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DEVELOPMENT HISTORY
OF THE ROOIVALK ATTACK HELICOPTER

BY

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ATLAS AVIATION

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OVERVIEW OF THE ROOIVALK PROGRAMME

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Abstract

The modern version of Blitzkrieg advocates a highly-mobile force of airborne weapons platforms. These forces must be capable of operating below the visible horizon of enemy defences and keeping out of range of the associated defence systems.

With minimum response time, such aircraft can be directed to key engagements in adverse weather by day or by night, bringing massive firepower to bear on unsuspecting enemy formations, while requiring minimal infrastructure for their deployment.

This is the mission of the attack helicopter. Rooivalk is the newest attack helicopter in its class that epitomises all the requirements of the high-intensity battlefield.

Rooivalk is a programme that has been born out of intensive battle experience and produced to a tough and exacting requirement. The capabilities of South African industry have been honed and perfected since the institution of sanctions, they have built up an impressive and highly capable industrial base despite all the odds. All of this makes the Rooivalk a programme not to be dismissed, as it is attracting serious attention from the outside and richly deserves to. From out of Africa a credible and versatile new weapon system has entered the world arena.

Team Rooivalk is highly-motivated, with limited resources, and they have brought a world-class attack helicopter into reality. All programme milestones have been met, and the team at Atlas Aviation are firmly convinced they will see their brainchild in production and that it will be exported.

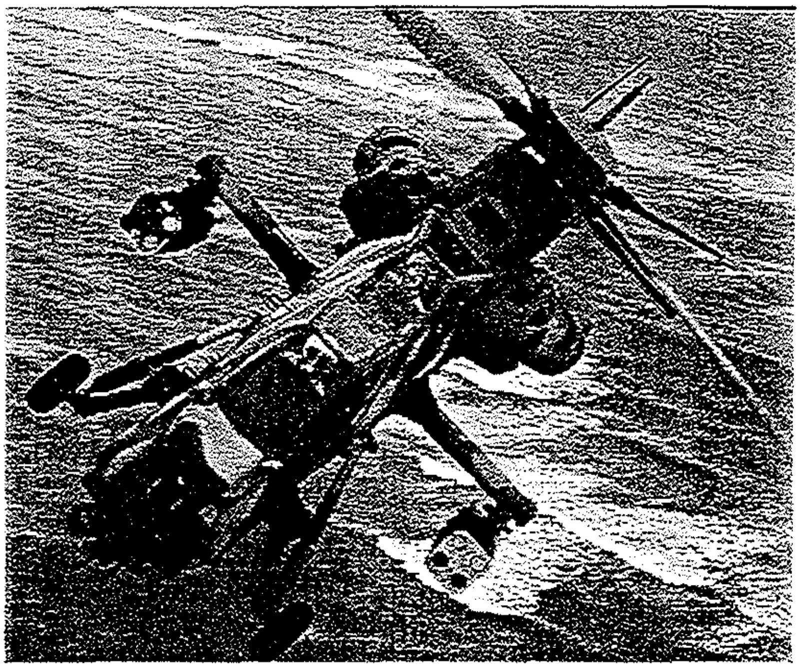


Figure 1: Rooivalk AH

1. Strategy

To meet the requirements that the South African Air Force had in an attack helicopter was a formidable undertaking for Atlas Aviation and South Africa and to ensure that the country had the capabilities to partake in such a venture, certain checks had to be made. For South Africa this was not new as many high technology ventures went through an audit process before full commitment was made. This would ensure that the venture was successful without runaway costs. Examples of this are the pilot plants of Sasol and the Atomic Energy Corporation in the civil sector and the G5 and G6 howitzers in the military. The ideas behind these projects was to obtain a key understanding of the technologies on a small scale while spending a lot on training the personnel involved, thus providing seeds for growth to potential production size units, remembering that South Africa did not have vast resources of off-the-shelf engineering staff. This allowed in the longer term less reliance on international supply of staff and components which could save vast sums of money. This same approach was applied to the attack helicopter requirement.

Back in the mid seventies when the requirements were first born, defence research funding was made available to explore the possibility of designing such a machine locally. This was undertaken at the CSIR where feasibility studies were carried out and by 1980 a contract was signed to design a technology demonstrator now known as the Alpha XH1, based on the Alouette III. This project was used as a school for engineers in preparation for bigger things to come.

By 1984, a decision was made to go ahead with the Rooivalk programme, the defence force having found the confidence in the engineering industry to tackle such a formidable task. Emphasis was placed on risk management and lessons learned from the European and American helicopter experience. This, together with a very close liaison with the User, laid the foundations for a sound and dynamic helicopter industry. This decision was not taken very lightly and strategies had to be put into place to ensure success, these included purchasing as many off-the-shelf components as was possible, back engineering existing components, multi-sourcing, parallel test and evaluation programmes, all of which to reduce the risk of failure. The mere fact that Rooivalk exists, epitomises this success.

Figure 2: Alpha Prototype

To put into context the development of the Rooivalk AH programme it is prudent to give an explanation of this process. Many critics have viewed the development of Rooivalk as a farce and that its existence was based on significant foreign aid and pure luck. This has been particularly a problem from international military watchers. This is of course totally unfounded as the programme is a wholly indigenous product that can be reproduced again. This has largely been negated after the Rooivalk entered the United Kingdom competition; their Ministry of Defence having carried out an extensive audit of the programme. The development process used was based on the American Military Standards (MIL-STDS) which is a set of documents describing the standards that military hardware has to comply to operating in the harshest of environments. This is a very expensive practice as exhaustive tests have to be performed before components and systems are qualified for use.

Atlas Aviation, the designer and developer of Rooivalk, is a division of DENEL. It has a work force of over 4 000 and has been involved in aircraft manufacture since 1964, whence it has grown into the leading South African aerospace company. Born out of the sanctions period in South Africa, it acquired and retains a total design, production and test capability for advanced fixed and rotary-wing combat aircraft and engines. Notable programmes are the Impala trainer and ground attack aircraft, the Cheetah supersonic interceptor, the Oryx medium transport helicopter and, more recently, the Rooivalk attack helicopter and the ACE all-composite trainer.

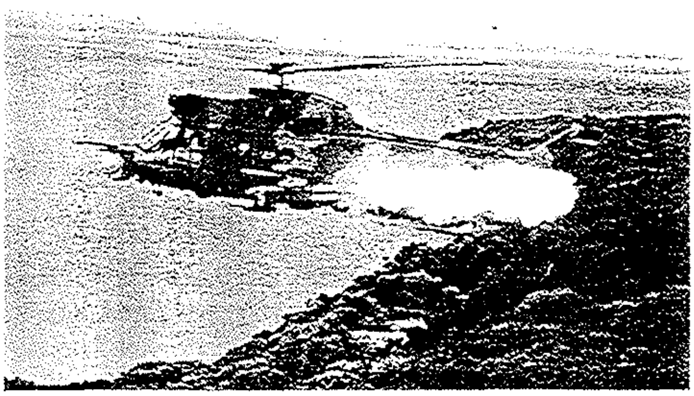


Figure 3: Puma J

Atlas Aviation draws its strength from its shareholders and their commitment to the AH programme. DENEL is an independent, diversified group that ranks amongst South Africa's leading manufacturers and suppliers of high-technology industrial and military products, systems and services. It is the holding company of 26 manufacturing and other business divisions which employ some 17 000 people. It has been responsible for the development of world-class products such as the widely acclaimed G5 and G6 Howitzers.

1.1 Historical Overview

Development of Rooivalk began in 1984. First flight was set for 1990 with an in-service date of 1993. Following now-established lines, Atlas Aviation set about converting two Puma J's to act as test-beds for the programme, both machines to take on very separate developmental tasks. As Rooivalk would employ Puma dynamics it made a highly symbiotic choice as a development platform. Puma J1 first flew in 1986 and undertook stubwing development, analytical programme validation and sub-systems evaluation. Puma J2 concentrated on weaponry, testing cannon (a 20-mm XC-20 in 'turreted' format as also fitted to the XH-1) and missile options (including unguided rockets, anti-tank missiles and heat-seeking air-to-air missiles for self-defence), stores release and evaluating the sight. All this allowed the airframe team to follow its path towards the first flight of the prototype Rooivalk.

The first Rooivalk airframe built was the Experimental Development Model (XDM) which first flew in February 1990. The XDM was used to perform structural and aerodynamic verification of the airborne systems, to open the flight envelope, and to do weapons carriage clearance. This phase was successfully completed in 1991. The XDM is today still serving as a test-bed.

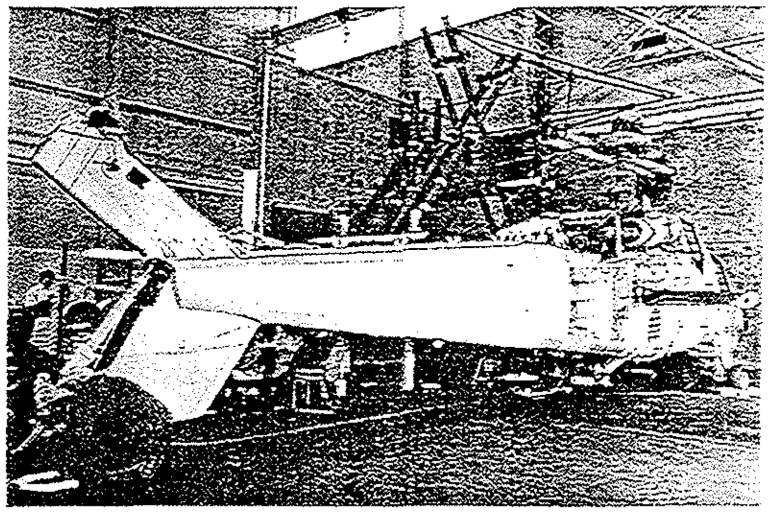


Figure 4: Assembly

The Rooivalk Advanced Development Model (ADM) was designed and built to verify the avionics design and implementation, to verify the weapons performance, and to verify design improvements. The technologically advanced avionics system proved to reduce the workload of the air crew significantly. Most of the traditional instruments have been replaced by two multi-function displays ("glass cockpit"). Initial weapons system tests, both of the cannon and ZT3 missile systems have been completed.

The detailed design and construction on the Engineering Development Model (EDM) commenced in March 1993. The objective of the EDM phase is to qualify the avionics, weapon systems, airframe and airborne systems prior to production. In addition, the EDM will serve as an evaluation vehicle for logistic supportability.

The original in-service date for the SAAF was 1993. This did not materialise due to a shift in emphasis from a military to a political solution in the region and resultant budget cuts. However, the requirement has not changed. The need for a combat helicopter as a force multiplier together with the Rapid Deployment Force (RDF) concept is regarded as essential.

1.2 South African Air Force Major Requirements

The major requirements for the South African Air Force (SAAF) in terms of the attack helicopter were formulated based on their operational experience. Studies were undertaken to determine a feasible configuration where the point of departure revolved around the sizing aspects, should it be a small or a large helicopter. However, both subjective assessment and objective operational analysis showed clearly that a Light Attack Helicopter would lack the necessary range, payload and survivability features required to be effective on the future high-intensity battlefield.

Concurrent with these studies the tactical employment emphasis began to shift from the defensive to the offensive. This served only to reinforce the requirement for a dedicated attack helicopter capable of destroying multiple, heavily armoured targets, at long-range, in a high-threat environment in support of ground forces by day and night and in adverse weather conditions. It required to have an autonomous target acquisition and engagement capability and in the reconnaissance role and should be able to hand over or receive targeting information via a radio data link.

Today, these remain the prime requirements of an attack helicopter for the SAAF. However, the international shift of emphasis away from the high-intensity threat towards localised military interventions and peacekeeping, requires that the attack helicopter also remains operationally employable and effective in a wide range of conflict scenarios.

The attack helicopter requirement demanded:

- Survival in a high-threat regime.
- Commonality with the existing medium transport helicopter fleet.
- Quick response to the mission task.
- Day and night operability.
- Low pilot workload.
- A very accurate navigation suite.
- Simple 'in the field' maintenance
- An operational lifespan of 30 years.
- The ability to come easily under existing Army command, control and communications systems.
- It must operate in the 'operational window' (5-15 m) for 95% of its life time.
- A long endurance and the ability to perform ferry missions over great distances.
- Be built within the existing industrial infrastructure of the RSA.

The primary User requirement of the attack helicopter was anti-armour with anti-air defence systems as a secondary requirement. From the start, Atlas Aviation were keen to endow the Rooivalk with the ability to take on other roles, providing they did not compromise the primary and secondary requirements.

1.3 Rooivalk Development Plan

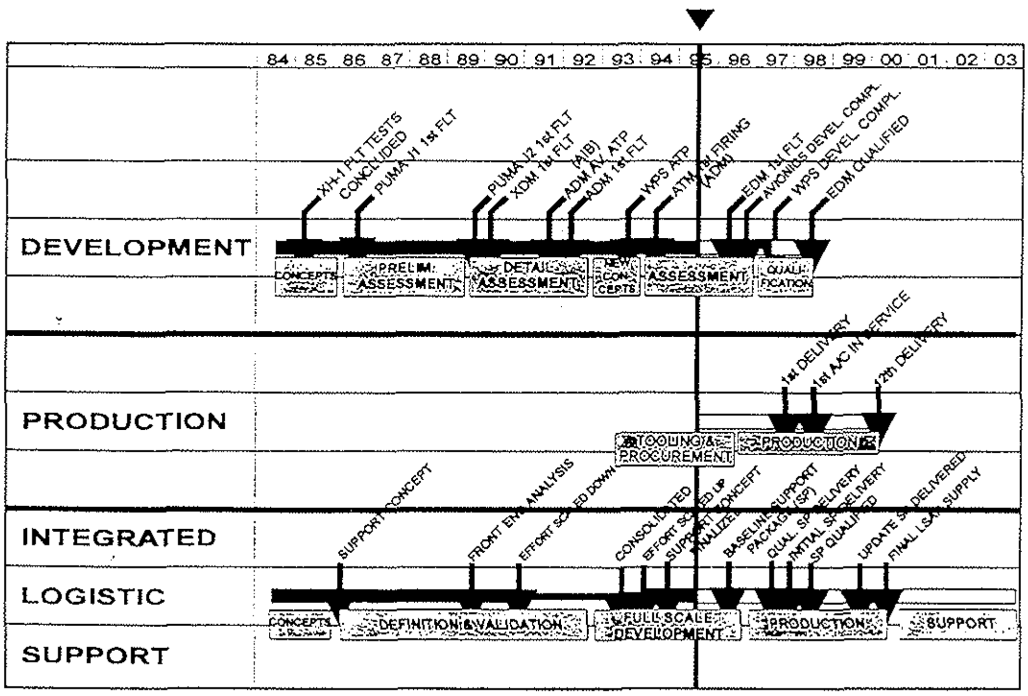


Figure 5: Development Plan Chart

2. Technical Overview

2.1 Design Drivers

The design of an attack helicopter has to encompass a multitude of requirements for it to fulfil its stated missions cost-effectively. Rooivalk has been designed in accordance with accepted military standards. From the outset the design drivers for Rooivalk were captured into six cardinal points

HIGH INTENSITY BATTLEFIELD	SURVIVABILITY	FIREPOWER
Critical 1st 24 hours Joint Combat Forces	Air defences Operational Windows	Tank Killer Capital Targets
AFFORDABLE AVAILABILTY	HIGH MOBILITY	DAY AND NIGHT
Reliable Inexpensive Support	Force Multiplier Deep Penetration	Stealth Tactical Surprise

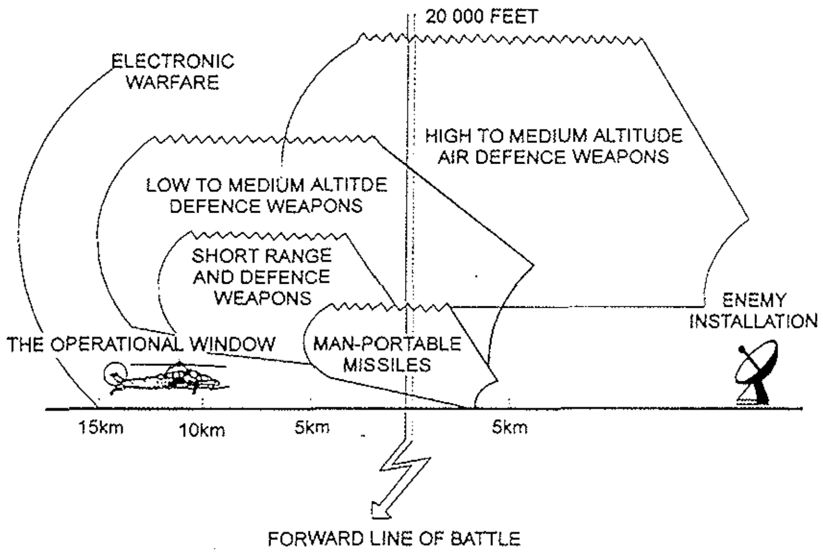


Figure 6: Design Drivers

In designing Rooivalk, the well established principles of firepower, mobility (translated to range and agility) and protection (translated to survivability) were analysed in depth. Key to the inevitable compromise was the South African long-range requirement which closely matched that desired for other export clients. This dictated a large internal fuel capacity but limited the amount of protective armour that could be carried. Fortunately this compromise matched the SAAF tactical philosophy which stresses concealment, stealth and surprise as the attack helicopter's principle protection mechanism.

The Rooivalk was conceived as a force multiplier against numerically superior forces, capable of operating in close support of Army units from remote locations with minimal support facilities. SAAF tactics in this regard demanded an attack helicopter with minimal dependence on support equipment, "hot" turnaround capability and a low crew workload to enable maximum concentration on the mission, rather than the aircraft. This is the concept of high-mobility warfare.

The primary mission of this aircraft demands an eyes-out-of-the-cockpit, Hands-on Collective and Cyclic Stick (HOCAS) approach for the pilot of the aircraft, precise and rapid control of the ranging/tracking instruments and avionics system management for the Weapon System Officer (WSO), and effective weapon deployment capabilities for both.

In addition, with a two-man crew, efficient communication and unambiguous task allocation are essential to ensure efficient coordination. These requirements indicated that an integrated system approach was called for.

2.1.1 Firepower

Rooivalk AH is equipped with a weapon system comprising:

a. The ZT6 (mmW) Anti-tank Guided Weapon (ATGW) active millimetre-wave guidance fire-and-forget missile. This missile is capable of defeating the predicted tank threat at a range in excess of 8 km and has a lock-on after launch capability.

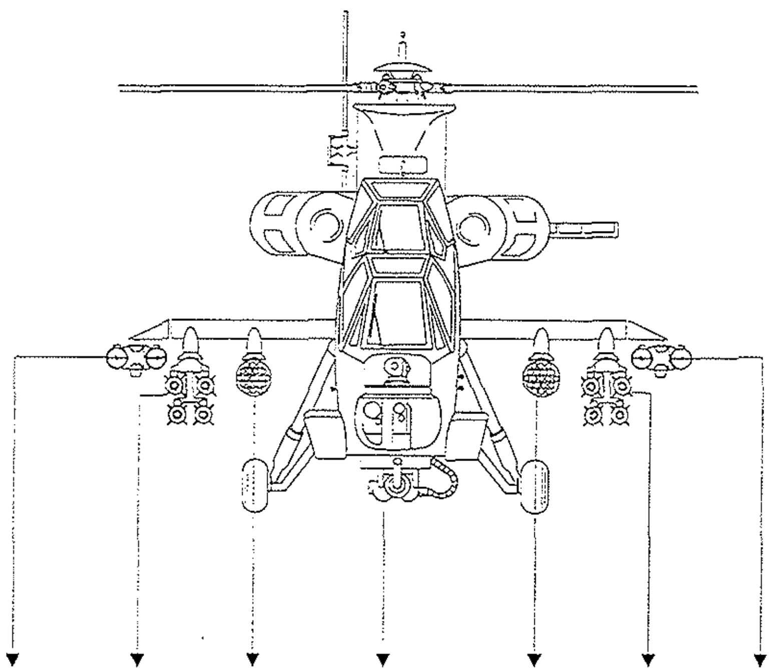
b. The ZT6 (SAL) ATGW system. This semi-active laser-guided missile has a range in excess of 8 km and will defeat the predicted tank threat. It is also effective in engaging point targets with extreme accuracy.

c. The Bristol Aerospace CRV 7 70-mm unguided rocket system. This system can be configured with a choice of warheads to engage personnel, APCs, bunkers or soft-skinned vehicles. The CRV 7 system is effective to 9 km, but accurate to 4,5 km in direct fire.

d. The Lyttelton Engineering Works F2 20-mm chin turret-mounted, high-velocity, high-speed cannon. The cannon has an effective range of 2 000 m and can fire a variety of ammunition to defeat personnel, soft-skinned vehicles, Armoured Personnel Carrier (APC)s and helicopters. The cannon is effective in the air-to-air and air-to-ground modes. It has a rate of fire of 740 rounds/min and 700 rounds can be carried.

e. The Matra Mistral Air-to-air Missile (ATAM) system for the air-to-air role. These infra-red fire-and-forget missiles can be used to destroy aircraft or helicopters at a range of up to 5 km.

Weapons can be carried in a wide variety of configurations, some of which are illustrated in Figure 7.



6	5	4	STATION	3	2	1
MISTRAL ATAM X2	ZT6 ATGW X4	70-mm ROCKETS X19	F2 20-mm CANNON	70-mm ROCKETS X19	ZT6 ATGW X4	MISTRAL ATAM X2
	70-mm ROCKETS X19	ZT6 ATGW X4		ZT6 ATGW X4	70-mm ROCKETS X19	
		750L DROP TANK		750L DROP TANK		

Figure 7: Firepower

The primary sight is stabilised and nose-mounted. It allows the aircraft to detect main battle-tank targets at distances greater than 8 km. The main sight is also used to point the cannon in both air-to-ground and air-to-air modes. The sensors in the main sight endow the aircraft with a significant Information, Surveillance, Target Acquisition and Reconnaissance (ISTAR) capability.

Rooivalk AH is also equipped with a helmet-mounted sighting and display (HMSD) system to which the main sight can be slaved. The HMSD is used to point the cannon in the quick-reaction air-to-ground and air-to-air modes.

2.1.2 Survivability

In order to survive in a high-threat environment, the Rooivalk design philosophy adheres to the following key concepts:

DO NOT BE SEEN
if seen
DO NOT GET HIT
if hit
DO NOT CRASH
if a crash is unavoidable
SURVIVE THE CRASH

In keeping with the emphasis on detection avoidance, emissions from the Rooivalk are minimised across all spectra, and the technology to ensure low observability of the aircraft has been applied extensively. This includes the use of radar absorbent material (RAM) on structures and components with high reflective potential to minimise the radar cross-section (RCS).

The Anti-tank missile maximises AH survivability through the long stand off range of the ZT6 missiles. In addition, the ZT6 millimetre-wave missile provides a true fire and forget capability, if required.

A comprehensive passive electronic warfare suite is integrated with the avionics. Active countermeasures are avoided and for systems which normally emit electromagnetic energy, a centralised control to inhibit these emissions is provided, allowing "quiet" navigation and target acquisition.

Aircraft agility is ensured through high excess power margins. A sophisticated flight control system is integrated to simplify control of the aircraft during nap-of-the-earth (NOE) flight and weapon delivery, and accurate navigation sensors ensure the ability to follow a pre-planned route either manually, or with aid from the flight control system.

Cable cutters are fitted in front of the aircraft protrusions (main rotor and cannon turret) with deflectors to minimise vulnerability to wire strikes.

Ballistic tolerance for calibre's up to 12.7 mm is designed into parts of the structure and all flight-critical controls, while the seats are armoured for the same design threat.

A 30 minute "dry run" capability is designed into the gearboxes to survive ballistic damage and self-sealing fuel tanks are installed.

Where systems are duplicated, spatial separation is maximised by installation of the two units in opposite locations. Where redundancy alone is not adequate, isolation capabilities are provided (e.g. in the hydraulic system), with separation categories similar to those for the aircraft wiring.

For the eventuality where the aircraft is detected and shot down, comprehensive crashworthiness features have been incorporated to ensure the survival of the crew. These features include a crashworthy structure and landing-gear, attenuating seats, frangible fuel couplings, emergency shut-off of fuel supply and electrical power and an emergency escape system.

2.1.3 Payload/Range

Rooivalk AH has a disposable load of 3-tonnes of which 1.5-tonnes can be internal fuel.

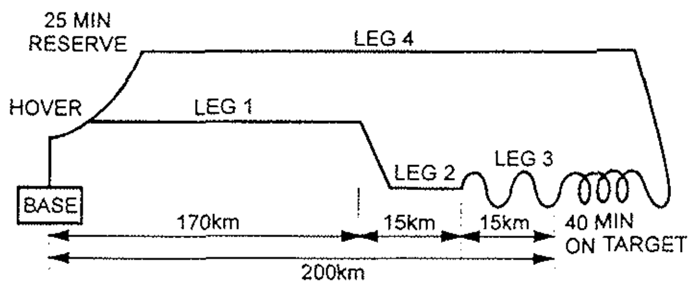


Figure 8: Payload Range

For example, it is possible for the aircraft to carry 16 ATGW, 2 air-to-air missiles, and 400 rounds of 20-mm ammunition over a distance in excess of 200 km to the target, spend 40 min in the target area, and land back at base with 25 minutes' fuel reserve.

Carrying external fuel, four air-to-air missiles and cannon ammunition, the Rooivalk can self-deploy over a distance of 1 000 km with 40 minutes' fuel reserve on landing.

2.1.4 Mission Management

On the high-intensity battlefield, effective management of mission tasks is paramount, especially at night and in adverse weather conditions.

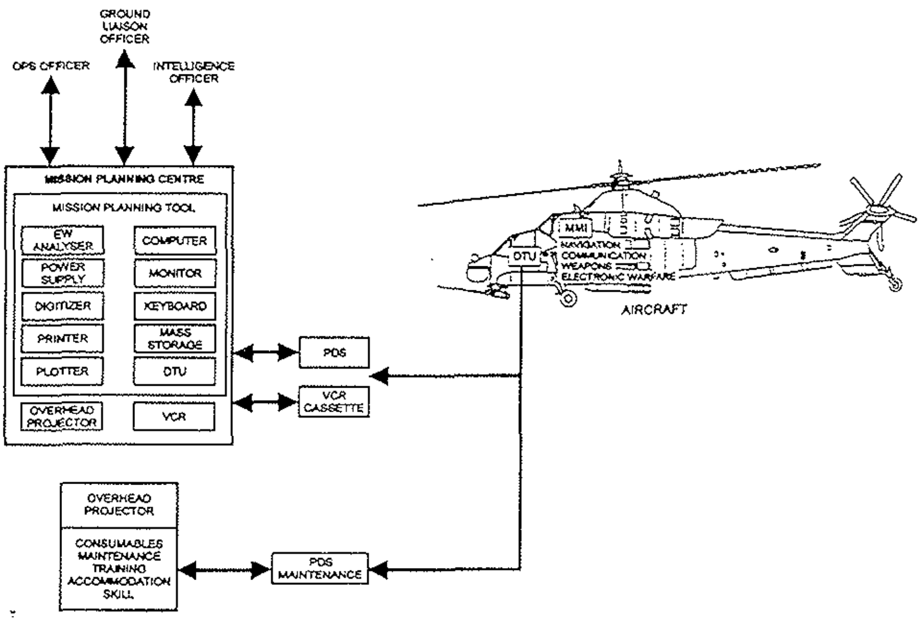


Figure 9: Mission Management

The Rooivalk AH achieves effective mission management through its on-board integrated management system and by incorporation of the following key features:

a. A Mission Planning Station (MPS) for the preparation of mission-related data for transfer to the aircraft. This includes digital maps, tactical flight plans, communications data, threat data and electronic warfare data.

b. Reduction of crew workload by:

   (i) Shared crew task management (Pilot and Weapons Systems Officer).

   (ii) A colour "glass cockpit" design, coupled to a user-friendly man-machine interface facilitating the display of flight and mission information.

(iii) Automated aircraft health and system usage monitoring, reporting malfunctions to air crew by exception only.

(iv) All primary control functions are located on the handgrips of the Pilot's flight controls (the hands-on collective and stick or HOCAS principle).

(v) Spacious, environmentally controlled cockpits with displays and controls optimised for ease of use.

(vi) Ultra low-level cockpit vibration levels to minimise crew fatigue.

(vii) Secure, frequency agile communications, including a data link.

Retrieval and analysis of post-flight mission data at the Mission Planning Station.

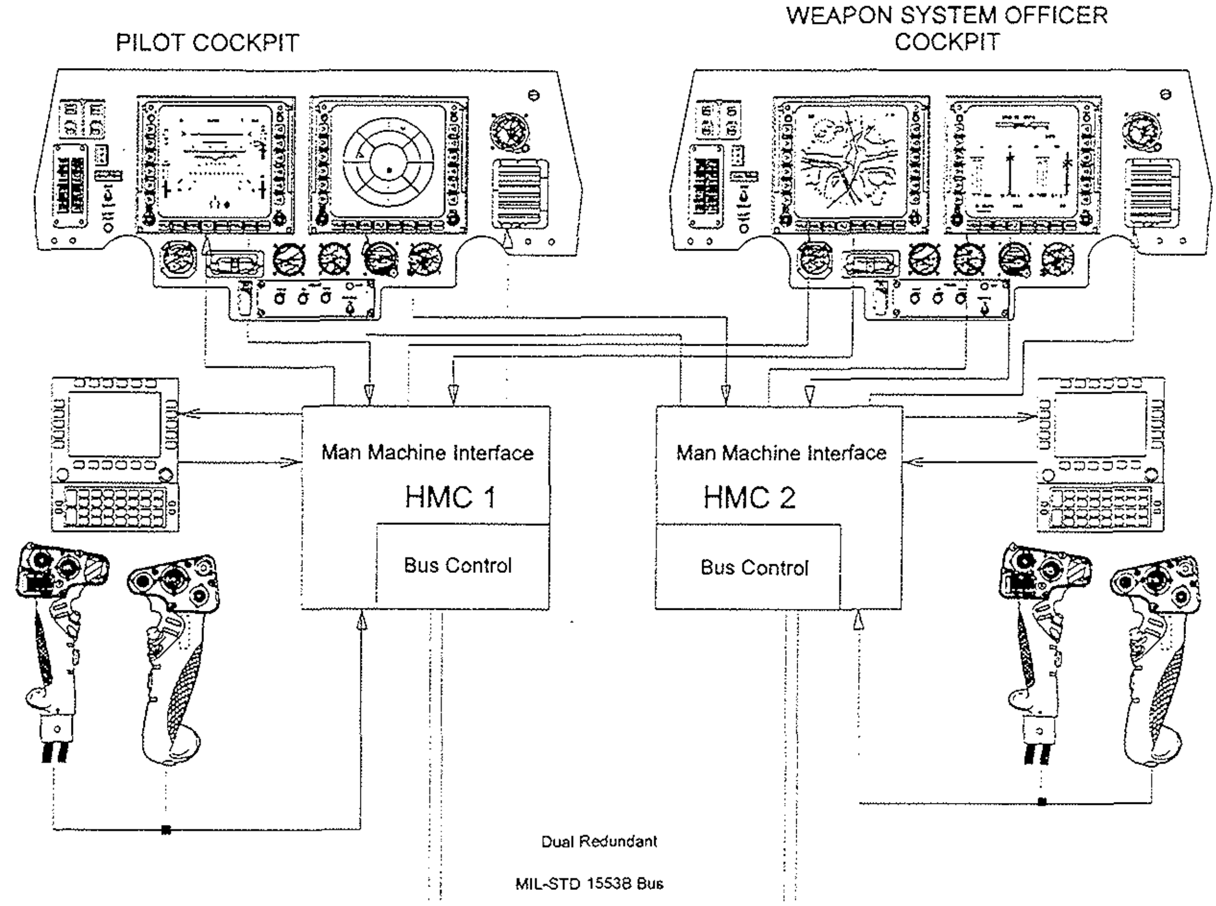


Figure 10: Systems

To ease the crew workload, a structured approach was followed with the allocation of controls and displays in keeping with their anticipated usage:

a. Information used during flight, in particular during adverse weather, as well as during weapon delivery, is presented head-up.

b. Likewise, critical controls such as flying aids and defensive weapon selections are accessible from the flight controls.

Other information is presented on head-down displays, selectable on Multi-function Displays (MFDs).

The choice of night-vision goggles imposes a requirement on the aircraft lighting system for NVG compatibility, which has been enforced for all cockpit instruments and light sources, as well as the cockpit paint work.

In order to ensure rapid isolation of faulty LRIs by maintenance crews, a concerted effort was made to test the system continuously, even in flight, through Built-in Test (BIT) facilities. In the case of boxes with built-in processors this function is integrated into its hardware and software, while for the air vehicle the BIT function is allocated to the health monitoring set. A display by exception philosophy is followed, i.e. all systems are GO unless indicated otherwise.

A structured reporting approach is followed in conveying failure conditions to the crew, which are broken down into system and air vehicle fault reports, after which these reports are categorised according to their effect on the safety of the aircraft or the success of the mission. Within these four categories the fault conditions are presented in chronological sequence, and access is provided to the accompanying effects and required crew actions.

2.1.5 Day/Night Operations

Vision, navigation, and aircraft flying qualities are of primary importance for AH night missions and missions in limited meteorological conditions. The combination of an image intensifier in the Helmet-mounted Sighting and Display (HMSD) and Pilot Night Vision System (PNVS) will facilitate both the piloting task and target acquisition at night.

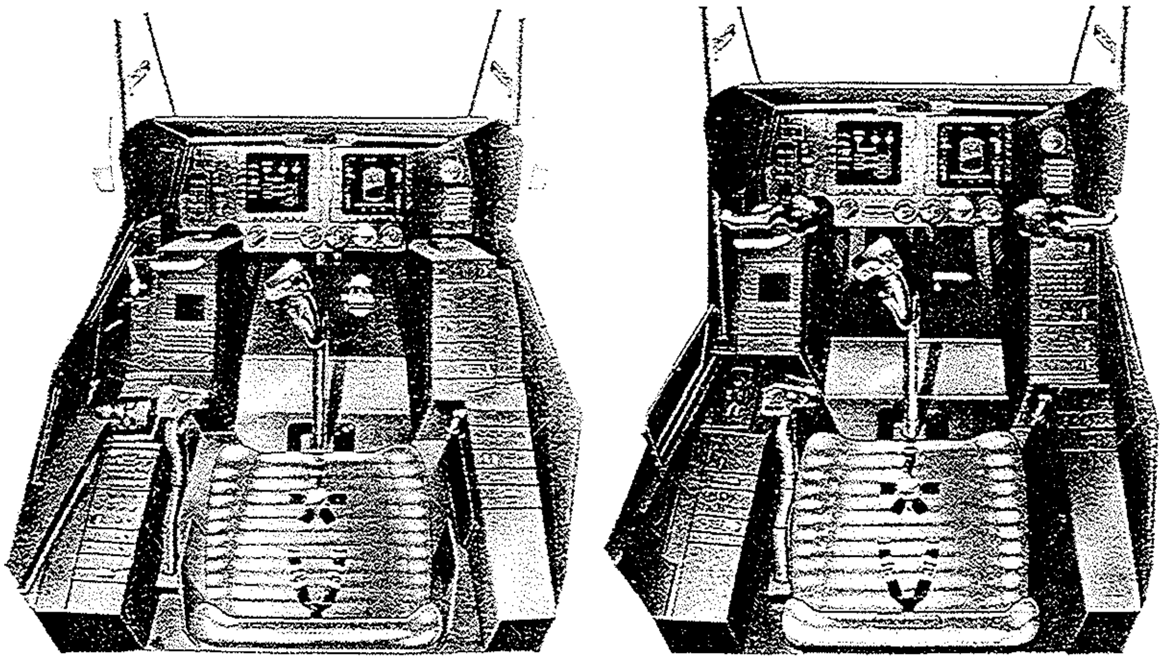


Figure 11: Cockpits

NOE flight under poor weather conditions demands an eyes-out approach at all times, making it necessary to overlay the sensor imagery with navigation and aiming symbology. In order to do this, a common video standard was chosen for sensors as well as symbology.

Key features of the Rooivalk AH night/adverse weather capability are:

a. Superior vision at night and in adverse weather. For night vision or vision in limited meteorological conditions, the Rooivalk air crew may select thermal images from the following sources:

   (i) Aircraft nose-mounted, stabilised sight with wide, intermediate and narrow field of view.

   (ii) Nose-mounted Pilot Night-vision System (PNVS)

b. Integrated helmet-mounted, third-generation, night-vision goggles as an alternative to IR imagery.

c. An excellent field of view is available from both cockpits.

d. Navigation. The navigation system performance provides the Rooivalk AH with superior navigation precision for operations at night and in adverse weather.

e. The global positioning system-dependent navigation enables a positional accuracy of 29 m.

f. When operating from only the independent, on-board sensors, the navigation system position error does not exceed 1% of the actual distance flown.

g. Aircraft Flying Qualities. Flying qualities of the Rooivalk AH are tailored to Nap-of-the-Earth flight at night and in adverse weather conditions. Pilot workload in the low-speed regime is particularly low, aided by enhanced AFCS functions. These include hover capture and hover hold modes.

2.1.6 Affordable Availability

From the outset, integrated logistics and supportability were key design drivers. This resulted in the following characteristics:

a. High reliability and ease of maintenance under field conditions, leading to quick operational turnaround times with a minimum of logistics support resources required. Statistically, the predicted overall fault rate is 224 per 1 000 flying hours for all faults and mission failure rate is 29 per 1 000 flight hours. Total maintenance man-hours (preventive and corrective at first and second line) per flying hour is predicted to be 2.53.

b. High-coverage built-in test equipment, reporting to a sophisticated health and usage monitoring system, monitors health usage trends and performance.

c. Component interchangeability with the Puma and Super Puma medium-transport helicopters.

d. High usage of off-the-shelf components and common support equipment.

e. Maximum use of existing support infrastructures.

f. Sponsons and cowlings double as working platforms.

g. Easily downloadable maintenance data to a Maintenance Data Station (MDS) for post-flight analysis.

h. Numerous large access panels.

i. Low-cost testing procedures to minimise transfer of "no fault found" items to higher levels of maintenance.

j. A design goal of 90% operational availability.

k. An inherent availability of not less than 97%.

2.2 Overall Layout

2.2.1 Principle Specifications

Table 1: Principle Rooivalk Specifications

Parameter	Specification	Notes
Empty Mass	5 189 kg	
Max. Take-off Mass	8 750 kg	
Anti-tank Mission Over-target Mass (Prime Mission)	7 278 kg	8 x ATGW, 4 x ATAM, 400 rounds 20-mm ammunition.
Fast cruise speed	138 knots	ISA sea level, (7 278 kg)
Max. Oblique rate of climb	2 015 ft/min	ISA sea level, (7 278 kg)
Max. range	377 nm 830 nm	Internal fuel External fuel
Hover Ceiling (OGE)	11 300 ft	ISA, (Prime Mission)
Manoeuvrability Normal max. Load factor Max. Transient load factor	 1.8 *g* 2.4 *g*	ISA sea level, (7 278 kg) 70 KIAS
Agility Excess Hover Power Margin Max. Translational Speed	 52 % 50 knots	ISA sea level, (7 278 kg) Gearbox T.O. limit
Engine Power	2 x 1 236 kW	Maximum Continuous
Single Engine Super Contingency	1 573 kW	30 Second

2.2.2 Principle Dimensions

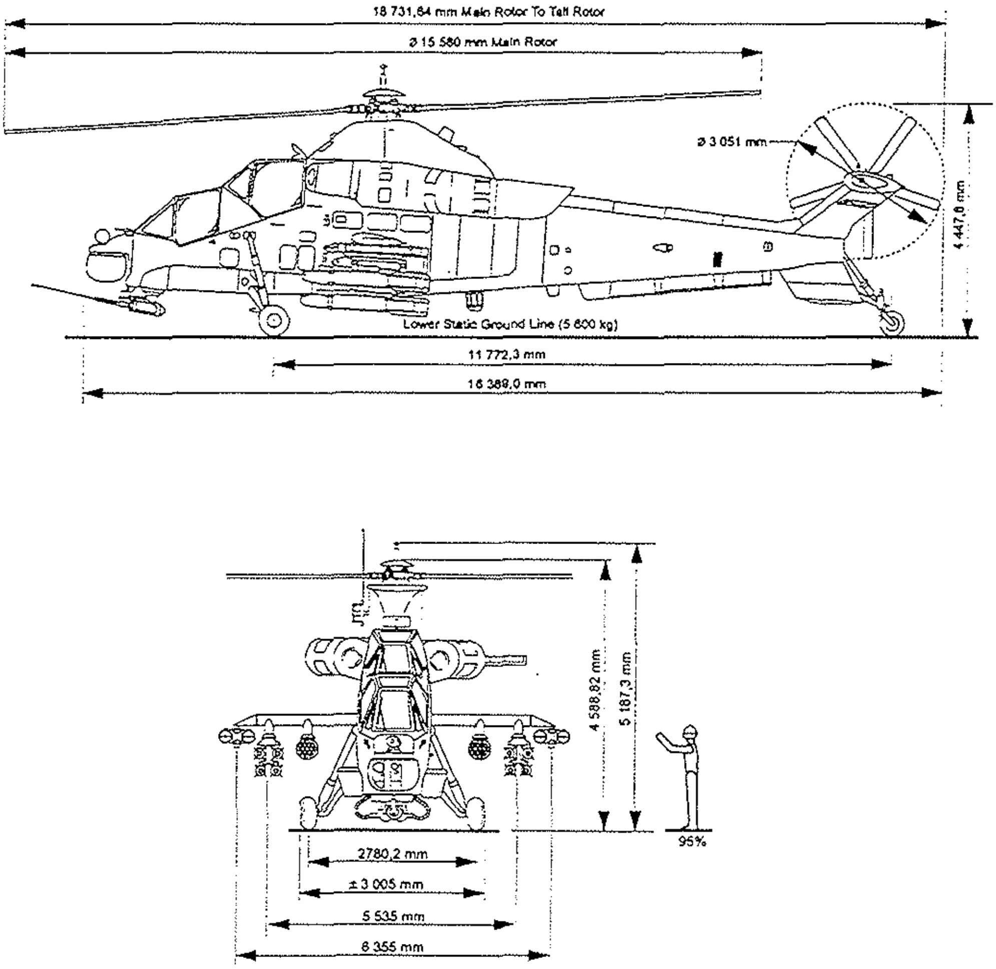


Figure 12: Principle Rooivalk Dimensions