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DEVELOPMENT OF THE WESTLAND 30

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1. INTRODUCTION

Visitors to the Sixth European Rotorcraft and Powered Lift Forum two years ago in Bristol may have heard Alan Doe's introduction to the Westland 30, a new short-range helicopter for the civil market (Ref.1). This aircraft which has now been granted civil certification, has entered service with British Airways Helicopters and 32 aircraft have been ordered by customers in North America and Europe.

The aircraft is now know as the Westland 30 Series 100 and two developments of the basic aircraft have since been designed. The first will shortly be commencing certification flight trials and is designated Westland 30 Series 100-60, while the second is in the prototype build stage and is designated Westland 30 Series 200.

This paper describes the differences between these developments and the basic aircraft, and the performance and other benefits which accrue, with reference to the sectors of the civil market for which the developments are optimised. The potential for further development is then examined, with particular attention to the main gearbox, semi-rigid rotor head and a composite main rotor blade.

2. WESTLAND 30 SERIES 100 - THE BASIC AIRCRAFT

We begin with a quick reminder of the basic aircraft, the Westland 30 Series 100 (Fig.1).

The concept of the Westland 30 (Fig.2) was to marry the proven dynamic system of Lynx with a new spacious cabin offering a standard of passenger comfort previously available only in fixed wing civil aircraft. The passenger layout is depicted in Fig.3. The cabin interior is carefully left unobstructed, with a liberal availability of hardpoints in the cabin floor - in this way a wide variety of roles both civil and military is made possible (Fig.4). The advantages of using the Lynx dynamic system are summarised in Fig.5.

3. WESTLAND 30 SERIES 100-60

The changes incorporated to the basic Series 100 aircraft in the design of the Series 100-60 and the benefits which result are summarised in Fig.6.

The primary feature is the incorporation of uprated Rolls Royce Gem 60-3 engines in place of the Gem 41-1 engines in the Series 100. The take off rating at SL ISA is improved by 180 h.p. from 1000 h.p. to 1180 h.p. This is accompanied by an increase in max. all-up weight from 12350 lbs to 12800 lbs, which is achieved without recourse to significant changes to the transmission or the structure. A digital Hamilton Standard engine control system is introduced for improved weight and engine response.

The main benefits of these improvements are seen in improved payload-range and WAT compliance. Fig.7 shows the increase in range at full payload of about 70 nautical miles over the basic Series 100. Fig.8 shows that the improvement in WAT compliance is about 1700 lbs at a given temperature or, expressed the other way, 15°C at a given weight.

4. WESTLAND 30 SERIES 200

The changes and benefits from the Series 100-60 to the Series 200 are summarised in Fig.9.

Again the major change is in the powerplant : the Gem engines are replaced in this aircraft by twin General Electric CT7-2 engines. To accommodate the high speed output of the CT7, reduction stages are incorporated onto the main gearbox. Changes are required to the main gearbox lubrication and opportunity is taken to introduce 3 micron oil filtration to reduce wear and prolong gearbox lives. One feature of the Westland 30 range is the vibration isolation of the engines and transmission on a 'raft' mounted on the fuselage via elastomeric bearings; the incorporation of the larger engines necessitates an extension to the raft decking beneath the engines for the Series 200. The CT7 engine is equipped with an integral particle separator. This has been shown by ingestion tests in the UK and USA to be extremely effective at separating small lumps of debris or shed ice. The Series 200 engine installation features sideways facing air intakes to protect the engine from bird ingestion and damage from large lumps of shed ice, thus providing an extremely high standard of overall engine protection.

The Series 200 is offered at the same all-up weight as the Series 100-60, to permit the use of the same proven structure and dynamic system and is therefore still optimised for the short haul operator. The very substantial increase in available engine power is however of benefit to two clearly defined sectors of the market:

(1) Customers operating from congested or restricted areas such as city centre heliports or oil rig platforms, where superb single engine performance makes vertical and short take-off/land possible with Category A safety levels. Fig.10 demonstrates this feature by showing that the single engine performance of the Series 200 allows hover out of ground effect on one engine in temperate climates, at aircraft weights approaching max. all-up weight.

(2) At the other end of the climate scale, Fig.11 shows that the max. all-up weight is completely unaffected by sea level WAT limitations up to ISA + 35°C and beyond, making the aircraft very attractive to operators in the tropics.

5. FUTURE DEVELOPMENT OF THE WESTLAND 30

The growth strategy for future developments of Westland 30 is summarised in Fig.12. The Westland 30 is well-placed for growth versions, in that the majority of those helicopter components which are expensive, time-consuming and of technical risk to design are, on the basic Series 100 aircraft, already of advanced technology and capable of considerable development. In this category are the semi-rigid main rotor head and the main gearbox. Such development of proven technology confers the advantages of safety (due to an extensive knowledge of the technology from rig and flight test), reliability (due to experience of failure modes and elimination of factors affecting reliability) and lightness (due to the elimination of any over-design as loads are progressively increased).

In parallel with the development of existing technology, advanced technology is available particularly in the fields of composite manufacture and electronics. The use of composites brings savings in weight, but also and more significantly a freedom from manufacturing constraints in the production of rotor blades, that allows advanced aerodynamic designs, with substantial performance improvements over the standard possible with the manufacture of metal blades. The recent advances in micro-electronics have made possible the use of computing functions on helicopters, at low weight and high reliability.

Fig.13 shows the application of the above strategy to the specific components of the Westland 30 range. In the remaining time available, it will be possible to cover five of these areas in more detail - the 3-pinion main gearbox, the semi-rigid main rotor head, the Lynx/W30 family composite blade, health and usage monitoring and the digital core avionic system (DCAS).

6. DEVELOPMENT OF EXISTING TECHNOLOGY

6.1. The 3-pinion main gearbox (Fig.14)

The Westland 30 main gearbox is built around a conformal wheel, supported by the main output shaft and driven by two pinions, which are in turn driven by two engine input bevels. The tail take-off drive is via a third conformal pinion at the rear of the box. This simple arrangement, known as the 2-pinion gearbox and used in the basic version of the Lynx helicopter, was substantially uprated by the addition of a load-sharing train, concentric with the conformal train (but free to rotate independently), and flexible quill-shafts between the input drive and the conformal pinions. In this way, any combination of loading on the two inputs is shared equally by the three conformal pinions.

The gearbox is capable of further development, as the main casting has demonstrated reserve strength and the gears that limit the present power capability can accommodate an increase in face-width within the geometrical constraints of the overall arrangement. In particular, the face width of the conformal train may readily return to the dimension it had before it was reduced with the introduction of the load-sharing train. The growth in power capability of the gearbox is shown in Fig.15 in terms of continuous rating with the development potential identified.

6.2 The semi-rigid main rotor head (Fig.16)

The semi-rigid main rotor head designed for the Lynx helicopter is hinged only in the feathering axis, the freedom in flapping being allowed by bending of the "cutlet" on the hub, and in lag by the bending of the "dogbone" attached to the blade, outboard of the feathering sleeve. Centrifugal loads are borne across the feathering sleeve by a torsion strap or "tie-bar". This design is light and provides a crisp and powerful response to control inputs. Fig.17 shows the potential improvement of the existing design in terms of cruise speed and all-up weight. These improvements may be achieved by the addition of a fifth blade arm; improved material and heat treatment; refined cutlet geometry; and a move from cylindrical to rectangular tie-bar recesses. These last two features may be more easily introduced with recent improvements in electro-chemical machining technology.

7. APPLICATION OF ADVANCED TECHNOLOGY

7.1 The Lynx/W30 composite main rotor blade

The Lynx/W30 composite main rotor blade (Fig.18) will be capable of retro-fit to existing Lynx and Westland 30 designs with dramatic blade life and vehicle performance improvement, as well as to later developments of both aircraft. As previously mentioned, the performance improvements result from the freedom in aerodynamic design afforded by the composite manufacturing method.

The innovative features of aerodynamic design are twofold. The more obvious is the advanced planform tip and the other is the use of advanced sections employing aft loaded and reflexed aerofoils distributed along the span. These features are now briefly studied in turn.

Fig.19 breaks down the benefits of the swept 'BERP' (British Experimental Rotor Programme) tips. On the advancing blade, the sweep postpones Mach No. limits and therefore extends Mach-related rotor limitations at both high and low speeds. This benefit was somewhat unexpectedly found to be extended when test results showed that the use of thin sections on the tip (again beneficial at high Mach No.) did not have the usual adverse effect on the retreating side of the disc. This tolerance to section on the retreating blade is thought to indicate that the effect of erosion or ice accretion on the leading edge of the tip will be less than typically found. However the primary benefit of the tip on the retreating blade is the containment of stall growth. The tip itself is extremely resistant to stall, as demonstrated by Fig.20. In this wind tunnel static experiment, the BERP tip did not stall until 22° incidence, as compared to 12° incidence on a conventional tip (ref.2). With the tip region unstalled, the growth of a stalled region inboard is controlled as shown by Fig.21 (ref.3). The lower half of this figure shows how vibratory control load divergence is thus contained, giving some 10% improvement in available thrust.

The development of aerofoil sections with increased lift capability is depicted in Fig.22, in terms of camber applied to the forward part of an aerofoil (nose droop) or the rear part (aft loading or, if negative camber, aft reflex). Also shown are the levels of CLmax achievable with combination of forward and aft camber. A development from the basic symmetrical NACA 0012 section, applied to the Lynx rotor, was RAE 9615 which achieved a significant increase in lift by a modest addition of nose droop. However this means of improving lift is limited by the resulting pitching moment - a blade Cmo of about -0.02 is about the minimum tolerable by a typical control circuit. A further development (RAE 9646) overcame this limitation by offsetting the pitching moment generated by more substantial nose droop, with the powerful effect of aft reflex. The net pitching moment is seen to be zero, but the CLmax has increased by some 30% over that of NACA 0012. The latest means of achieving greater lift capability as featured in the design of the Lynx/W30 composite blade, is by distributing sections with varying combinations of nose droop and aft reflex, along the span of the blade. Thus near the tip of the blade, where lift capability is paramount, RAE 9645 is used to achieve a further increase in CLmax by the use of more aft loading than RAE 9646: then the pitching moment generated is reduced to about zero over the blade as a whole, by the use of sections such as RAE 9648 with appreciable aft reflex, over the inboard portion of the blade.

The overall extension of blade aerodynamic limits possible with the distributed sections and the 'BERP' tip is shown qualitatively in terms of thrust coefficient and advance ratio on Fig.23, by a comparison between the existing Lynx blade and the Lynx/W30 composite blade.

7.2 Usage and health monitoring

The benefits of usage and health monitoring are outlined on Fig.24, which also clarifies the distinction between them.

Usage monitoring not only reduces operating costs through less frequent replacement of components exposed to fatigue or creep, but also contributes to safety as the integrity of the component is no longer dependent on a predicted spectrum of usage, but on the recorded actual usage. With a display of the damage being accrued by dynamic components, operators can actually extend component lives by the use of non-damaging flying techniques. Also component weights may be reduced, as design factors formerly included to cover damage prediction errors may be removed.

Health monitoring is designed to provide early warning of failures from unpredictable causes and therefore contributes chiefly to improved safety standard. However as in the case of usage monitoring, health monitoring contributes to extending on-condition maintenance, which reduces operating costs through less frequent component renewals.

The usage and health monitoring fits for existing Westland 30 designs and under active consideration for future developments are summarised in Fig.25. Derek Astridge is giving a detailed paper on this subject later in the forum (ref.4).

7.3 Digital Core Avionic System (DCAS) (Fig.26)

DCAS is a cockpit management system being jointly developed under an agreement between WHL and Racal-Decca Ltd. The system is being actively considered for future developments of Westland 30.

The diverse functions of the system and the benefits to be derived are listed in Fig.26. Among its other functions it is ideally suited to manage the expanded usage and health monitoring functions mentioned and is of equal service to the pilot and maintenance crew in storing and displaying operational and diagnostic information. In this capacity it is fully compatible with colour or monochrome CRT displays which offer improved flexibility over existing instruments.

8. CONCLUDING REMARKS

The paper has reported on two developments of the Westland 30. The Series 100-60 will shortly be commencing certification work and the design of the Series 200 is virtually complete.

The aircraft has been shown to be suited to further development and some of the areas in which development is being actively considered have been described. Other development investigations precluded from description by time available are further redundancy in the hydraulic system and automatic flight control system, and the development of an undercarriage offering improved protection to passengers and crew in the event of exceptionally high rates of descent.

The over-riding emphasis in further development of the Westland 30 is on maintaining and improving on the Westland 30's inherently high standard of safety and reliability.

9. REFERENCES

1. R.A. Doe, Westland WG30, Forum Proceedings of the 6th European rotorcraft and powered lift forum, Paper No.6, Sept. 1980

2. G.M. Byham and S.J. Newman, A wind tunnel experiment on the aerodynamic characteristics of two tip planforms, WHL Research Paper 525, June 1976

3. F.J. Perry, A statement and classification of the aerodynamic performance benefits to be expected from advanced main rotor blade tip planforms, WHL Aero Tech Note/GEN/031, August 1981

4. D.G. Astridge, Health monitoring of helicopter gearboxes, Forum Proceedings of the 8th European Rotorcraft Forum, Paper No. 7.3, Sept. 1982

Fig. 1. Westland 30 Series 100

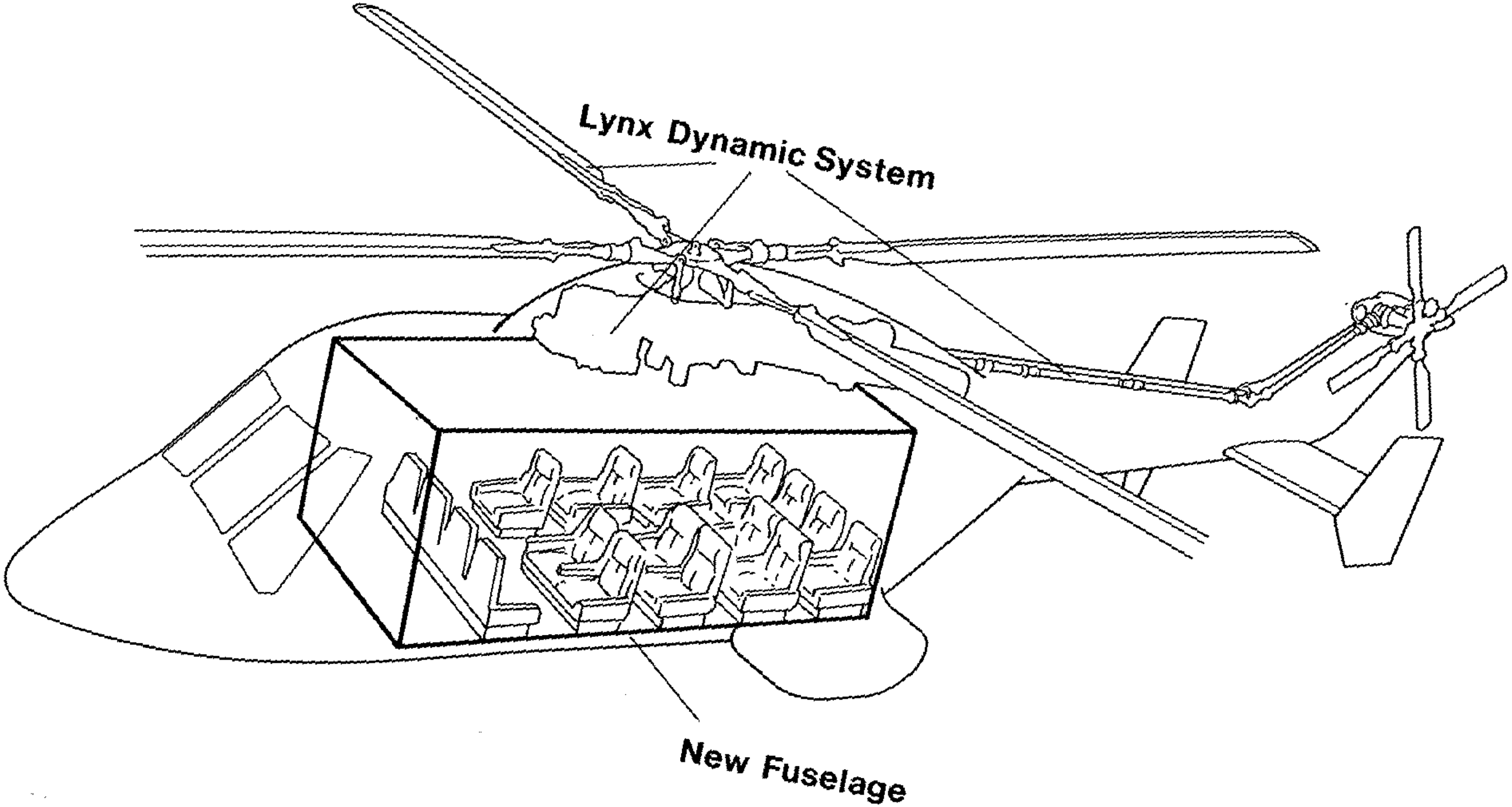
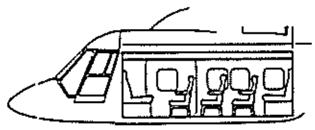


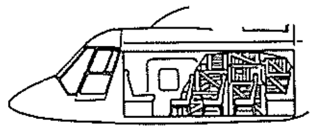
Fig. 2. Concept of Westland 30

Fig. 3. Westland 30 Series 100 Cabin Interior

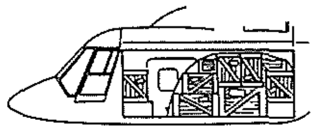


17 Passenger Version

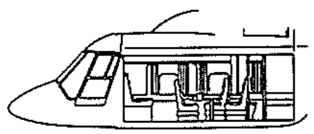
Layout



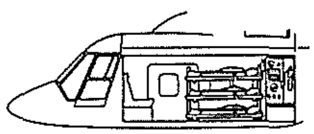
Passenger and Cargo



Freight Payload



VIP/Executive



Air Ambulance

Fig. 4. Westland 30 Series 100
Possible Layouts

Advantages of using Lynx Dynamic System

- Proven safety and reliability
- Superb handling qualities
- Excellent maintainability
- Proven tolerance to icing conditions
- Rotors well clear of head height on pad
- Low profile main gearbox leaves unobstructed cabin

Fig. 5. Westland 30 Series 100
Advantages of Using Lynx Dynamic System

Changes from SERIES 100

- Introduction of uprated Gem 60 engines
- Increase of all-up weight from 12350 to 12800lbs
- Introduction of digital engine control

Benefits

- Improved Payload-Range
- Improved WAT compliance

Fig. 6. Westland 30 Series 100 - 60
Changes and Benefits

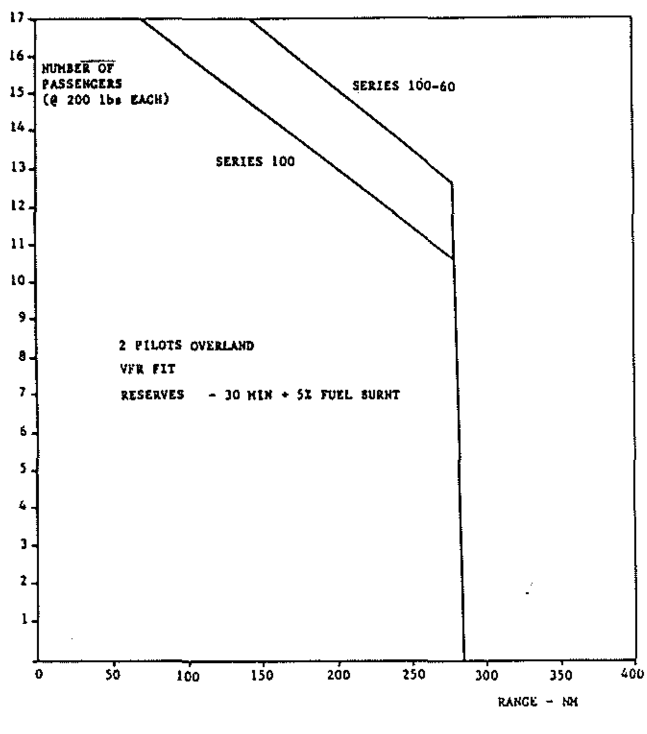


Fig. 7. Westland 30 Payload/Range

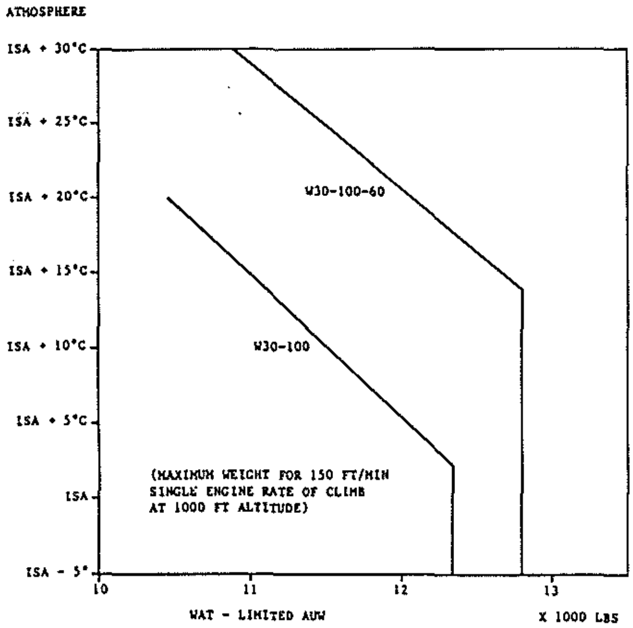


Fig. 8. Westland 30 Series 100 - 60
WAT Limit at Sea Level

Changes from SERIES 100-60

- Introduction of General Electric CT7 engines
- Reduction stage onto main gearbox
- Introduction of 3 micron filtration
- Extension of raft
- Side-facing intakes

Benefits

- Category A short field performance
- Improved hot climate capability

Fig. 9. Westland 30 Series 200
Changes and Benefits

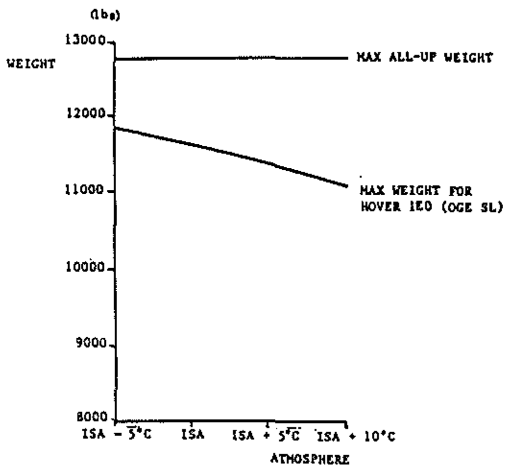


Fig. 10. Westland 30 Series 200
Max. Weight for Hover,
One Engine Inoperative

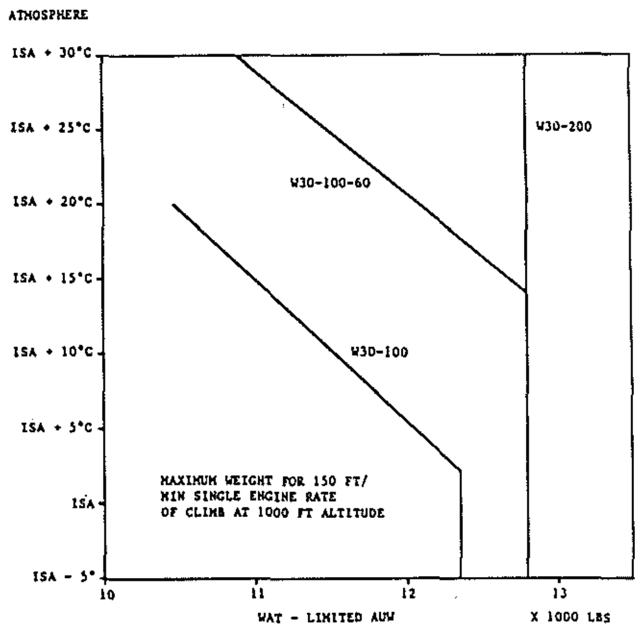


Fig 11. Westland 30 Series 200
Payload/Range

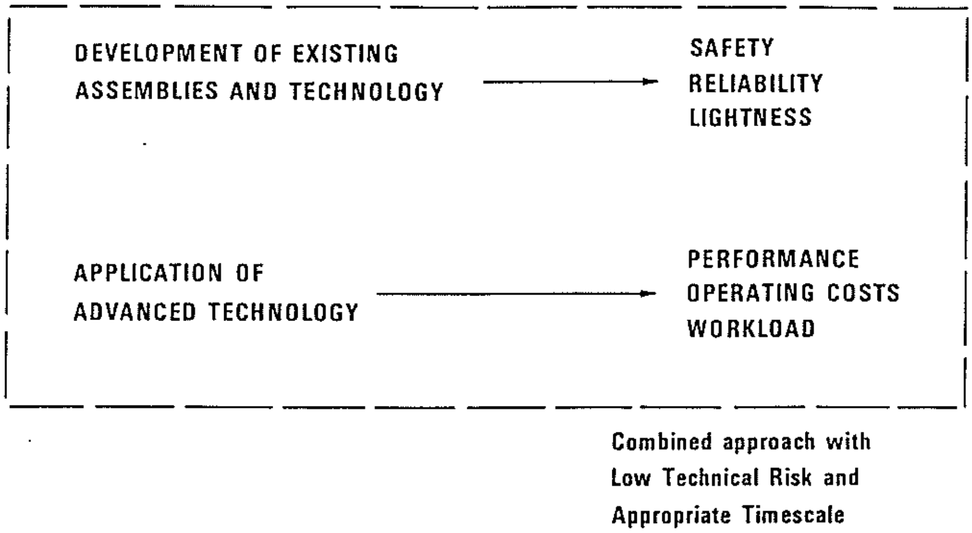


Fig. 12. Growth Strategy for Westland 30

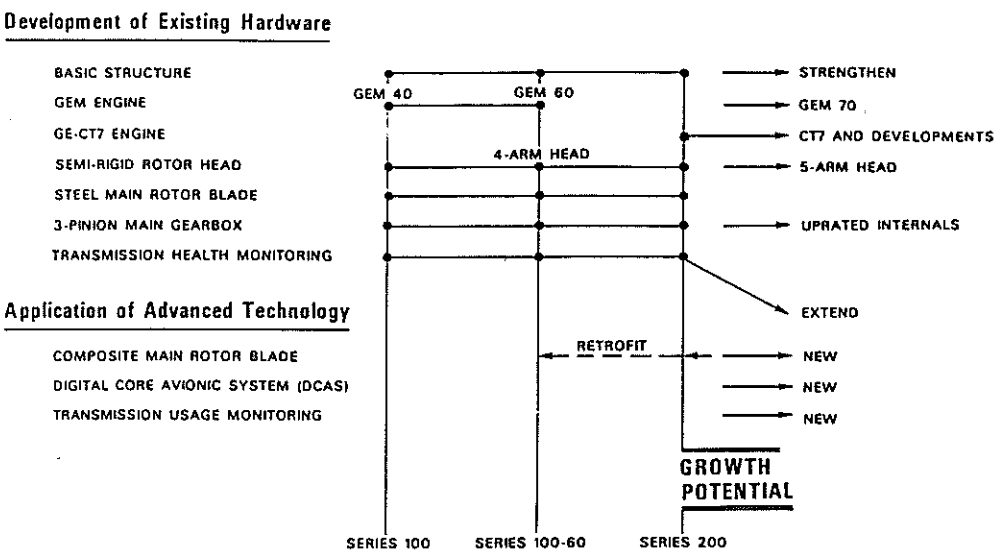
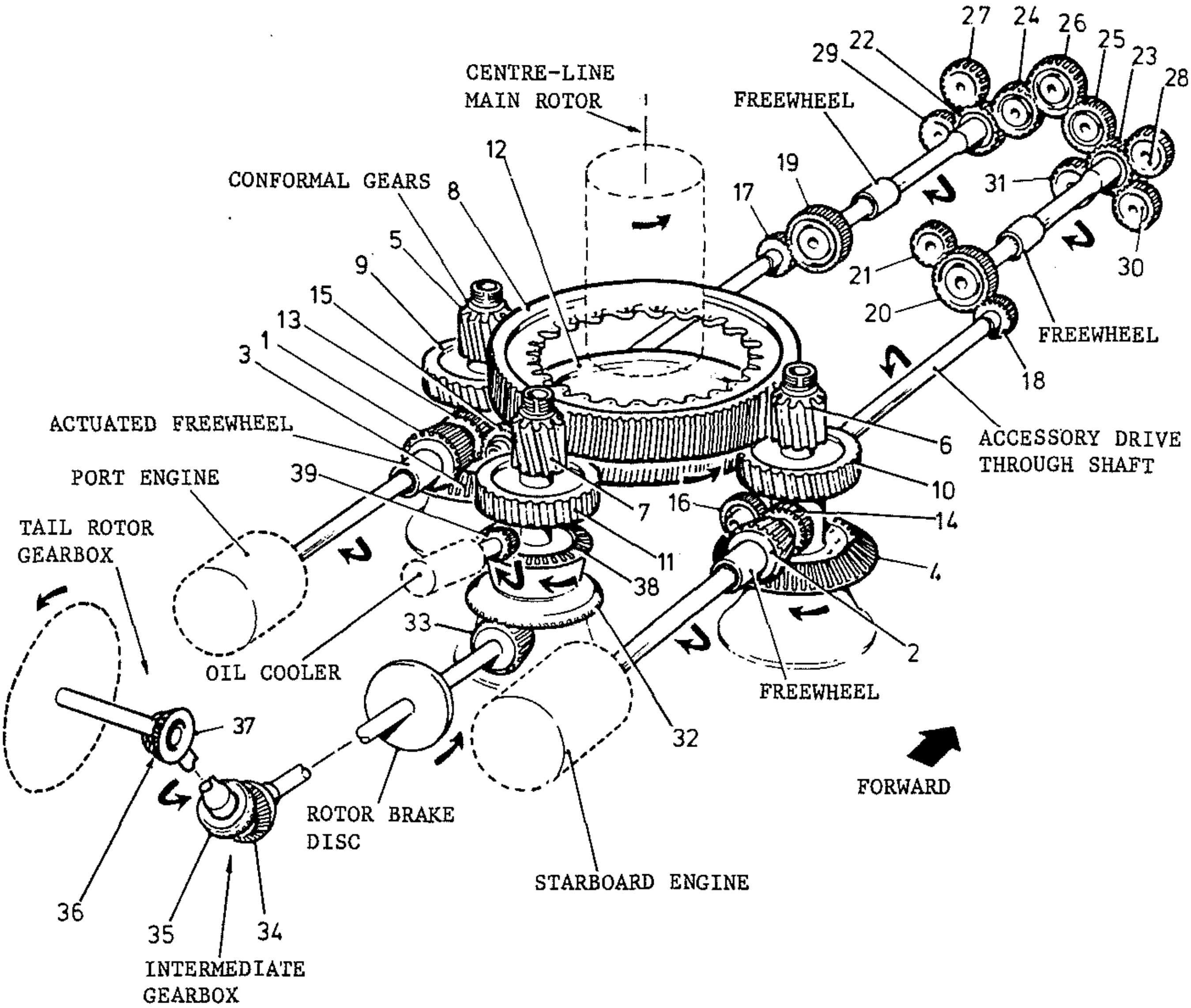


Fig. 13. Growth Potential of the Westland 30



GEAR	TITLE	GEAR	TITLE
1	Spiral Bevel Driver	21	Tacho Spur
2	Spiral Bevel Driver	22	Freewheel Housing Spur
3	Spiral Bevel Driven	23	Freewheel Housing Spur
4	Spiral Bevel Driven	24	Idler Spur
5	Conformal Pinion	25	Idler Spur
6	Conformal Pinion	26	Idler Spur
7	Conformal Pinion	27	Generator Spur
8	Conformal Wheel	28	Generator Spur
9	Load Sharing Pinion	29	Hydraulic Pump
10	Load Sharing Pinion	30	Hydraulic Pump
11	Load Sharing Pinion	31	Oil Pump Spur
12	Load Sharing Wheel	32	Tail Take Off Driver
13	Accessory Driver Aft	33	Tail Take Off Driven
14	Accessory Driver Aft	34	Inter GB Input
15	Accessory Driven Aft	35	Inter GB Ouput
16	Accessory Driven Aft	36	Tail GB Input
17	Accessory Driver Fwd	37	Tail GB Output
18	Accessory Driver Fwd	38	Oil Cooler Driver
19	Accessory Driven Fwd	39	Oil Cooler Driven
20	Accessory Driven Fwd		

Fig. 14. Westland 30 3-Pinion Main Gearbox

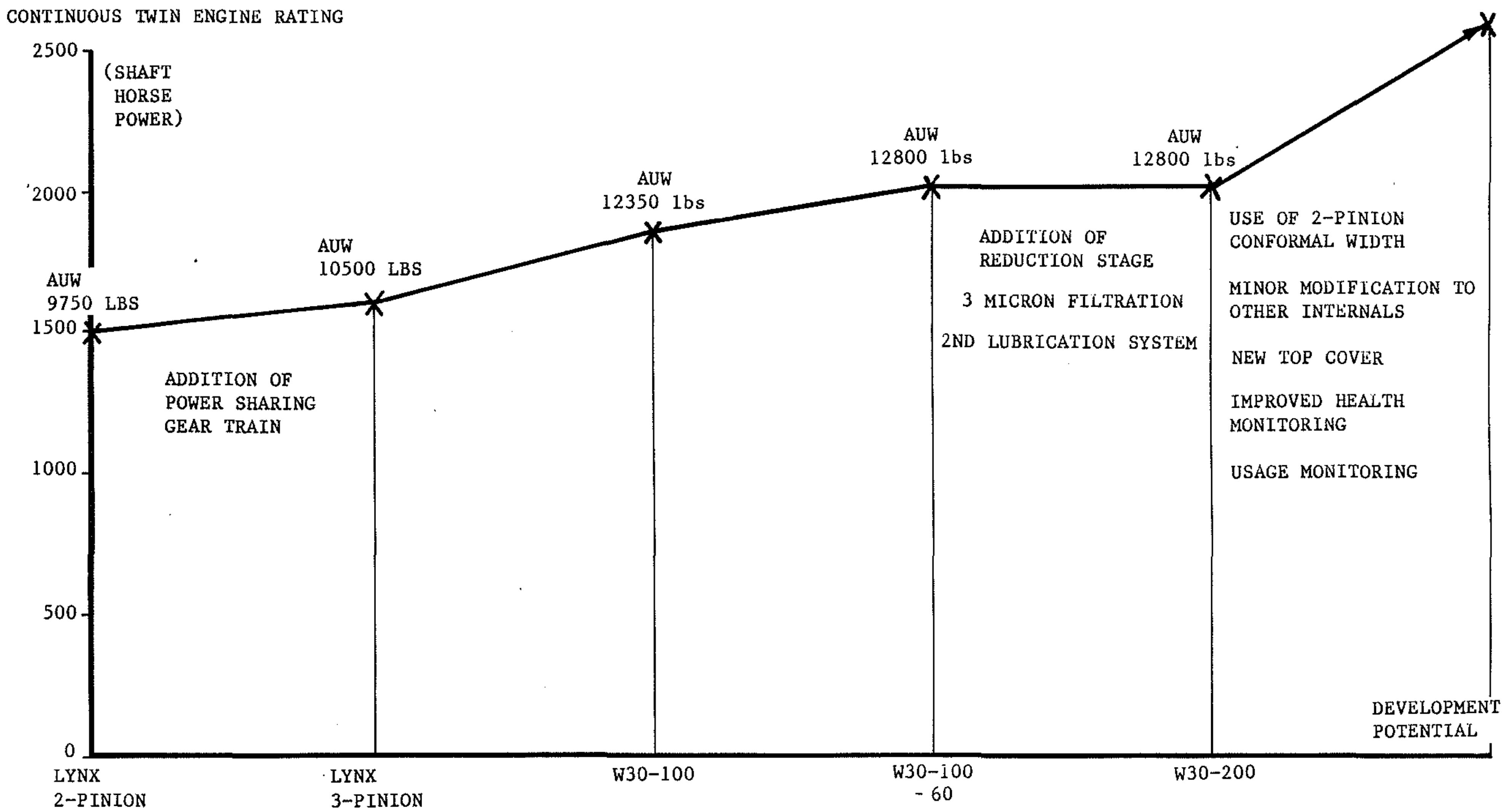


Fig. 15. Development of Lynx/W30 Main Gearbox

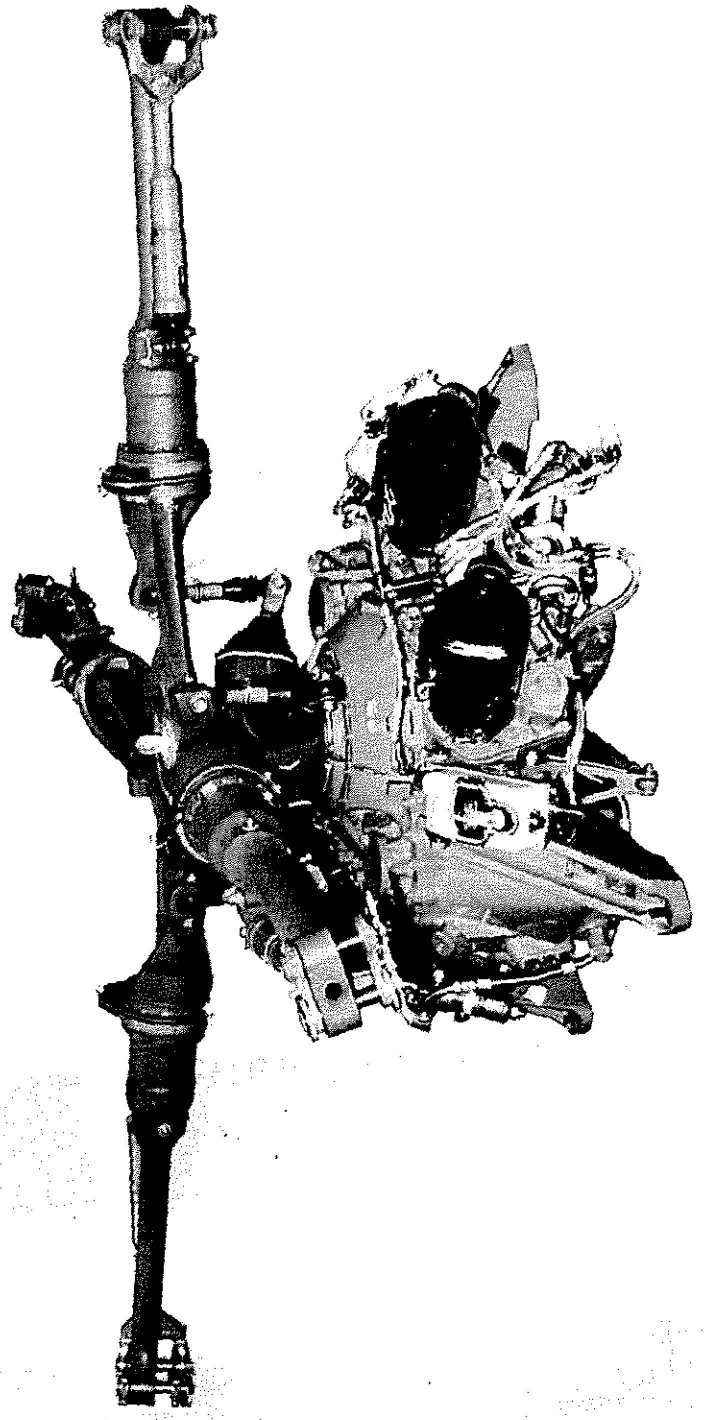


Fig. 16. Semi-rigid Rotor Head

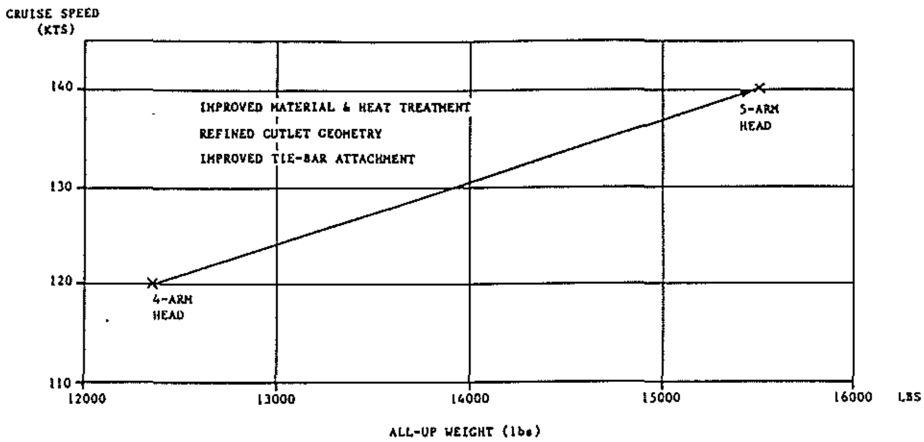


Fig. 17. Potential Improvement in Speed/Weight Capability of Main Rotor Head

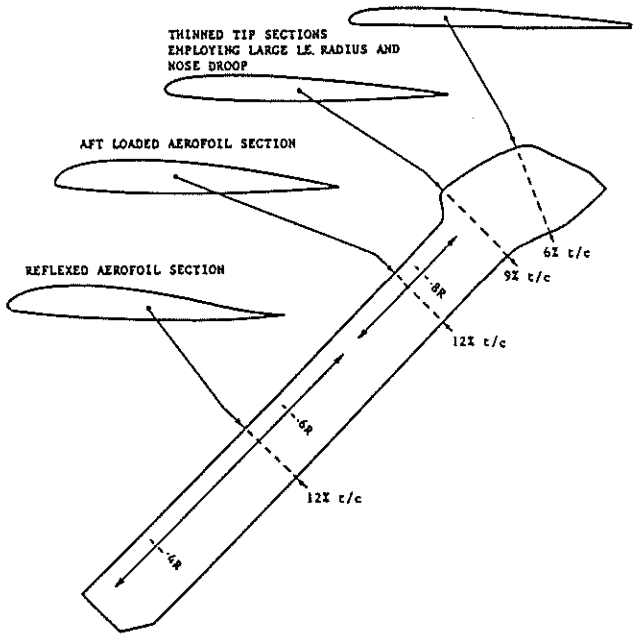


Fig. 18. Lynx/W30 Composite Main Rotor Blade

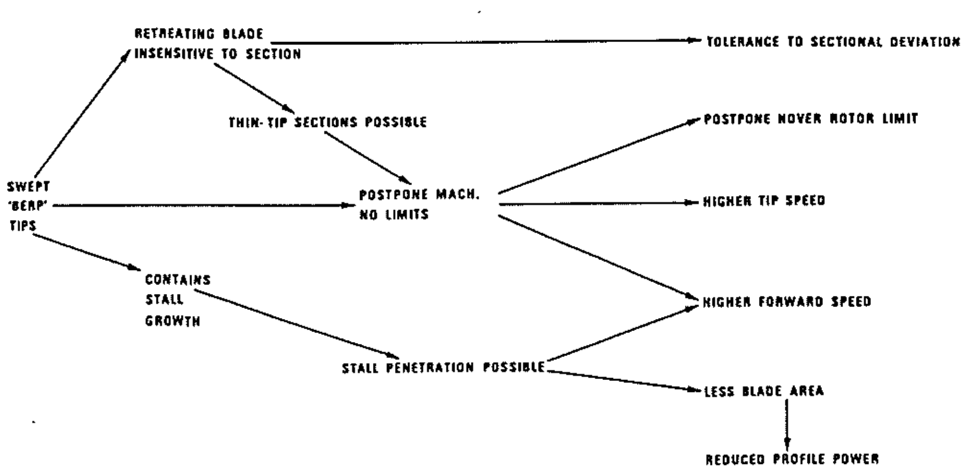


Fig. 19. Lynx/W30 Composite blade: Benefits of Swept 'BERP' Tips

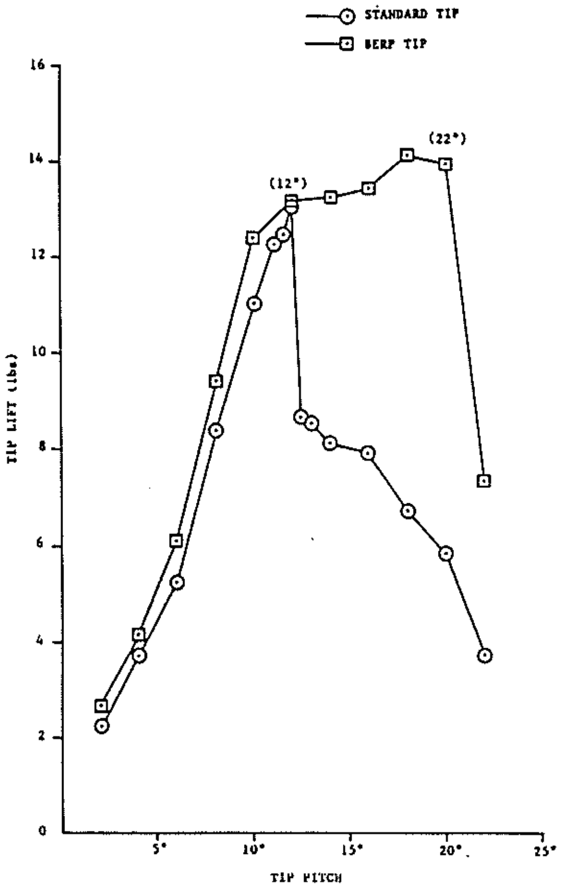


Fig. 20. W30 Composite Blade:
Delay of Stall on a BERP Tip

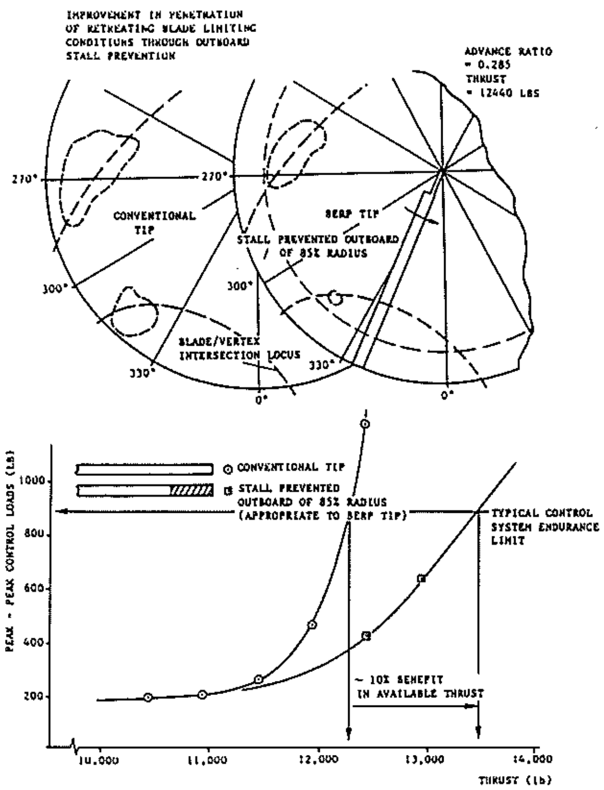


Fig. 21. W30 Composite Blade:
Thrust Advantage of Stall Growth Containment

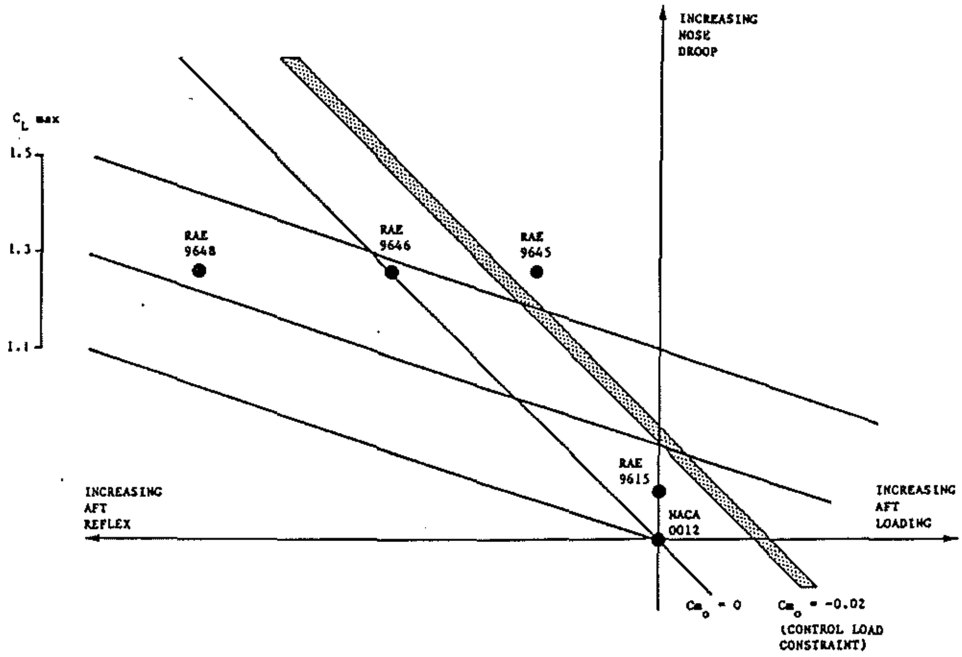


Fig. 22. Lynx/W30 Composite Blade:
Development of Sections with Increased Lift Capability

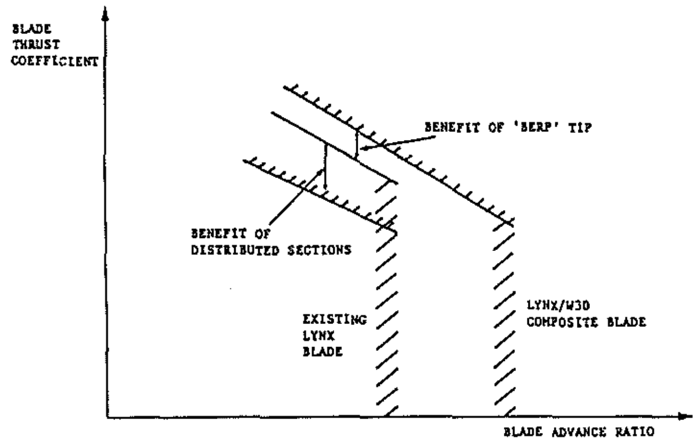


Fig. 23. Lynx/W30 Composite Blade:
Overall Improvement in Aerodynamic Limits

<u>USAGE MONITORING</u>

* RECORD AND DISPLAY OF FATIGUE LIFE USAGE
  - IMPROVES SAFETY
  - REDUCES WEIGHT
  - REDUCES OPERATING COSTS

<u>HEALTH MONITORING</u>

* EARLY WARNING OF UNPREDICTABLE FAILURES
  - IMPROVES SAFETY
  - REDUCES OPERATING COSTS

Fig. 24. Benefits of Usage and Health Monitoring

SERIES 100 AND 100-60

MAGNETIC PLUGS (ALL GEARBOXES)	· DETECT WEAR CONDITION
OIL SAMPLES (ALL GEARBOXES)	
QDM (MAIN GEARBOX)	
OIL FILTER ANALYSIS (MAIN GEARBOX)	
GROUND RUN VIBRATION ANALYSIS (ALL GEARBOXES)	· DETECT GEAR CRACKS
INTRASCOPE (ALL GEARBOXES)	· VISUAL INSPECTION

SERIES 200

AS SERIES 100 PLUS -	
ENGINE HISTORY RECORDER	· FATIGUE AND THERMAL USAGE
VIBRATION ANALYSIS OF REDUCTION STAGES	· DETECT GEAR CRACKS

FUTURE DEVELOPMENT (SHORT TERM)

TRANSMISSION USAGE MONITORING
QDM ON AFT GEARBOXES
IN-FLIGHT VIBRATION ANALYSIS
IMPROVED DATA TRANSFER

(LONG TERM)

ROTOR SYSTEM USAGE MONITORING
AIRFRAME USAGE MONITORING

Fig. 25. Usage & Health Monitoring for Westland 30

FUNCTIONS	BENEFITS
CENTRAL CONTROL/DISPLAY FOR RADIO AND NAVIGATION EQUIPMENT	WEIGHT SAVING IN DEDICATED CONTROLLERS, COMPUTERS AND LOOMING
COMPUTING FACILITY FOR NAVIGATION, TACTICAL, HEALTH AND USAGE MONITORING SYSTEMS, AUTOPILOT, LANDING SYSTEMS AND FUEL MANAGEMENT	REDUCES PILOT WORKLOAD / DUAL-REDUNDANT AND SELF-CHECKING } IMPROVES SAFETY
STORAGE AND DISPLAY OF FLIGHT PLAN/CHECKLIST	ADAPTABLE TO WIDE RANGE OF CUSTOMER REQUIREMENTS
CONVENIENT DATA TRANSFER DEVICE FOR MAINTENANCE AND OPERATIONAL USE	REDUCES MAINTENANCE HOURS

Fig. 26. Digital Core Avionics System (DCAS) for Westland 30