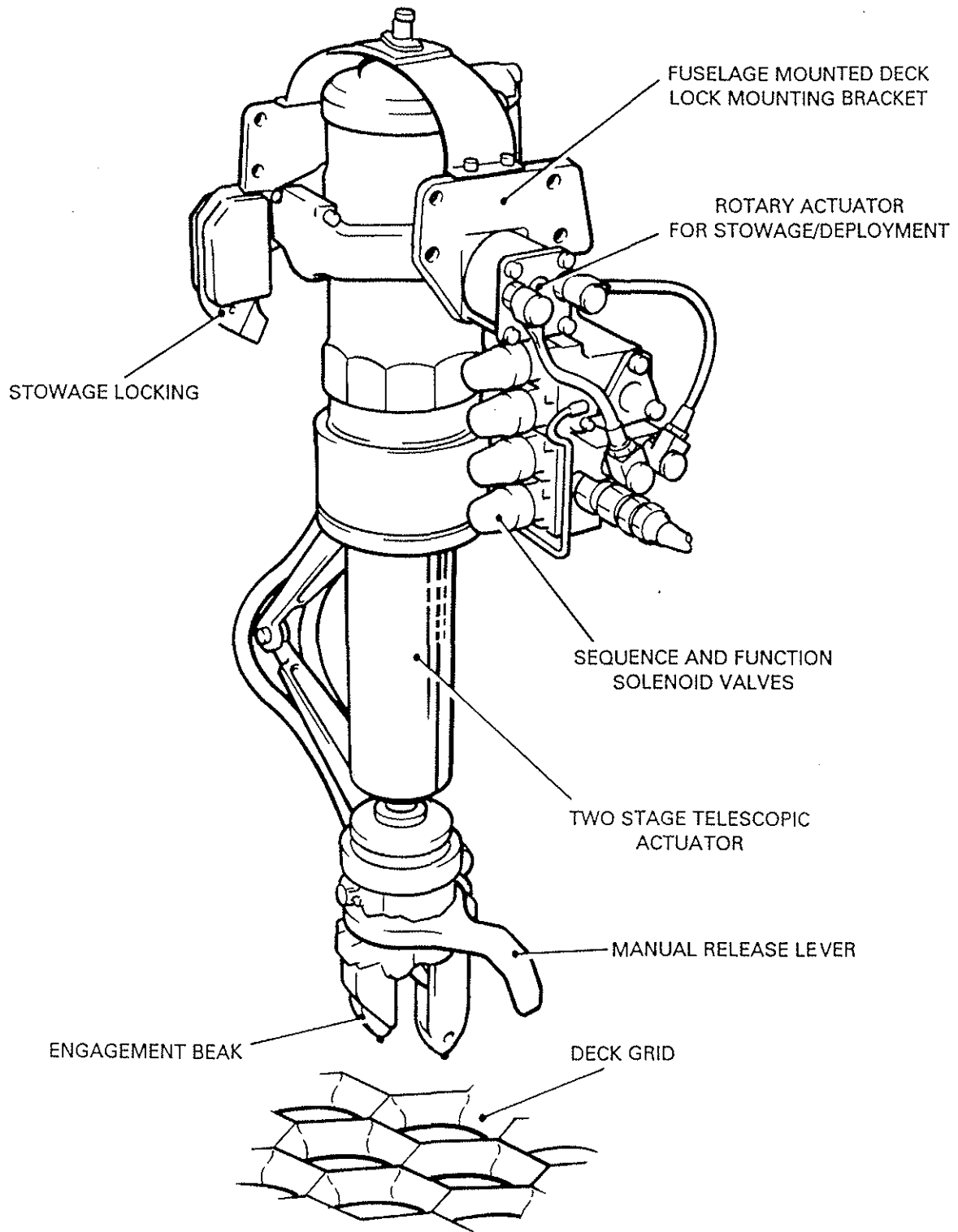


Figure 4 DECK LOCK AND DECK GRID

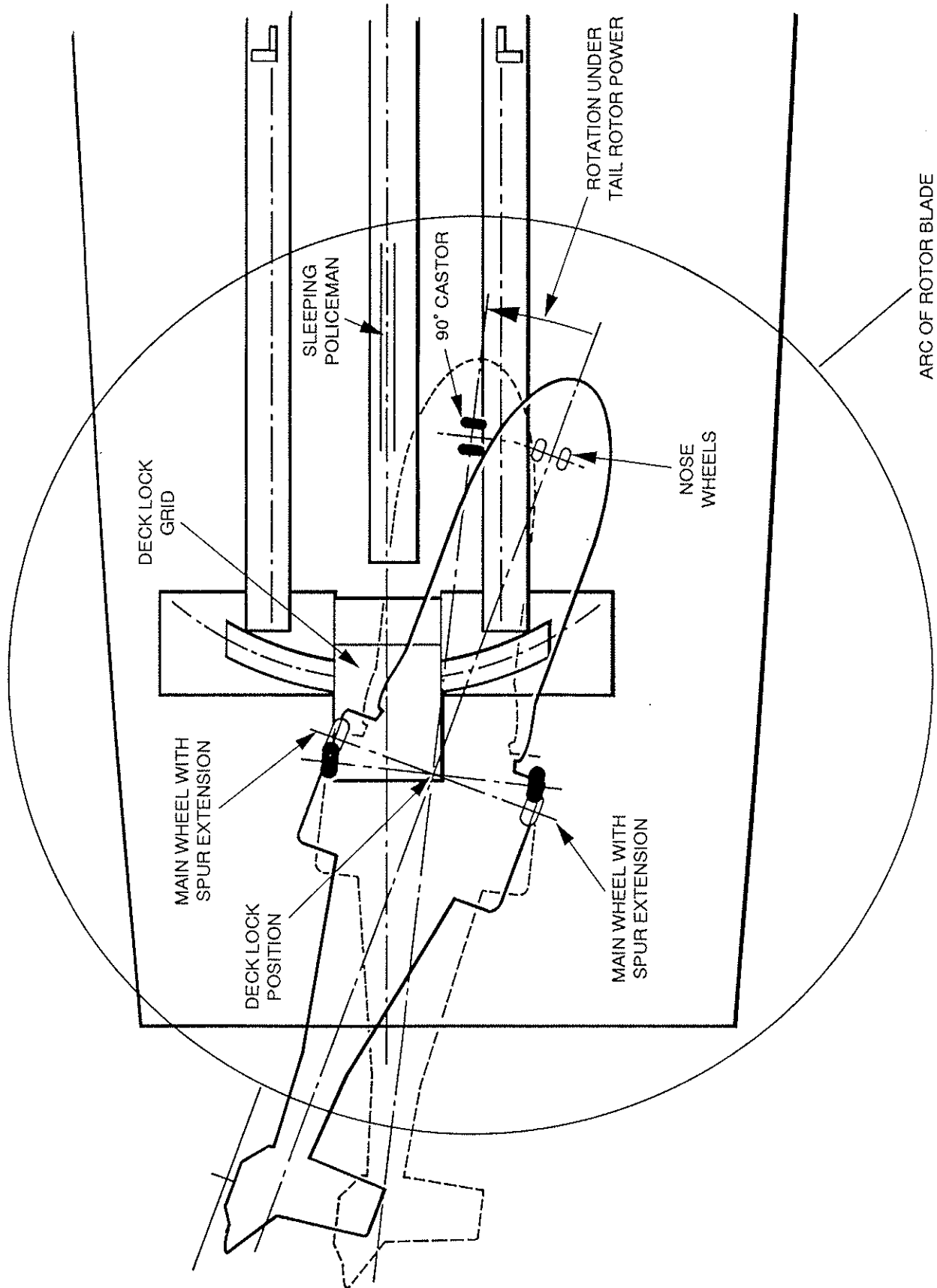


Figure 5 AIRCRAFT LANDS IN WORST POSITION, 20° OFFSET; DECK LOCK ENGAGED

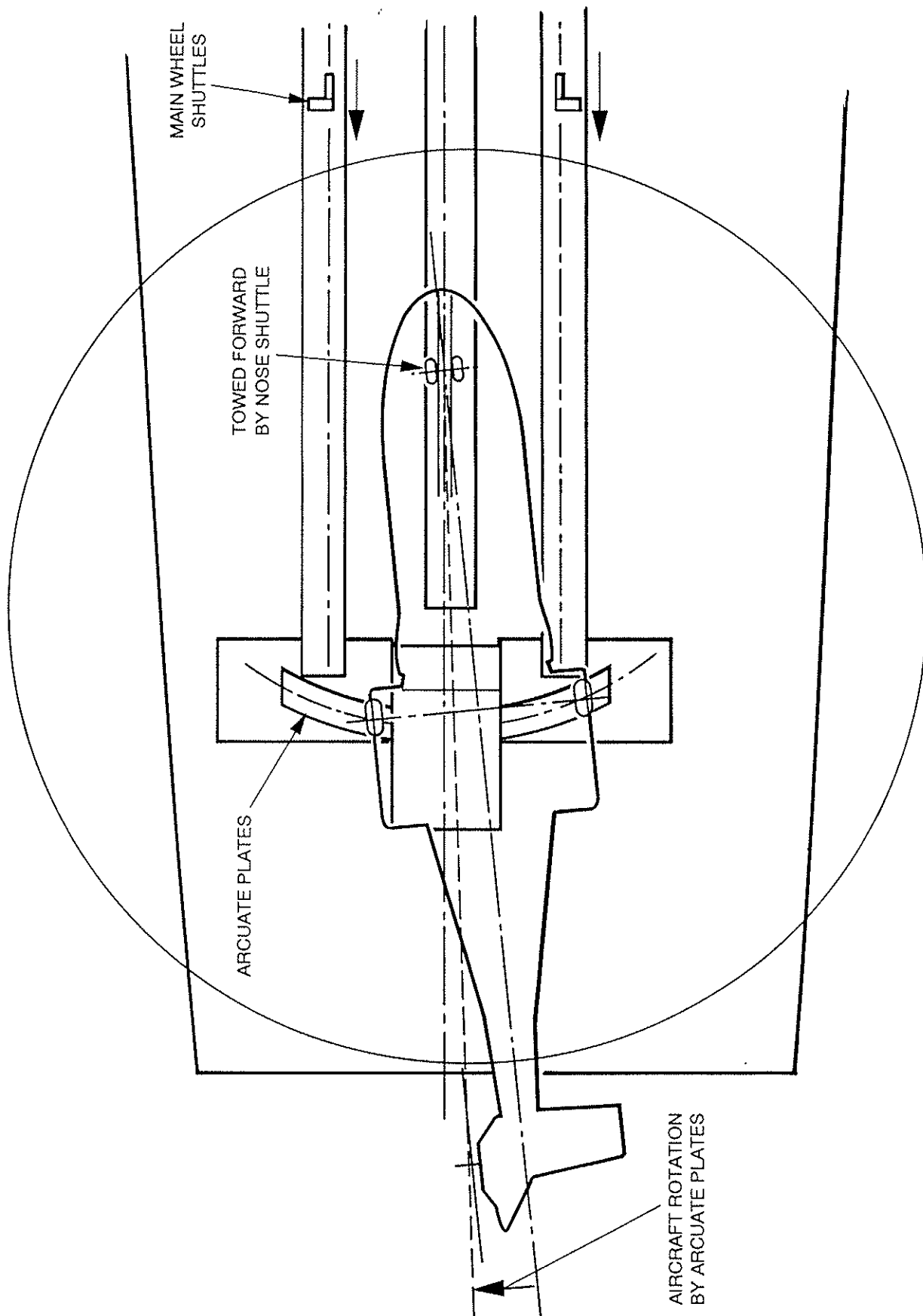


Figure 5A TOWED FORWARD UNTIL MAIN WHEELS ARE ON ARCUATE PLATES

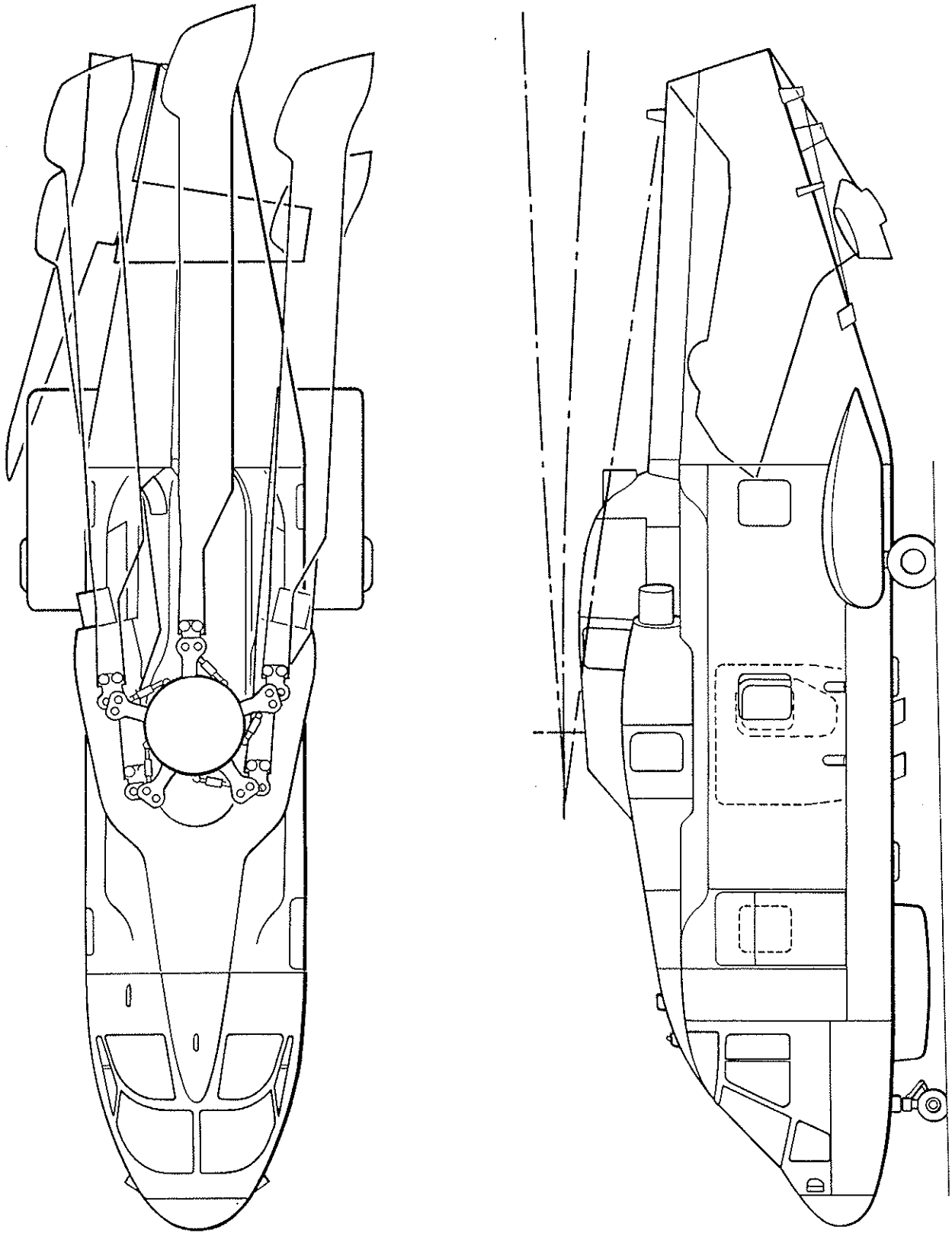


Figure 6 EH101 FOLDED CONFIGURATION