DEVELOPMENT OF A LOW COST PRODUCT: THE K-MAX[R] STORY

by
Michael V. Hoagland
Project Engineer
Kaman Aerospace Corporation
P.O. Box 2
Old Windsor Road
Bloomfield, CT 06002

Abstract

Kaman Aerospace Corporation is creating the world's first medium lift commercial helicopter specifically designed for external lift. K-MAX[R] is an "aerial truck" designed for lowest operating costs, the highest level of safety and reliability, and overall economic viability. To achieve low cost, K-MAX[R] utilizes intermeshing rotor technology which exhibits superior lift due to the efficient use of power, and offers a simple and reliable design with no tail rotor or hydraulic system. This paper describes the successful achievement of low acquisition costs through employing integrated product teams to design a simple, producible product. With a focus on potential user applications, K-MAX[R] can carry more payload for fuel used, can be maintained with minimum manpower, is single piloted, and has fewer parts to maintain and track. To the operator, this means reduced cost and increased revenue generation capability.

Introduction

K-MAX[R] shown in Figure 1, is based on a unique and innovative intermeshing "synchro-lift" technology pioneered by Kaman. This technology, developed primarily for military use, has direct application in the commercial sector. The potential commercial market was surveyed for end-use requirements and factors to be considered in the design process to ensure maximum performance margins for the K-MAX[R]. The logging application was found to impose the most strenuous operational requirements because of severe repetitive loads inherent in helicopter logging operations. The logging application also imposed restrictive environmental constraints. The K-MAX[R] was developed to accommodate this most rigorous application.

Figure 1. K-MAX[R] : The Aerial Truck.

The result of Kaman's design efforts to meet these requirements is a simple, reliable, single seat helicopter which uses traditional aircraft materials but is uniquely rugged with new levels of pilot protection, visibility, and maintenance ease. K-MAX[R] capitalizes on the advantages of intermeshing rotor lift efficiency and the well-established Kaman aerodynamic servo-flap control system integrated into all Kaman helicopters.

A key technical goal for K-MAX[R], to ensure its commercial viability, was to incorporate simplicity and durability to achieve unprecedented reliability and low operating costs. This goal is achieved by:

- using a derated engine for increased reliability and performance margin;

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- designing the transmission and composite rotor blades for infinite life under full load operation;
- designing all components to exceed a life span of 10,000 hours with a time between overhaul of 2,500 hours;
- designing for single pilot operation; and
- constructing the rugged airframe of conventional sheet metal for economy and durability.

Intermeshing Rotor and Servo Flap Technology Benefits

Intermeshing rotor helicopters, as compared to other Vertical Take Off and Landing (VTOL) technologies, are simpler and more efficient in their use of the available power because of their high-aspect ratio rotors, low disc loading and use of servo flaps mounted on the rotor blades for rotor control. The use of servo flaps eliminates the need for hydraulic control due to low control system feedback loads. Since hydraulic control of the rotors is not necessary, the need for a hydraulic system and maintenance associated with hydraulics is eliminated. Additionally, intermeshing rotor helicopters offer the major advantage of no tail rotor. This results in reduced weight, simplicity and more efficient use of the available power in generating lift. Typically, up to thirty percent of main rotor horsepower can be consumed by a tail rotor, in certain instances. (1)

A significant benefit of the K-MAX^R intermeshing technology is the high gross weight to empty weight ratio which allows more fuel and payload to be carried. Figure 2 illustrates the gross weight/empty weight ratio for intermeshing rotors compared to other VTOL powered lifters. This high gross weight/empty weight ratio was achieved

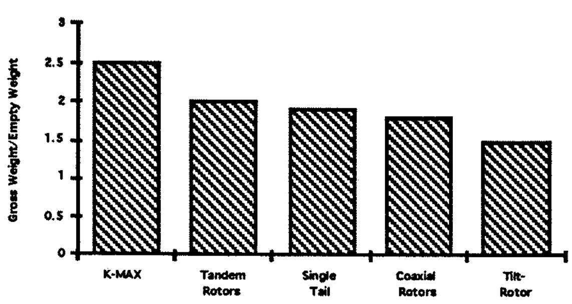

Figure 2. VTOL Powered Lifters Comparison

through compact rotor drive packaging and the use of aggressive concurrent engineering development, Computer Aided Design/Computer Aided Manufacturing (CAD/CAM) and related technologies which allowed Kaman to produce a state-of-the-art intermeshing helicopter.

The intermeshing rotors are displaced and tilted laterally resulting in a high-aspect ratio rotor system which allows each rotor to entrain large volumes of free air with minimal vortex losses (energy losses). By making use of the third (lateral) dimension possible with the intermeshing configuration, each rotor is supplied with a significant supply of undisturbed air resulting in improved rotor performance. Furthermore, since the two rotors counter rotate and generate lift, a large disc area results. The large disc area produces low disc loading which in turn reduces power requirements and the amount of fuel burned thereby resulting in longer endurance. (1)

Another benefit of intermeshing rotors with the servo flap system is the inherent simplicity which results in fewer parts and high reliability as compared to other VTOL configurations. K-MAX^R uses a single central transmission for power transfer from the engine to the rotors. As previously mentioned, there is no hydraulic system, no tail rotor and associated dynamic components. (1)

K-MAX^R Development Approach

Lessons Learned. The K-MAX^R represents the culmination of lessons learned from when the company was founded in 1945 to the present. Since that time Kaman has produced over 400 intermeshing helicopters for the U.S. Navy, Marines, and Air Force, proving the technology reliable with an exceptional safety record. As an example, Kaman's intermeshing H-43 Husky helicopters (figure 3) are currently in use by commercial users for various vertical lift applications. These users expressed a high degree of satisfaction and cost effectiveness using the H-43 which is a surplus U.S. Air Force aircraft. The H-43 was found to clearly have the agility and altitude advantages of the intermeshing configuration necessary, for example, to harvest timber at any altitude.

Figure 3. H-43 Husky.

The positive feedback from the H-43 users gave Kaman the necessary insight and confidence to commit to the K-MAX^R project knowing that commercial viability was assured. The lessons learned from the various military and commercial users is that the simplicity, reliability, and efficiency inherent in intermeshing helicopters gives the user distinct advantages in ownership.

Market Survey. Kaman's survey of the commercial helicopter market in 1990 clearly identified the need for a helicopter designed specifically for vertical lift applications requiring repeated load/unload cycles. This survey revealed that helicopter operators used commercial aircraft (people movers) and surplus military aircraft for applications they were not designed for, thereby not realizing full economic potential. Kaman set out, therefore, to capture a niche market by developing the K-MAX^R specifically for vertical lift applications where repeated load/unload cycles are the norm. These applications include logging, reforestation, fire fighting, construction, mineral/oil field development and support, seismic exploration, and all forms of high altitude work requiring exceptional lifting performance. By developing a helicopter focused on these vertical lift applications, Kaman could design-in the end use requirements and user factors critical for a commercially viable vertical lift helicopter.

System Development Overview. The K-MAX^R is designed from the ground up as an aerial truck to be a cost-effective money maker for the user. The innovative approach for K-MAX^R mandated from the outset that specific features important to the various users be incorporated, thereby allowing the users participation and "ownership" in the K-MAX^R design. The potential commercial market, therefore, was surveyed for end-use requirements and factors to ensure the user's operational and environmentally friendly features and performance margins were considered. For example, the nature of helicopter logging requires high cycles of load/unload repetition carrying maximum loads with spike load conditions. This application required a thorough understanding of the operational scenario to develop the mission fatigue spectrum, used in part, to size the aircraft. One area of the design, for example, where this was a particular driver is the gearbox. The gearbox uses a stronger freewheel unit which is typically subjected to high cycle fatigue conditions due to the repetitive power on/off cycles associated with log lifting. These conditions can adversely impact the life and reliability of the gearbox if not properly considered early on. Figure 4 shows the K-MAX^R in the logging role.

Other user requirements center around the ability of the pilot to safely and efficiently operate the helicopter by incorporating human engineering factors. These factors included maximized pilot visibility using unique "bubble" windows coupled with a narrow cockpit that enhances visibility both left, right, and downward. Also, the main landing gear is set back to give a clear sight line of the external load. Placement of pilot controls and instruments are compatible with vertical reference operations. For hot weather operations, the pilot doors can be removed. For increased pilot protection during rough landing and crash conditions, the pilot's seat is the first energy absorbing seat to pass the new FAA crashworthy seat requirements.

Factors affecting the environment were considered early on and features were incorporated to make the K-MAX^R environmentally friendly. For example, in certain regions of the country such as the northwest national parks, logging operators are restricted from all logging activities on weekends and holidays. This restriction is in response to tourist complaints of excessive noise generated by the single main/tail rotor

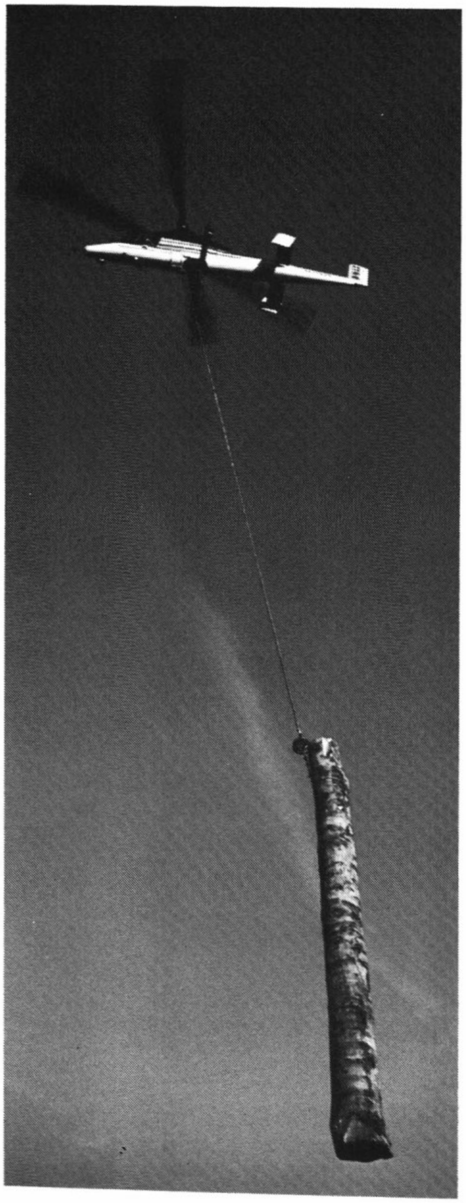

Figure 4. K-MAX® in Logging Role.

type of helicopters. The intermeshing configuration is inherently quieter than these conventional helicopters due to the absence of a tail rotor and a low rotor tip speed. This could possibly expand the time window for operator use of the aircraft. Recent noise testing determined that K-MAX® is 4-5 db lower than the FAA required level for its weight class.

The fuel system features vents which are designed to seal and prohibit fuel leakage in the unlikely event of a crash or rollover. The fuel system also has a fuel collector that collects fuel drained by the engine during start-up and shutdown cycles. Additionally, the engine exhaust is located relatively high on the aircraft and directs the exhaust gases aft and slightly upward preventing the possibility of fire in dry, unimproved landing sites.

While K-MAX® has been designed to be environmentally friendly, the greatest positive impact on the environment is in the use of K-MAX® as compared to current methods that are not environmentally acceptable or economically competitive. For example, the environmental benefits for the logging industry are significant when compared to conventional logging methods that destroy the soil and landscape and can adversely impact the ecological balance and protection of endangered species such as the northern spotted owl. Major changes in current logging practices are being mandated by the U.S. Forest Service where selective cutting via a helicopter will be the only environmentally acceptable means to harvest timber.

K-MAX® Description. The K-MAX® intermeshing rotor consists of two side-by-side counter-rotating, torque balanced rotors synchronized through a rugged single main transmission. The K-MAX® will lift 5,000 lbs. on its cargo hook to an altitude of 8,000 feet (out of ground effect) at normal rated power at standard day. The helicopter weighs 4,800 lbs. empty and carries 6,000 lbs. on the cargo hook at lower altitudes. Figure 5 is a three-view drawing indicating overall dimensions.

The K-MAX® prime power is supplied by a single Textron Lycoming T5317A-1 gas turbine engine. It easily achieves maximum lift capability with the engine operating in its continuous power range of 1350 shaft-horsepower (SHP) with appreciable reserve. The K-MAX®/T5317A-1 engine configuration has been derated to 1,500 equivalent SHP, enabling K-MAX® to achieve its performance objectives. The engine maintains a high degree of temperature margin, allowing it to achieve higher equivalent power under hot day or high altitude conditions. This engine was chosen because it is well suited to meet the design objective and provide performance, reliability, durability, and low life-cycle/maintenance costs.

The main transmission of the K-MAX® drive system is rated to deliver 1420 output horsepower to the two intermeshing rotors,

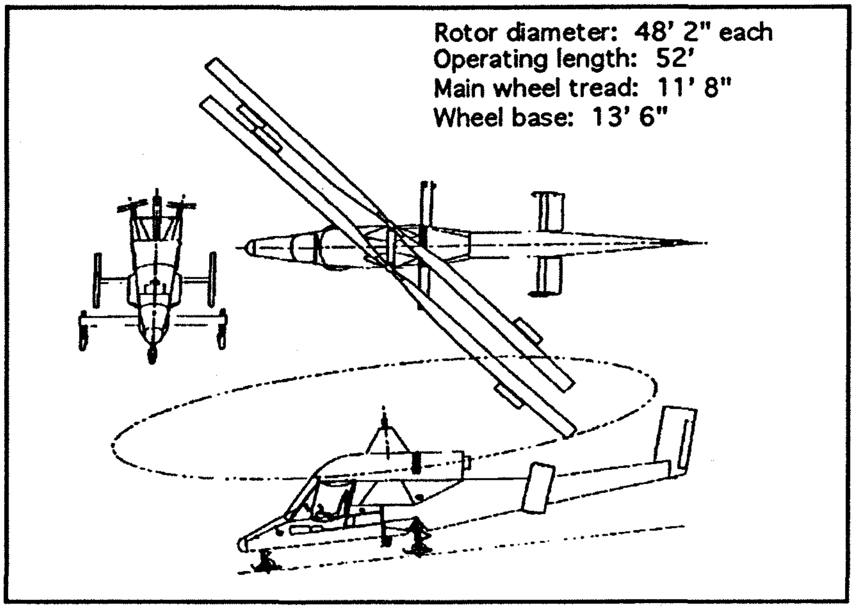

Figure 5. Three-view K-MAX[R] Drawing.

horsepower to the power takeoff, oil cooler fan, and the oil pump. The transmission input is designed for 1528 horsepower which supplies the output power and accounts for 45 horsepower in friction and pumping losses. A Kaman-patented KAflex coupling transfers the engine torque to the transmission input shaft. This coupling requires no maintenance and is designed for infinite life.

The K-MAX[R] fuselage is semi-monocoque 2024 alclad sheet aluminum structure, with major hard points for attachment of rotors, engines, transmission, landing gear, and rotor control system machined from aluminum, steel bar and plate. It is designed as a rugged, easy-to-produce airframe, reliable and durable with minimal maintenance between overhauls.

The K-MAX[R] has two main landing gear and a nose gear. The landing gear is tall to clear tree stumps and other obstructions, wide to safely land on sloping ground, and set back to give the pilot a clear sight line of the external load. The landing gear wheels are also equipped with "bear paws" (flat plates) which increase the contact area and prevents sinking into soft ground, snow, or irregular terrain.

The electrical system is a simple 28 volt DC system with a lead-acid battery.

Provisions have been made for an additional generator or pump, if required, mounted on the transmission that could supply up to 50 HP for customer needs .

Development of Low Acquisition Costs

The K-MAX[R] development benefited from the many in-place quality systems and the concurrent engineering approach using integrated product teams. With a focus on investing for the future, a number of productivity enhancements such as capital investment and cost effective production methods were implemented. As a result, the value of the early production lots of K-MAX[R] helicopters has been competitively set for a helicopter in this weight class and capability at about $3.5 million.

To develop low acquisition costs, Kaman designed the K-MAX[R] under the philosophy of "easy to draw, easy to make". Kaman's approach is counter to the trend in the aerospace industry which tends to aim at sophisticated avionics capability and "creature comforts". The focus was on the eventual users of the K-MAX[R] , understanding their needs, operating environment, and the economics for revenue generation for whatever the external lift application. This led to the concept of the "aerial truck", a simple, rugged, reliable workhorse.

While weight considerations tend to be a top priority in the design of any new aircraft, it was second to simplicity and ease of maintenance. This approach resulted in fewer parts count and less complicated tooling. The fuselage is constructed of aluminum 2024-T3 and T42 alloys with steel fittings inside, designed for minimum maintenance and easy access. The airframe consists of five subsections - nose/cockpit, center fuselage, aft fuselage, landing gear, tail boom - and is designed to be interchangeable and modular allowing for parallel assembly activities. There are few compound curves which keeps expensive stretch die tooling and custom made form blocks to a minimum, cutting manufacturing time. The fuselage skin thickness in load bearing areas measures 0.050 to 0.060 inch, compared to typical thicknesses of 0.032 inch in other helicopters. This cut the number of frames, stringers and rivets required and eliminated the need for a keel beam. For example, the thicker skins allowed a reduction in the number of parts in the engine support area from 168 on the H-43 to 68 parts on the K-MAX^R . Access panels are designed to be structural (stress bearing) so as to eliminate local strength doublers and parts count. Multiple uses of the same structure such as stiffeners was employed to reduce the number of different structural elements. Most bulkheads and flat structure were built using off-the-shelf extrusions instead of performing sheet metal forming or machining.

The rotor control system is a mechanical arrangement making it easier to build and trouble shoot in the field vice electronic controls. The system is modular, interchangeable, and easily removable with assembly work and rigging occurring on the bench.

As much as possible, hardware and equipment (i.e., instruments, cooling fans, latches, bearings, particle separators etc.) were selected off-the-shelf to achieve economies of scale. Engineers designed around what was available to avoid requalification requirements and expense. For example, the K-MAX^R wheel brakes are from a cataloged item already qualified to a FAA governed Technical Standard Order (TSO). This saved approximately $125K in requalification expense not to mention development time for a new design.

Throughout the development process, 3-D modeling was employed extensively. Typically, the designer created a computer-aided-design (CAD) in 3-D at a workstation, followed by the manufacturing engineer (ME) taking the design and design tools to produce numerical control (NC) tapes. This 3-D capability coupled with an aircraft mockup allowed routing of systems and location of penetrations and other equipment to be pre-planned to minimize manufacturing cost.

Kaman Quality Systems. As a military helicopter producer of the U.S. Navy's SH-2 series helicopter, Kaman has in place Quality procedures compliant to MIL-Q-9858A, MIL-STD-1535A and other related standards. These quality procedures assure a consistently reliable process disciplined in ensuring K-MAX^R quality and resultant cost benefits.

Kaman has established a comprehensive statistical process control (SPC) program as a means to ensure product quality control and reduce cost. SPC is designed to measure and monitor key sources of variation (i.e., man, methods, materials, measurement, and machine) through analytical studies of production/inspection data and test results. Manufacturing processes for the K-MAX^R such as various machining, forming, painting operations utilize SPC methods. [2]

The importance and success of the K-MAX^R project and the need to become more competitive in the marketplace have resulted in Kaman instituting a number of initiatives such as "Kaman Quality Management" (KQM), a program to implement Total Quality Management concepts and goals. This quality management program establishes an organized continuous process improvement activity involving everyone in the organization in a totally integrated effort toward improving performance at all levels. KQM is the foundation for K-MAX^R Integrated Product Teams (IPTs) which taps personnel resources from the production floor right up to the CEO office.

Integrated Product Teams. Throughout the development of the K-MAX^R , IPTs have been used which allowed Kaman to achieve first flight of the K-MAX^R in less than 18 months. Key ingredients to IPT success were the manufacturing engineers, production and specialty engineering personnel working co-located with design engineers to ensure the

K-MAX^R design was producible, easily testable and supportable.

In the design of the electrical system, the electrical ME, as part of the IPT, worked with the designers to reduce the number of harnesses by integrating several into a single harness, determine how to route and where to terminate wiring harnesses. The ME, knowledgeable about wiring harness fabrication, testing, and installation, was able to affect the design early in the development. This early influence resulted in approximately 95% of the wiring harnesses fabricated, assembled, and tested before installation in the aircraft using a modular approach. Utilizing CAD, wiring boards were developed from the designers schematic that replicated lengths, bending radii, and other features. Once the modular harnesses were laid up and clamped on the wiring board they were then tested in the shop. What remained is a negligible installation time to plug in and final clamp into the aircraft. The modular wiring harnesses are divided in each area of the fuselage sections with connectors at each bulkhead making for easy replacement during repair activities. Compared to past practices where wiring is non-modular, laid up and tested in the aircraft, this new modular approach is easier, saves considerable time in fabricating, testing and installation. Another byproduct of this time saving technique is the assembly of the aircraft is now done in parallel vice in series, thereby allowing other installation and assembly functions to continue unhindered reducing final assembly time.

Material selection was evaluated for producibility considerations. For example, in the area of tube bending the ME determined that changing the type of material such as changing from a T3 or T6 condition to an O condition would ease the workability of the material and avoid annealing and subsequent re-heat treating processes. The design was also modified to ensure suitable radiuses and tolerance relaxation allowing use of in-house capital equipment.

Another example of IPT influence was in the design of the horizontal stabilizer. The design considered the rigging requirements by designing in jig holes making the mechanics final assembly job easier and foolproof.

During the K-MAX^R development, Integrated Logistics Support (ILS) personnel played an effective role on the IPT. Working alongside designers, the ILS IPT member determined optimum maintenance features such as the number and location of access panels and use of common field tools. To develop effective and easily understood technical and maintenance manuals as well training materials, ILS personnel worked closely with aircraft mechanics during testing to acquire the needed hands-on perspective.

The IPT was not limited to Kaman personnel only, but included potential customers and key subcontractors. For example, to achieve interchangeability of parts in the transmission, the gear manufacturer was instrumental in gear pattern development. Using a high torque/low RPM test setup, patterns were ground that would compensate for temperature and case deflection resulting from maximum operating loads. This approach saved development time by minimizing gear regrinding to achieve the desired tooth pattern. It also makes it easier to stock parts since the gear parts are interchangeable eliminating the need to replace whole gear sets.

Productivity Enhancements. To achieve low production cost, Kaman has invested in capital equipment, tooling, facilities, and implemented improvements in methods and machine utilization.

In the area of capital equipment, a numerical control (NC) tube bending machine was purchased which eliminated the more traditional hand bending of tubes making it an automated process, reducing scrap rates and producibility costs. On the K-MAX^R, like all helicopters, there are fluid lines - engine oil, transmission oil, fuel, pitot/static system, rotor and parking brake system - that require forming and bending to fit the uniqueness of the aircraft. By automating the tube bending process, more than 100 tubes per day can be produced versus the 8 per day using hand bending techniques. To form the tube ends, a tube end finisher machine was purchased keeping this work in-house eliminating vendor cost and shipping time.

To reduce rotor blade recurring production cost, Kaman has invested in a 5-axis numerically controlled machine. With this new machine, the blade spar block machining time is cut in less than half since two blade spars can now be machined simultaneously and at greater feed rates. The new equipment also reduces setup time and enhances repeatability compared to current methods. Furthermore, the blade spar shop was relocated and additional equipment procured to provide needed environmental control, reduce manual labor/material handling, and allow implementation of work flow improvements.

Kaman has established a multi-gang drilling center which enables the rotor blades and grips to be drilled together saving time over earlier intermeshing rotor methods where blades and grips were drilled separately. The blades and grips are produced with hard tooling to tight tolerance achieving interchangeability, an important aspect for field support.

The airframe assembly and subassembly process was modified for efficiency gains. For example, the mechanical arrangement in the main assembly building was modified to better utilize the existing monorail system and reduce material handling. Sheet metal, machine shop, and tubing shop work cells were established to reduce parts/subassembly flow and improve the sequencing of manufacturing operations. In these work cells, the process typically starts with raw stock and produces the completed part. Future plans focus on co-locating more elements of the manufacturing process using a rapid prototype layout concept and expanding the use of work cells for other functional areas.

A Drivematic automatic riveting machine and Colèco Kit were used to drill rivet holes, install and seal rivets in stringers and fuselage skin. Assemblies were divided into smaller subassemblies for greater utilization of the Drivematic machine.

For machined parts, drill fixtures were used that allowed better utilization of drill presses reserving the NC machines for more complicated operations. Additionally, Kaman's investment in the NC Trump router has cut in half the machining time of more traditional methods of hand loading and pin routing each part. With the Trump router, multiple flat pattern sheet metal panels can be cut.

For wiring harness testing, a state-of the-art Omni test machine was purchased which more easily tests harnesses before installation in the aircraft and is less cumbersome to program than previous test equipment.

A major facility investment includes a 20,000 square foot aircraft hangar for K-MAX[R] which is an FAA approved repair facility. This hangar contains a side shop for routine maintenance purposes and overhaul services.

In addition, Kaman has updated its unique rotor test stand to whirl helicopter blades. This stand can rotate in either direction, thereby providing a facility for testing and evaluating both left and right hand rotors.

Development of Low Ownership Costs

The lower operating costs of the K-MAX[R] are derived from inherent reliability of the intermeshing technology, lower fuel costs, fewer parts and systems to maintain and track, and reduced personnel requirements. For example, the K-MAX[R] is designed as a single seat helicopter with maximum visibility eliminating the need for an additional on-board observer and the attendant cost of multiple crew. The K-MAX[R] also makes significant use of Karon bearings which have long life and no lubrication requirements. Because of the simplicity and reliability of the K-MAX[R], minimal maintenance personnel are required.

Inherent in the K-MAX[R] design are considerably fewer dynamic components as compared to other helicopters. There is no tail rotor drive shafting, couplings, gearboxes, or control system as typically found in conventional helicopters. Hydraulic servos, pumps, and plumbing are eliminated. This provides the operator a number of benefits:

- reduced number of components to be inspected and maintained;
- reduced requirement for spares support;
- reduced component time tracking, inspections, overhaul, inventory control, and logistics;
- reduced manpower support;
- reduced special tool and support equipment requirements; and
- reduced cost.

These features ensure safe, reliable, continuous operations at sites that are remote from existing helicopter service centers.

Cost Effectiveness Comparison. Competition for K-MAX[R] comes from the currently used surplus military and commercial aircraft designed for other purposes. These competitor aircraft are inefficient in lift due primarily to the power drain from the tail rotor. They also generally have more highly loaded rotor discs as compared to the intermeshing configuration where both rotors generate lift resulting in a larger disc area and lower disc loading, which also results in reduced power requirements. This gives the K-MAX^{R} the advantage of carrying more payload (i.e., timber, water, equipment, etc.) generating increased revenue for the user. In addition, because of lower power requirements for the K-MAX^{R} fuel consumption is less resulting in lower operating costs. For example, in the fire fighting application (figure 6), K-MAX^{R} with a hook capacity of 6,000 lbs can deliver a substantial load of water and fire retardants onto a forest fire. Figure 7 compares K-MAX^{R} to competitor helicopters using water buckets to fight fires. Since each helicopter uses a different capacity water bucket and burns fuel at different rates, figure 7 normalizes the differences by illustrating the number of gallons of water delivered per gallon of fuel used for various numbers of trips per hours. K-MAX^{R} clearly can deliver more water for every gallon of fuel burned.

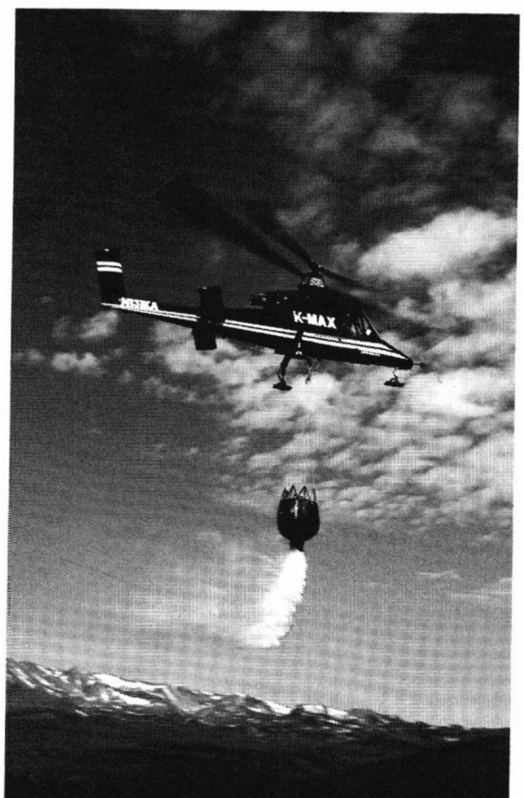

Figure 6. K-MAX^{R} Lifting Water Bucket.

Another fire fighting example is shown in figure 8 where K-MAX^{R} is compared to the S-64E, B-212 and B-205 for dropping water using water tanks vice water buckets. In this example, K-MAX^{R} is significantly more efficient due again to its lift efficiency (high gross weight to empty weight ratio) and the capacity of K-MAX^{R} to accommodate a high volume water refill system by utilizing the auxiliary transmission pad that is rated to provide an additional 50 horsepower. While figures 7 and 8 are shown using data for sea level capability, as the altitude requirements increase, K-MAX^{R} becomes increasingly more operational and cost effective.

Lease Program. The newness of the K-MAX^{R} concept and its operation in relatively unfamiliar market areas justifies a cautious and conservative strategic approach as Kaman and potential industry users learn more about the profitability and potentials of the K-MAX^{R} . This approach entails leasing the initial lot of aircraft at a rate of $1,000 per hour based on a 1,000-flight-hour program. Of this amount, approximately $600 represents financing charges and depreciation that can be partially credited towards aircraft purchase. The direct operating costs make up the $400 balance of which $250 is airframe related and $150 represents engine costs. Leasing also allows Kaman to establish the reputation of the aircraft by placing it with credible customers who will use it properly and within its limitations, and will provide additional benefits of promoting long-term revenues.

Health Monitoring. Specific types of data will be monitored and recorded to assess the health of the aircraft, both leased and sold. Each aircraft will be instrumented to record torque, engine speed, engine exhaust temperatures, and hook loads. The recording instruments will have memory to allow data collected and downloaded after approximately every flight to ease the operator's bookkeeping task. The data will also be sent back to Kaman for evaluation to ensure proper use and performance of the aircraft. With this information, maintenance requirements can be more easily predicted by monitoring usage thereby minimizing unscheduled maintenance. Again, the aim is to reduce the users operating cost.

Customer Support. As part of the capture strategy, Kaman has established a support

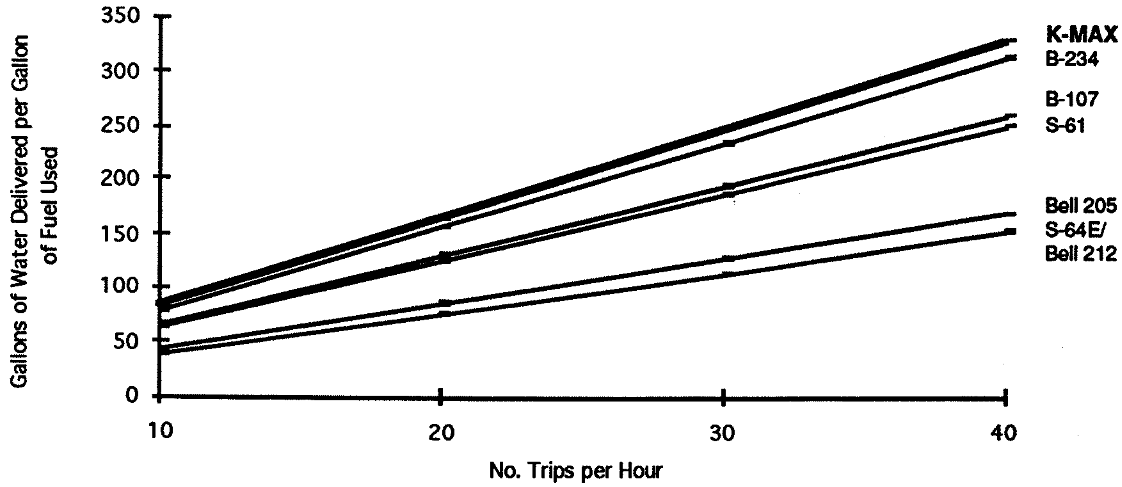

Figure 7. Helicopter Comparison Using Water Buckets to Fight Fires (at sea Level).

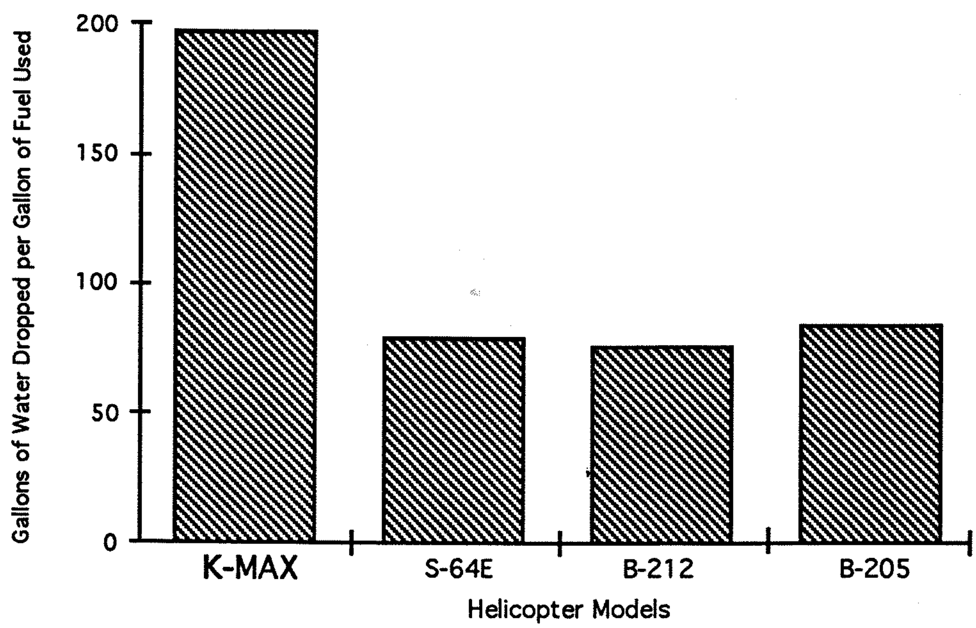

Figure 8. Helicopter Comparison Using Water Tanks to Fight Fires (at sea Level)

staff that will assist customers in various after market efforts including technical support, training, technical publications, and spares. A group has been established to train pilots and mechanics to operate and maintain the K-MAX® . Parts support for K-MAX® will be integrated into Kaman Industrial Technologies Corporation's (KIT) significant capability in warehousing and distribution of industrial products.

To minimize cost of ownership, it is critical that aircraft down time be kept to a minimum since production stops, crews become idle, and revenue is lost. Emphasis will be placed on speed of delivery for parts and services to minimize aircraft down time. This is of extreme and equal importance to Kaman as the lessee of the aircraft and to those who are owner-operators.

A history of part usage and other key information will be kept for each K-MAX® customer in the computer network, further reducing administrative costs and time for each customer. Electronic Data Interchange (EDI) also will permit customers direct access to Kaman's network to have total visibility to K-MAX® parts, customer history, and ordering.

Summary

With a multi-faceted approach, Kaman has created the K-MAX® helicopter focused on the external lift market that is developed for low acquisition and ownership costs. This comprehensive approach mandated that potential users be part of Kaman's integrated product team and that innovative design and manufacturing concepts be implemented for a highly producible low cost product. Designed for simplicity, reliability and durability, K-MAX® delivers payload more efficiently with reduced fuel costs, fewer personnel, and lower overall operator costs while generating maximum revenue.

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