# CONTENTS

The highlights of the Hot Cycle story are shown in this compilation of presentation charts. A brief word of explanation accompanies most charts to enhance the continuity of the story — from concept, through R and D accomplishments, through current programs, to applications.

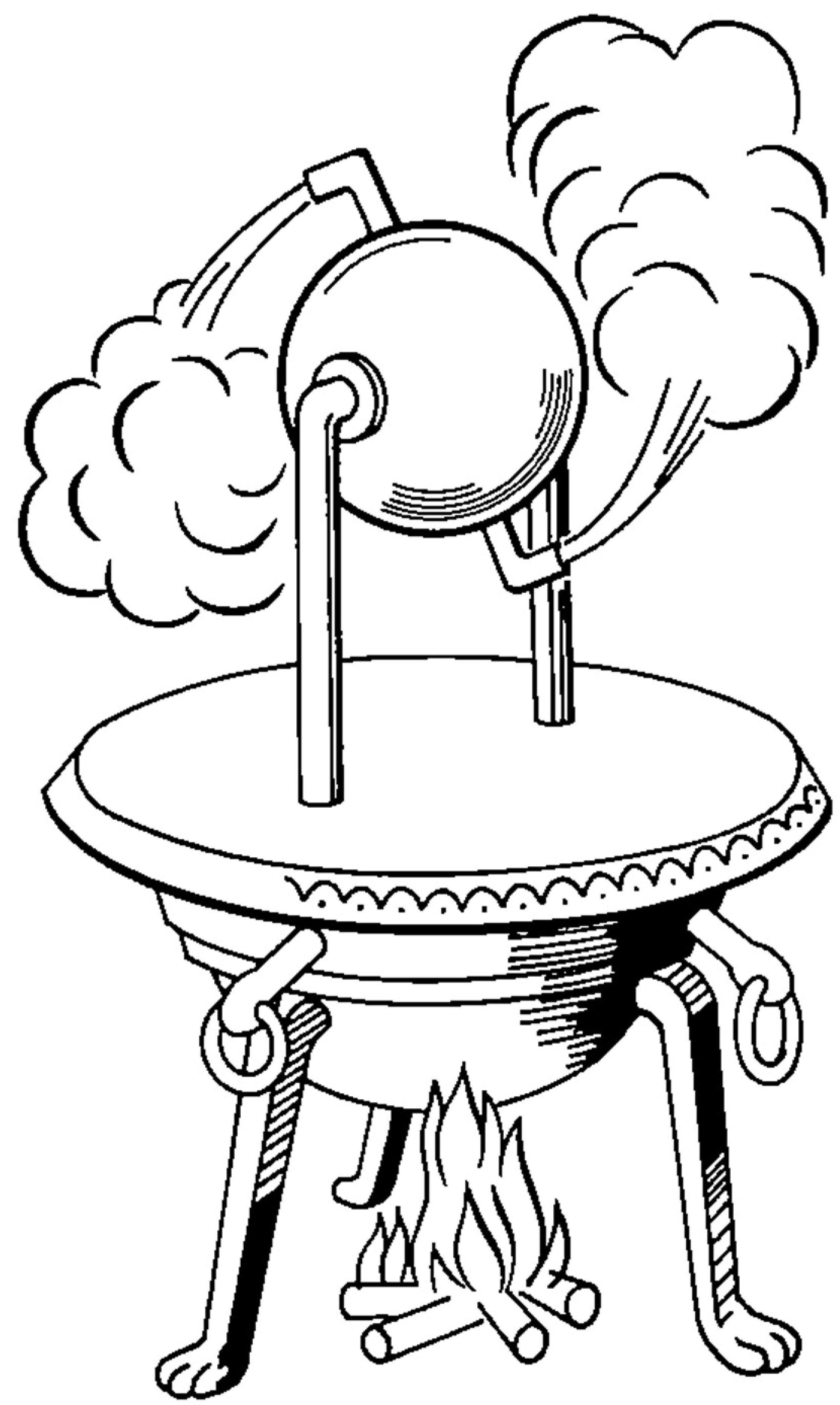
# HOT CYCLE
# SYSTEM CONCEPT

# ORIGIN

The Hot Cycle Rotor Propulsion System had its genesis in Hero's Turbine nearly 2000 years ago in Alexandria. A gas generator, consisting of a kettle of water heated by a fire underneath produced gas (steam) which was ducted into a sphere and out through two jets directed to produce rotation.

This first heat engine was invented 1700 years prior to any other form of heat engine. The reason for its early invention was the extreme simplicity of the concept.

# Hero's Turbine-About 100 AD

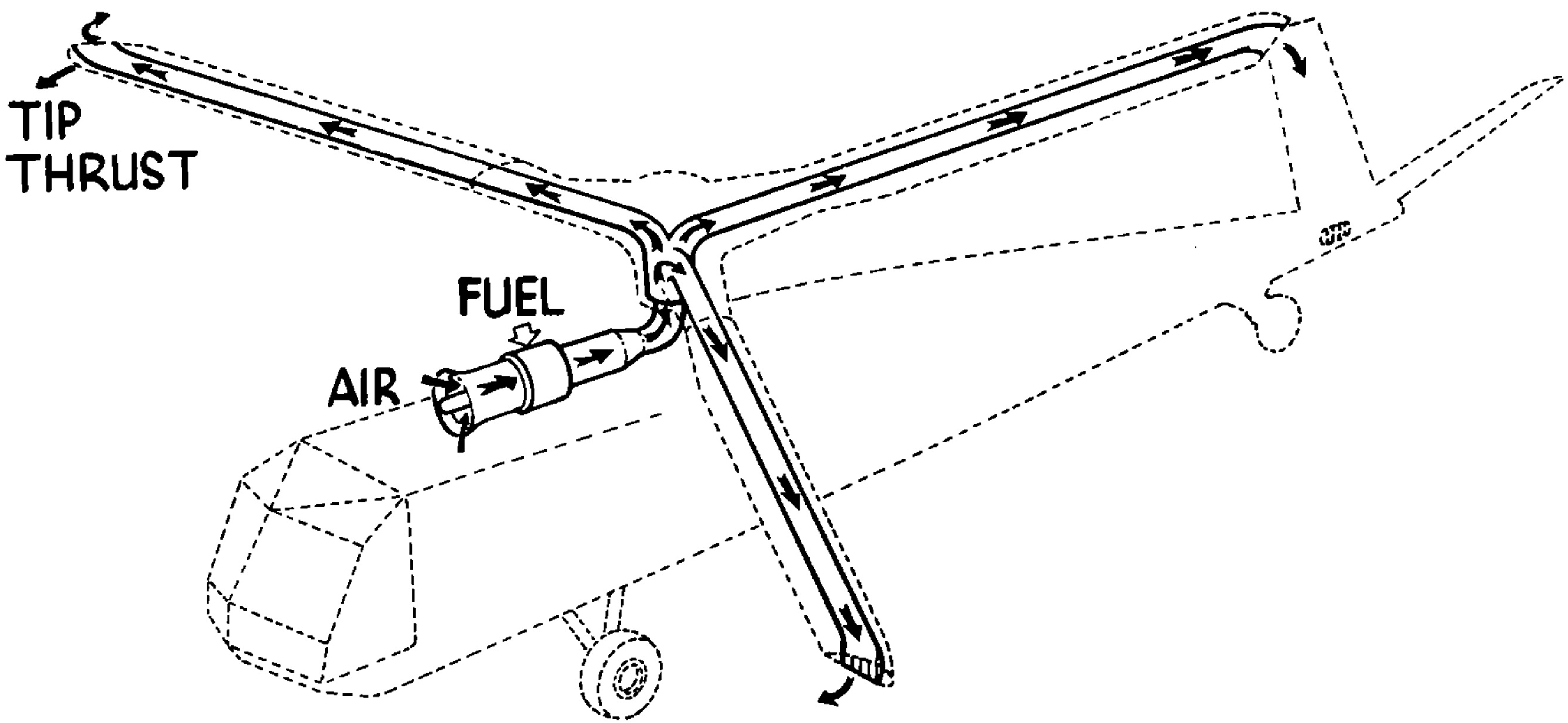


# CONCEPT

The Hot Cycle concept applies the principle demonstrated by Hero's Turbine to provide the simplest possible helicopter rotor drive system. A turbojet gas generator supplies high energy gas through ducts to the rotor tips, where jets propel the rotor in the same manner as Hero's Turbine. The rotor itself becomes the power turbine, converting the energy of the gases directly to rotary power. The conventional power turbine, gear boxes and shafting are eliminated and no tail rotor is required since there is no shaft torque to react.

Large improvements in payload capability and economy are offered by the Hot Cycle System because of its simplicity and light weight.

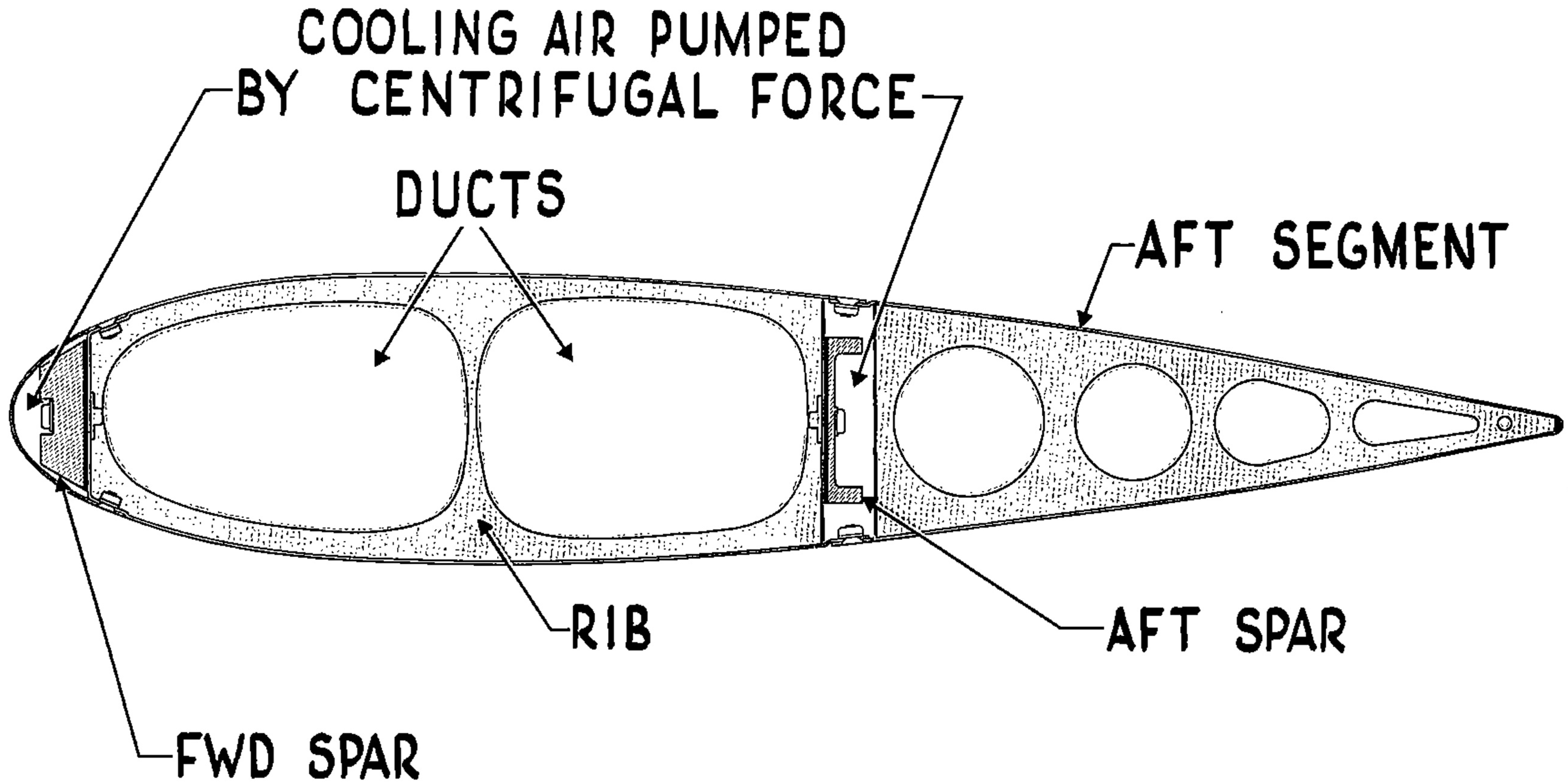
# Hot Cycle System



# HOW CONCEPT IS APPLIED TO A ROTOR

The patented Hughes blade structure is illustrated here. The Hot gases pass through the two central ducts which are attached to the skin by closely spaced ribs. The duct-skin structure is divided into sections along the blade span, with flexible connections between adjacent sections to effectively eliminate axial loads in the hot parts. The two spars are the basic structural members and carry essentially all the centrifugal and bending loads in the blades. The spars support the duct-skin sections and leading and trailing edge fairings, with the skin-duct sections essentially "floating" between the spars. This arrangement isolates the hot ducting portions from vibration-induced stresses and allows for relative thermal expansion. The spars, which carry all major loads, are kept cool by a flow of ambient air which is pumped spanwise by centrifugal force.

# *Blade Cross Section*

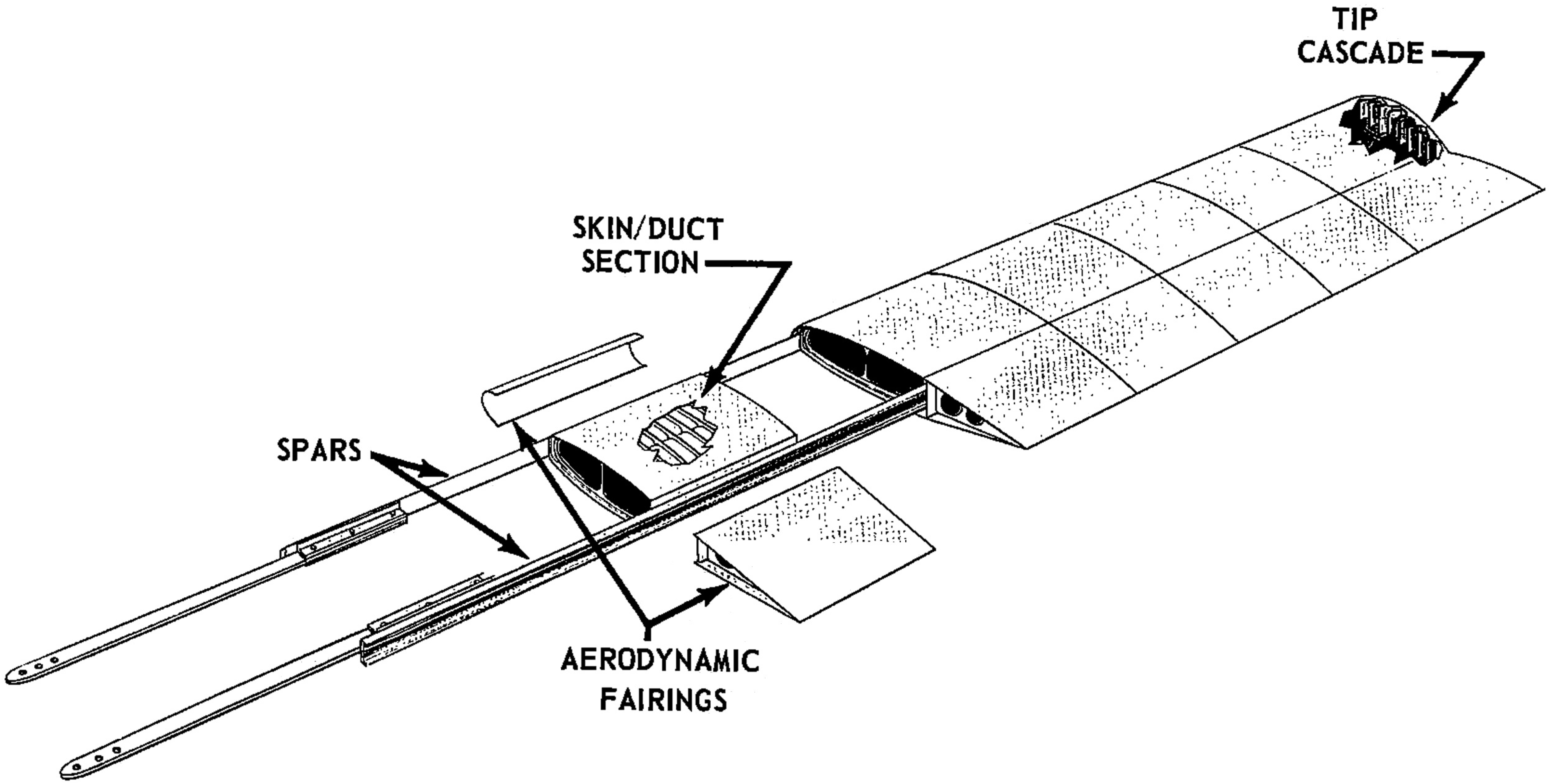



U. S. PATENT 3, 096, 826
FOREIGN PATENTS PENDING

Another important factor in the Hot Cycle Blade is that the dynamic characteristics in bending are determined by two spars. This permits tuning the blade by varying the spar cross-section to obtain the optimum natural frequencies, thus minimizing vibration problems.

The cascade at the blade tip turns the hot gas stream through a 90 degree angle and accelerates it to jet velocity to provide the thrust for driving the rotor.

# Hot Cycle Rotor Blade



# FEASIBILITY

A program sponsored with Hughes by the U.S. Army, Navy and Air Force proved the feasibility of the Hot Cycle Rotor. This program culminated in a sixty-hour whirl test which was completed in 1962.

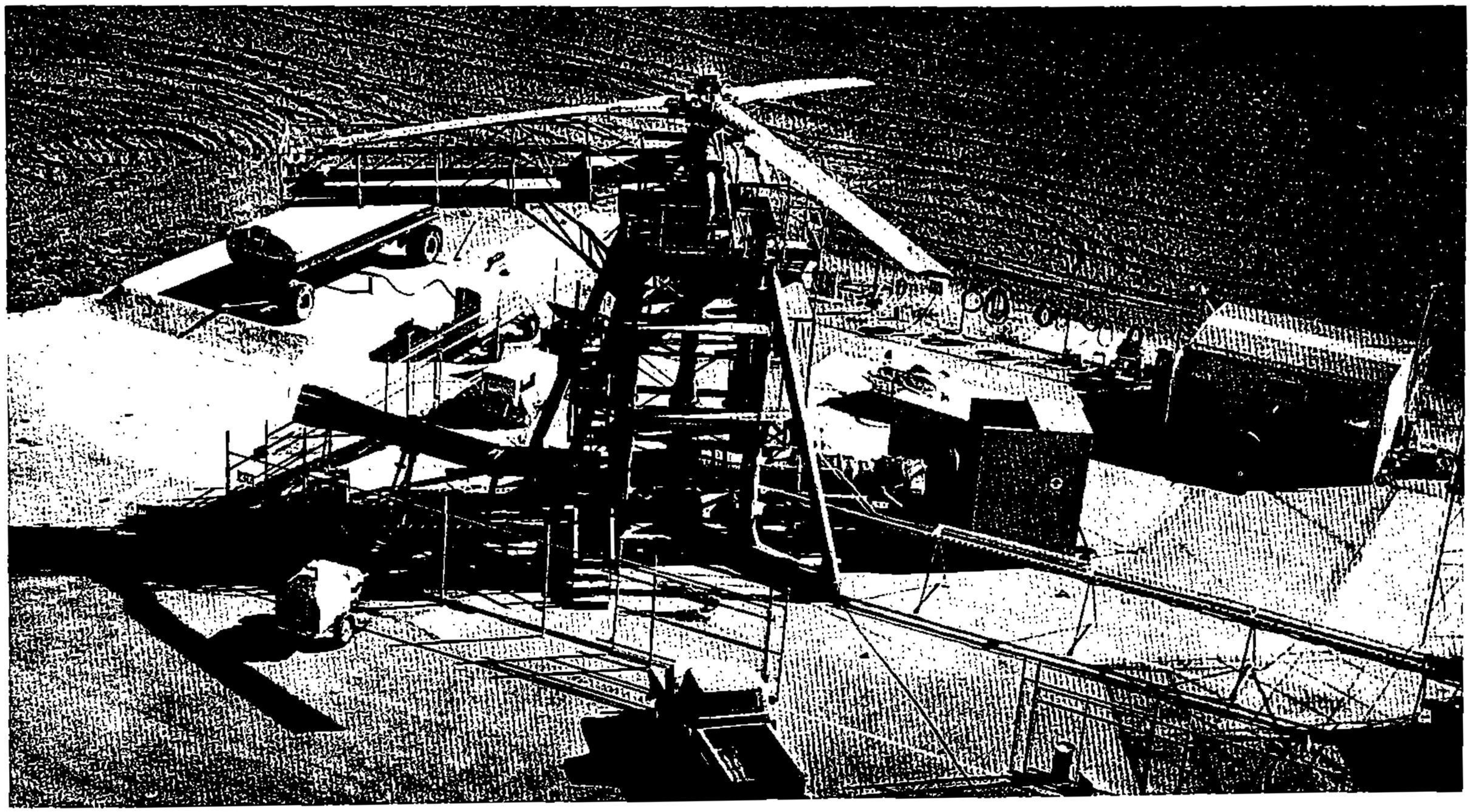
RESULTS OF INITIAL WHIRL TEST

1. Leakage less than 1/5 of 1% of gas flow
2. Temperature margin on spars of 400° F.
3. Flight design weight met within 2%
4. Excellent dynamic stability
5. Noise comparable to a similar-sized conventional shaft-driven rotor.

The Hot Cycle Rotor which provided these excellent results was designed once, built once, and tested once with complete success. It is almost unheard of for such an advanced concept to be so successful in the first attempt.

The fact that these outstanding results were obtained on the initial whirl test substantiates the basic feasibility and soundness of the Hughes blade design.

# Hot Cycle Whirl Test



# XV-9A
# HOT CYCLE
# RESEARCH HELICOPTER
# (Current Program)

# THE RESEARCH AIRCRAFT

Following successful completion of the 60-hour whirl test, a follow-on program is currently underway to provide flight research data on the Hot Cycle Propulsion System. This program, sponsored by the Army Transportation Research Command, included the design, construction and testing of the XV-9A Hot Cycle Research Aircraft which utilizes the rotor from the initial 60-hour whirl test program. Power is supplied by two General Electric YT-64 gas generators furnished by the U. S. Navy. For the test program, the research aircraft has been extensively instrumented to obtain flight data which will aid in any future fabrication of a prototype. Flight testing started in November 1964.

DIMENSIONS:

| | |
|---|---|
| Rotor Diameter | 55 Ft. |
| Length | 45 Ft. |
| Height | 12 Ft. |

WEIGHTS:

| | |
|---|---|
| Empty | 8,600 pounds |
| Design gross | 15,300 pounds |

POWER PLANT:

Two General Electric T-64 gas generators

PERFORMANCE:

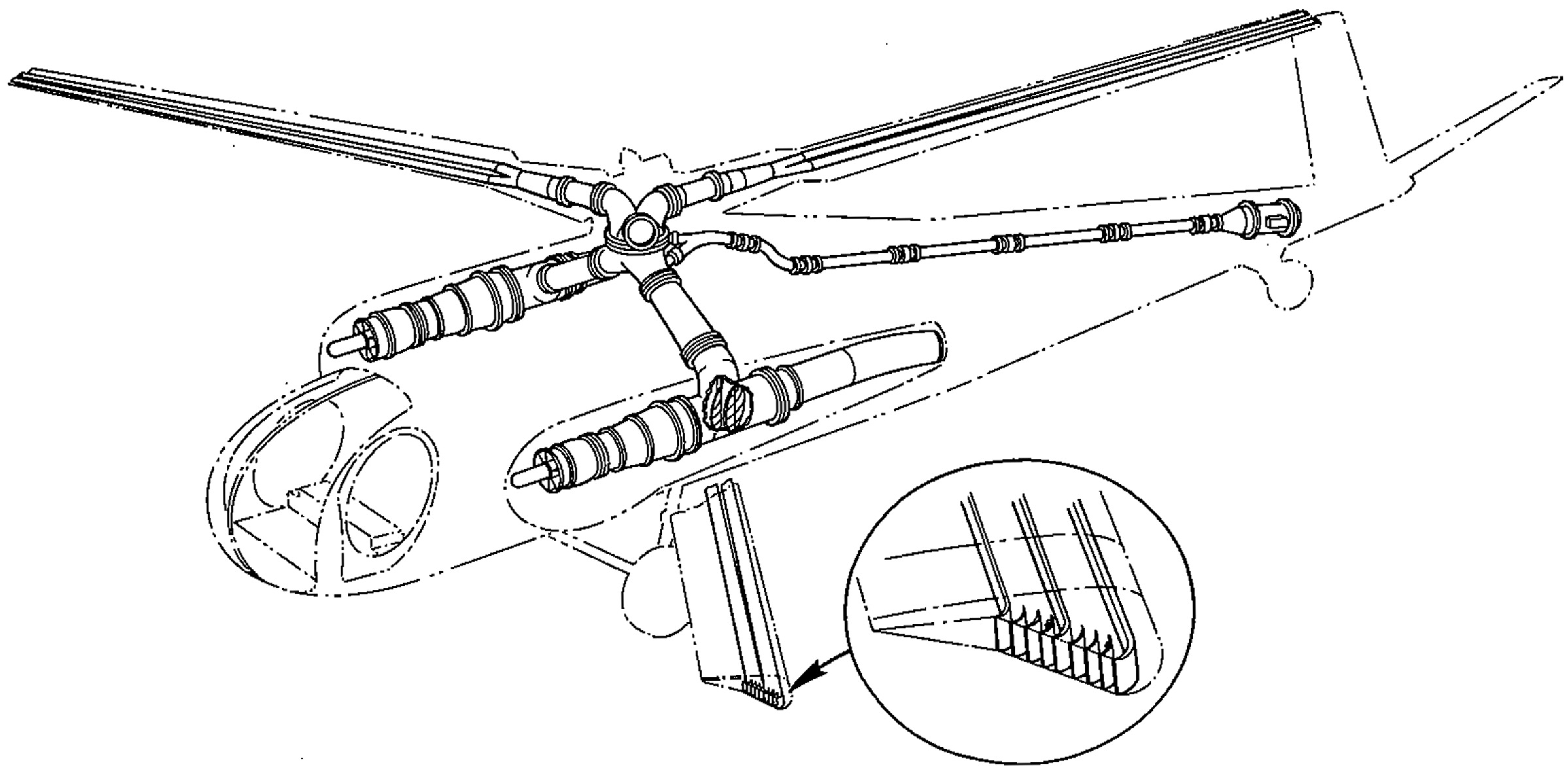
| | |
|---|---|
| Max. Gross Wt. | 25,500 pounds |
| Max. Speed | 170 MPH at 10,000 pounds gross wt. |


ARMY

# CONTROLS

The gas flow from the engines in the XV-9A is directed either out of the tailpipes (during starting) or to the rotor by pilot-operated diverter valves located just downstream of the engines. Directional control in hover and at low speed is accomplished by jets thrusting laterally at the tail and controlled by the rudder pedals. Other controls are by conventional helicopter methods.

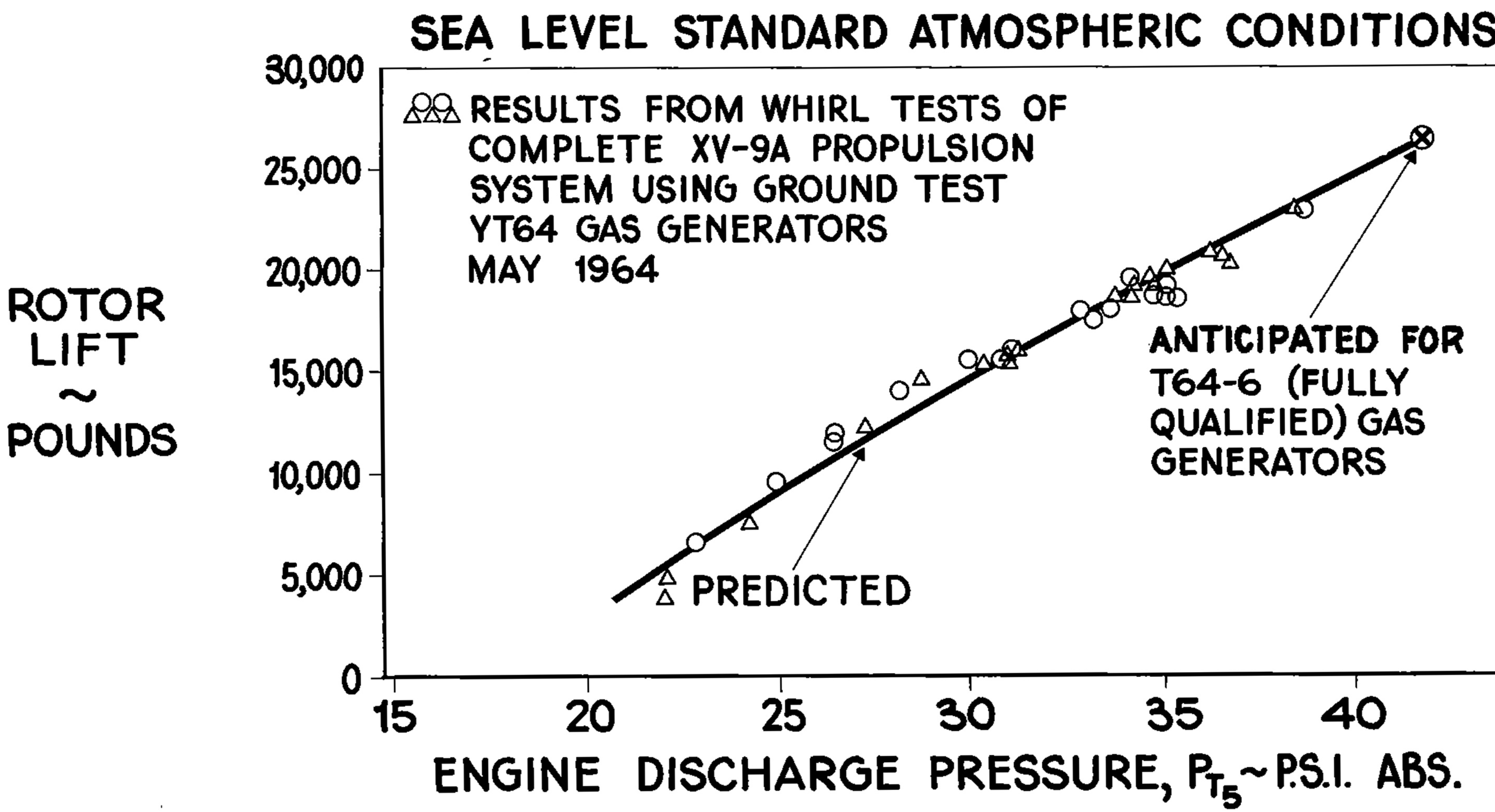
# Hot Cycle Research Aircraft Propulsion System



# ROTOR PERFORMANCE

The verification of performance predictions by recent whirl test results of the complete XV-9A Propulsion System is indicative of the accuracy of the performance prediction method. This same method is used in all the performance predictions for design studies of possible future Hot Cycle aircraft.

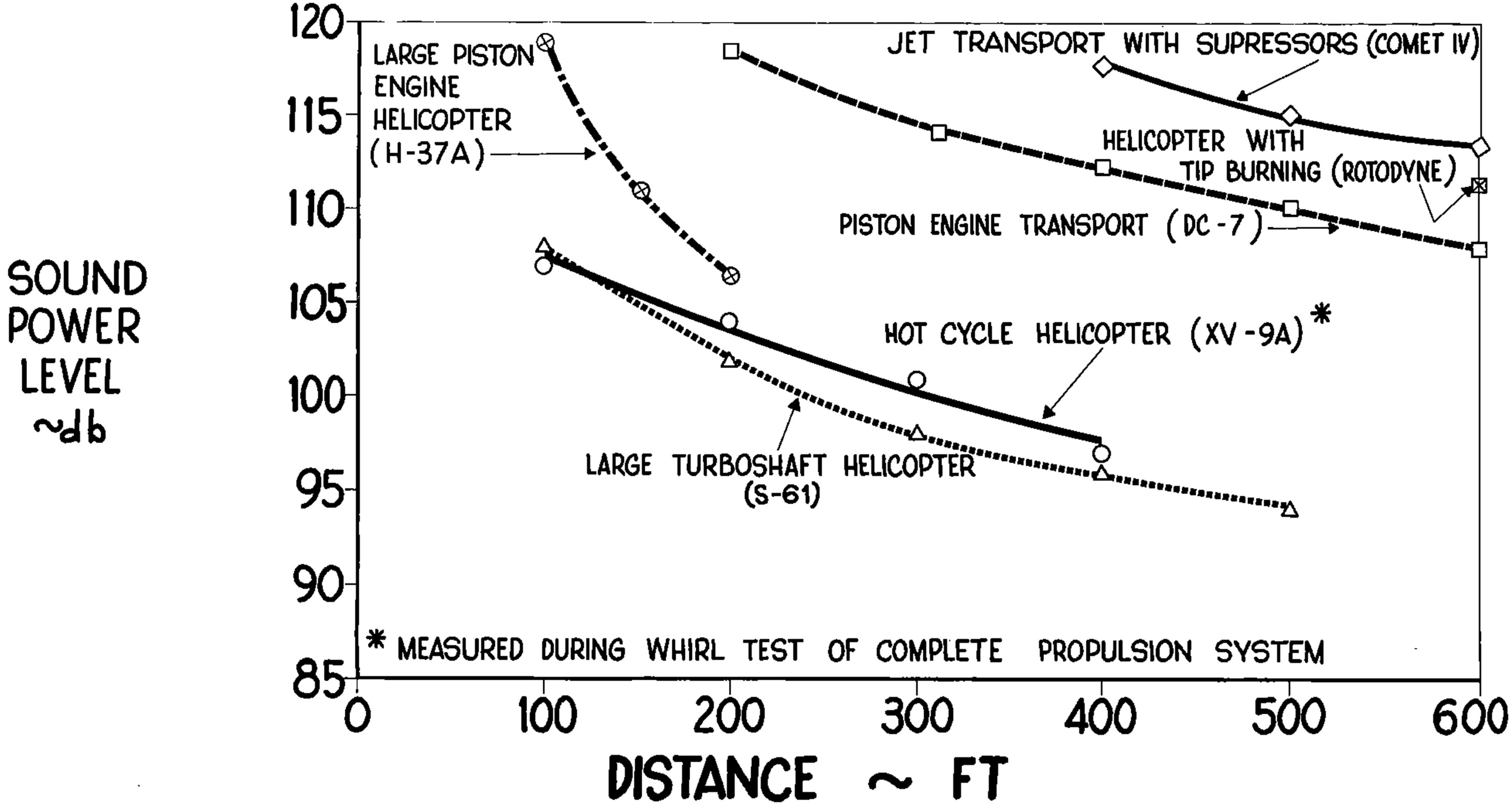
# XV-9A Propulsion System Performance



# LOW NOISE LEVEL

Noise measurements show the Hot Cycle System to be very comparable with conventional turboshaft helicopters of similar size and very substantially lower than fixed wing transport aircraft, and helicopters using rotor tip jet burning.

# Noise Comparison-Take-Off Condition



# CONSIDERATIONS FOR DEVELOPMENT OF HOT CYCLE

The Hot Cycle Propulsion System offers these potential advantages over other conventional rotary-wing aircraft:

1. Greater simplicity
2. Lower empty weight
3. Lower initial cost
4. Lower operating cost

The Hot Cycle concept retains the proven operational features of the helicopter:

1. Low downwash velocity
2. High hover efficiency
3. Excellent stability and control
4. Autorotative landing capability
5. Low noise level

# POTENTIAL
# HOT CYCLE APPLICATIONS

A) HEAVY LIFT

B) HIGH SPEED V/STOLS

C) MULTI-PURPOSE

# HUGHES' HOT CYCLE
# HEAVY LIFT HELICOPTERS

# HUGHES' HEAVY LIFT CONCEPT

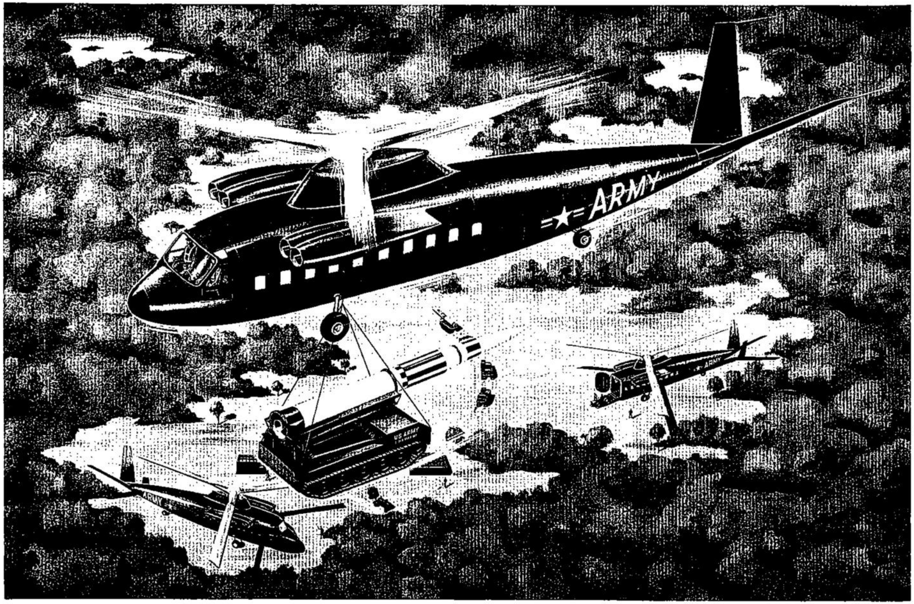
The Heavy Lift Hot Cycle helicopter design presented here will transport a payload of 20 tons on a typical flying crane mission. This design utilizes four General Electric T64 gas generators mounted in pairs in nacelles on either side of the fuselage. Design studies have included both specialized load-straddling flying cranes and the streamlined configuration shown here.

The specialized flying crane shown on page 31 offers significant benefits for certain types of external load missions, while the streamlined configuration shown here provides maximum mission flexibility.

Outstanding payload and economic benefits are provided by both types due to the simplicity and light weight of the Hot Cycle Propulsion System.

The configuration shown here has an optimum depth/length fuselage, providing a minimum weight craft suitable for the basic external load mission. The resulting streamlined fuselage also provides low drag, improving ferry range and cruise performance; and a sizeable compartment (7 x 8 x 30 feet) is available for a variety of internal loads.

# Hughes' Heavy Lift Concept

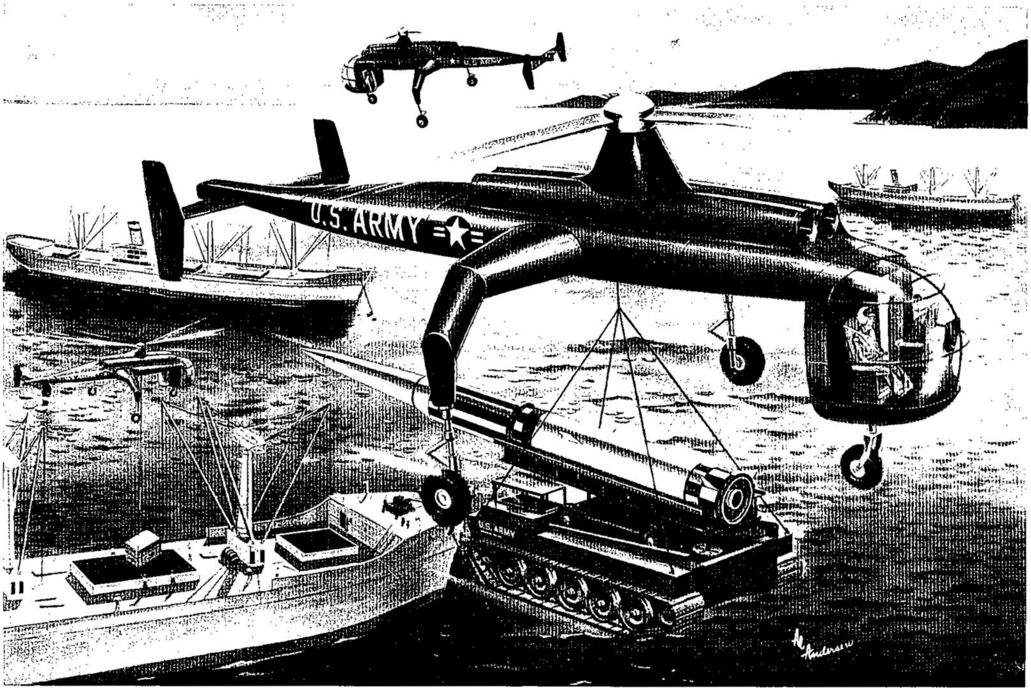


# HUGHES' CRANE CONCEPT

The specialized flying crane shown here provides maximum utility in the transport of external loads, and special-purpose or passenger/cargo pods can be carried beneath the strong-back. In addition to a central hoist, a four-point winch system and a number of mounting points are provided for maximum flexibility in lifting and carrying a wide variety of loads.

Performance on flying crane missions is essentially the same as for the configuration shown on the previous page.

# Hughes' Crane Concept



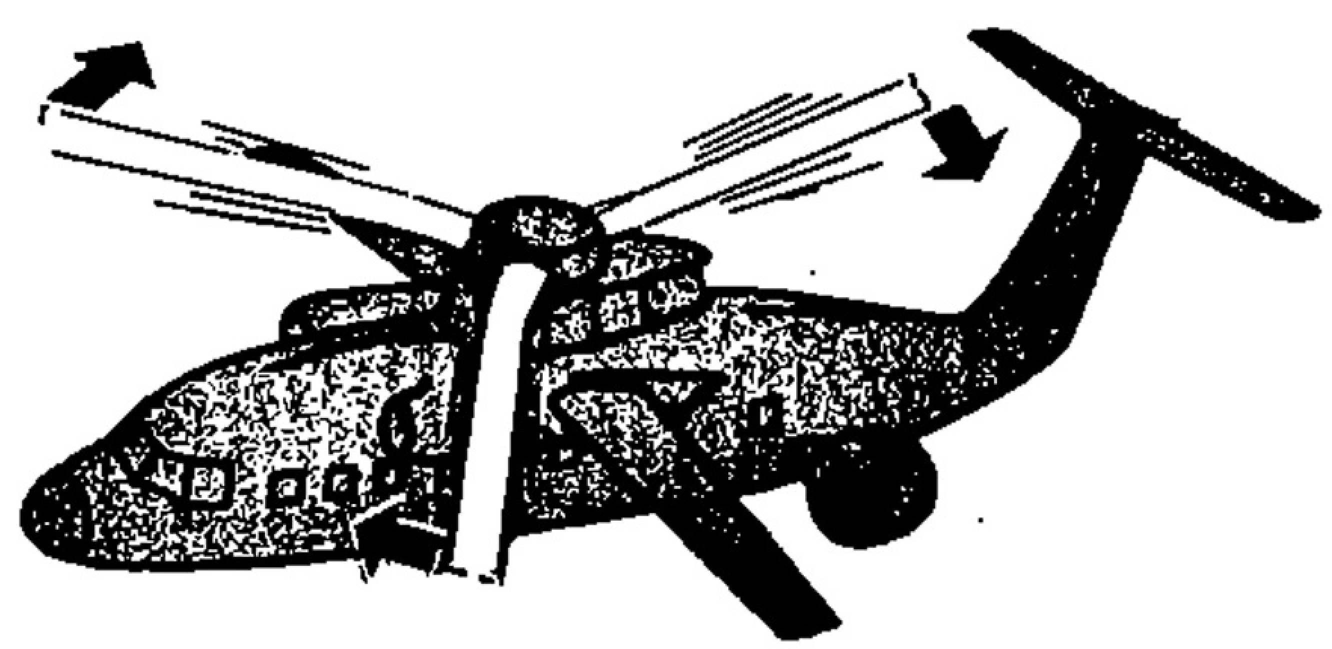
# COMPOUND HELICOPTER CONCEPT

In a basic helicopter, the rotor does three things: Provides lift to keep it airborne, provides thrust to propel it through the air, and controls the direction of flight.

By adding wings and forward thrust fans, the rotor can be relieved of its propulsion function and a major part of its lift function.

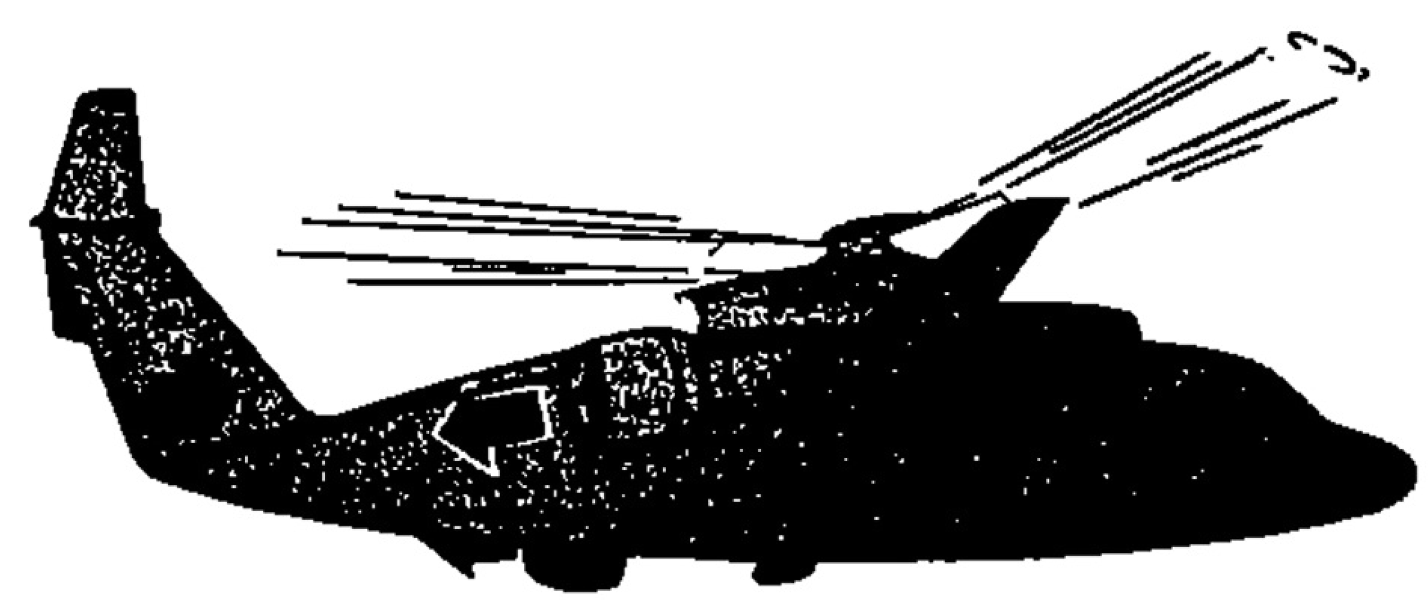
With the rotor thus unloaded, cruise speeds can be greatly increased, while still retaining the desirable vertical lift capability of a helicopter.

## HELICOPTER



HOVER

## AIRPLANE



HIGH SPEED

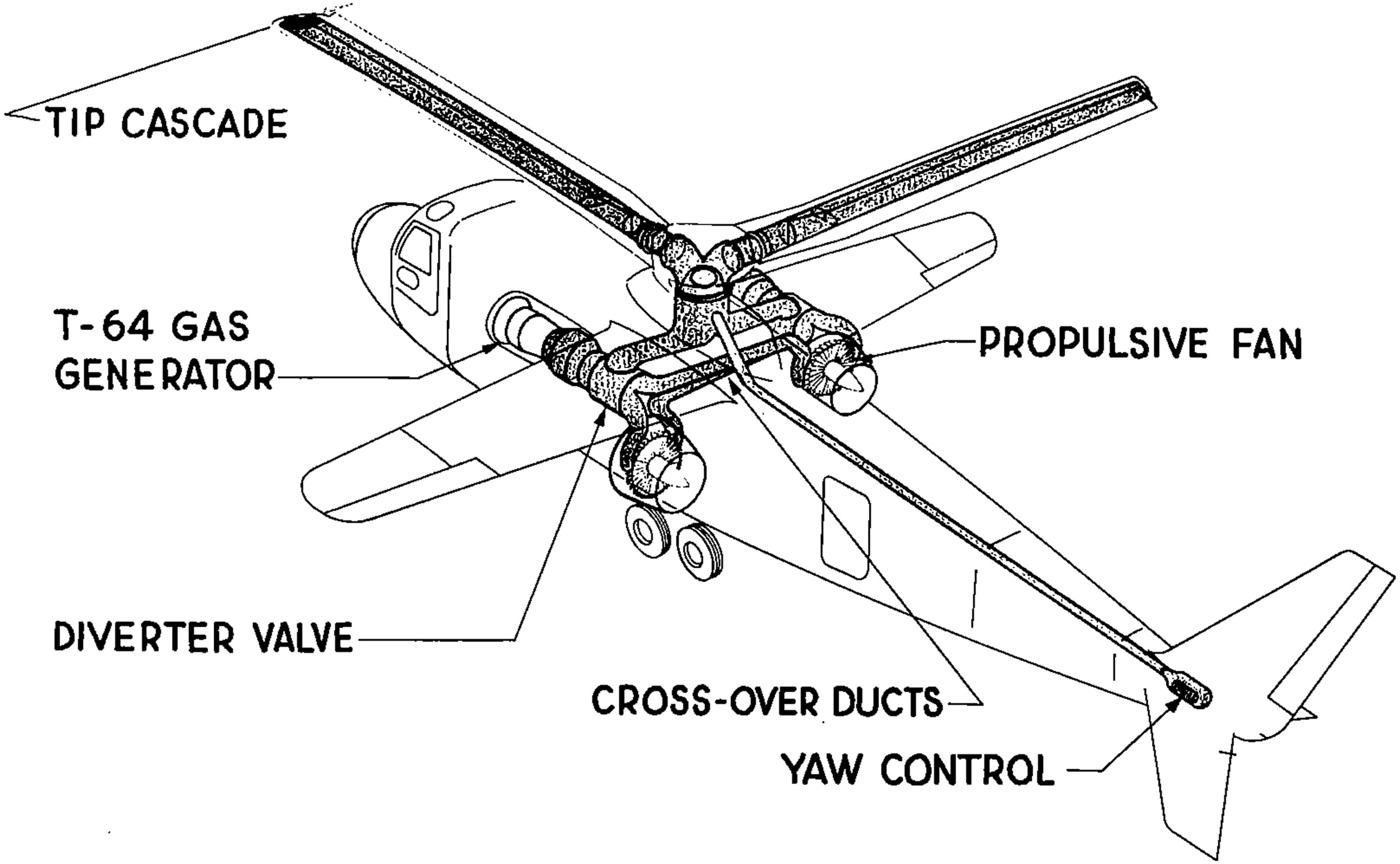
# HIGH SPEED V/STOLS

# HOW THE COMPOUND WORKS

The simple and light weight propulsion system of the Hot Cycle Compound Helicopter is illustrated here. Two gas generators supply high energy gas to power either the rotor — for VTOL and low speed (helicopter) flight — or the tip-turbine driven propulsion fans — for cruise (airplane) flight. Valves are provided behind each engine to divert the gases to the rotor or the fans, as required. Each cruise fan derives one-half of its power from each engine — thus permitting single engine operation in airplane flight with no assymetry of thrust.

At speeds below 100 MPH, this aircraft will operate as a helicopter, with the associated excellent hover and low-speed performance and flying qualities. At higher speeds up to 300 MPH, it will fly essentially as an airplane, with the rotor in autorotation and with wings and propulsion fans providing efficient cruise performance.

# Hot Cycle Compound Propulsion System Schematic



# HUGHES' MILITARY TRANSPORT CONCEPT

The Hot Cycle Compound Helicopter design shown here would provide VTOL transport of a 5-ton payload for 500 miles at 300 MPH for a cost of less than 20 cents per ton-mile. Flying as a helicopter, it can carry external loads of up to 7 tons.

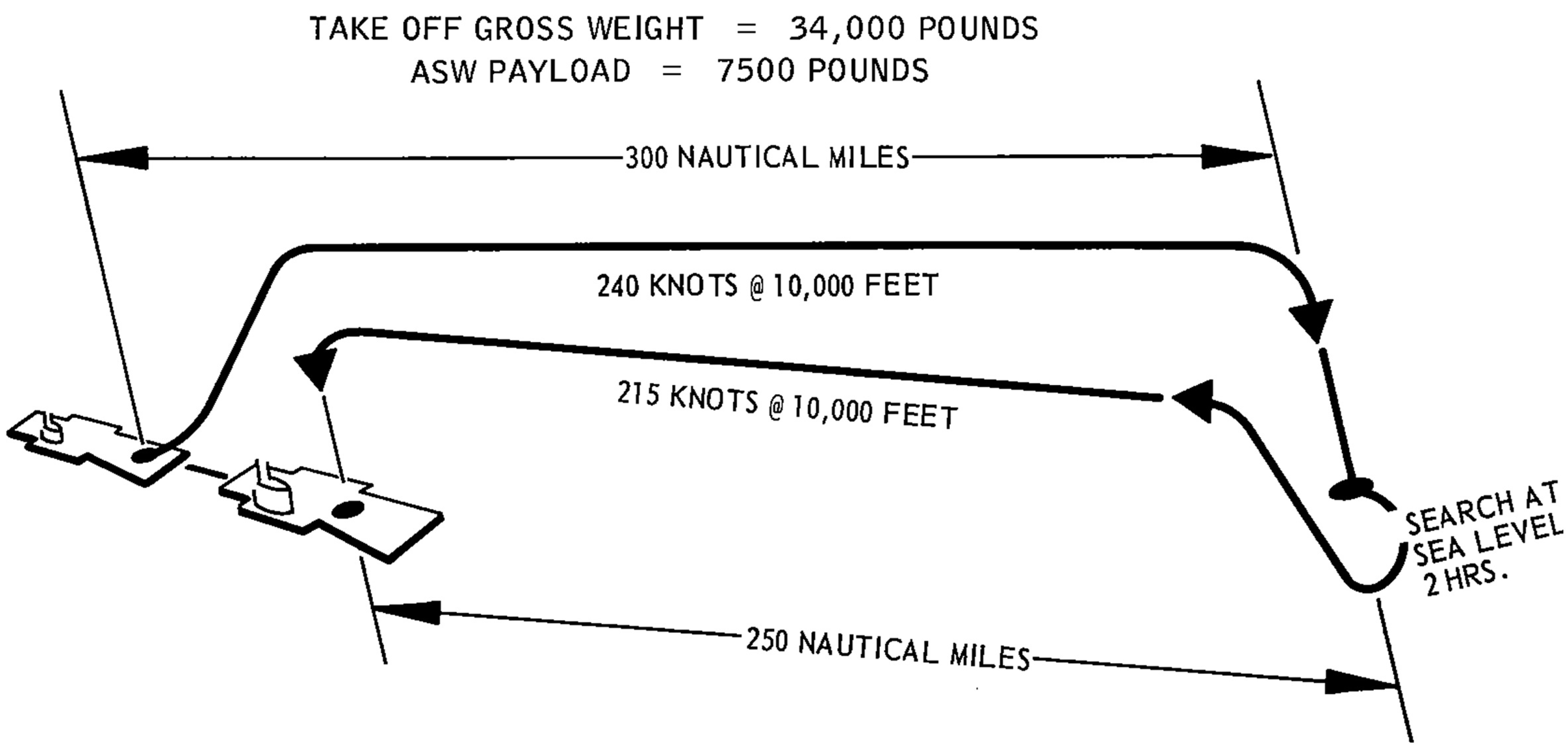
The propulsion fans and diverter valves are derived from another Army program, and the gas generators are obtained from the General Electric T64 turboshaft engine by removing the power turbine and drive shaft. All propulsion system components have been proven by full-scale tests.

# Hughes' Military Transport Concept

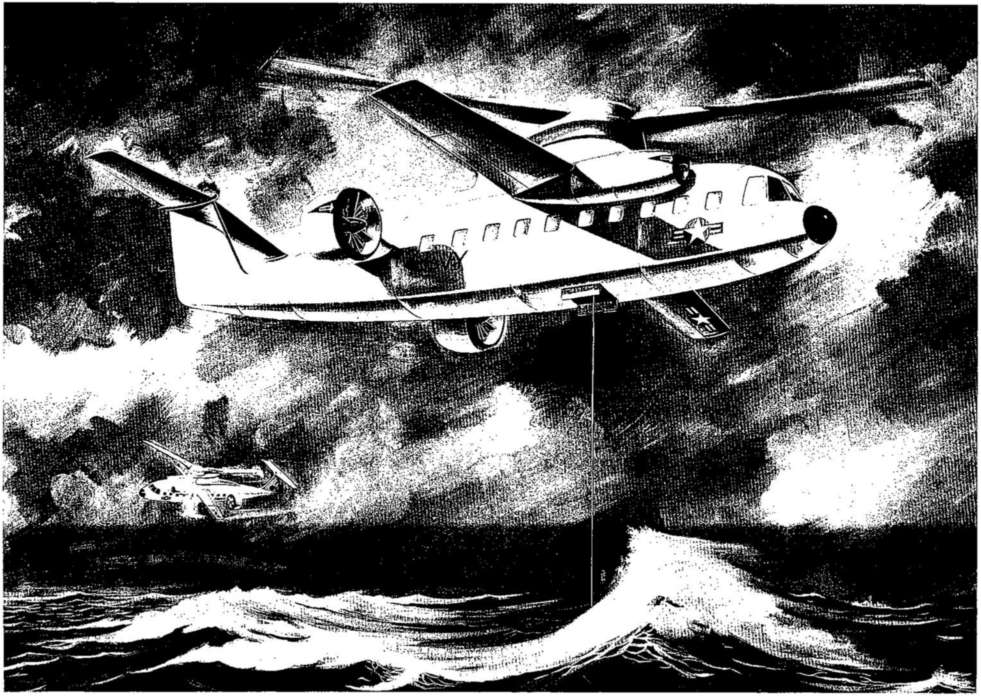
# HUGHES' ANTI-SUBMARINE WARFARE CONCEPT

The Hot Cycle compound helicopter promises large advancements in capability and economy for the carrier-based Anti-Submarine Warfare mission. It combines the hovering efficiency and low downwash velocity of a helicopter with the capability of efficient flight at speeds up to 250 - 300 knots.

This combination of characteristics gives the Hot Cycle compound unique promise as a replacement for current carrier-based ASW aircraft of both the rotary wing and fixed wing types and of providing a marked improvement in mission performance, capability and economy.



# Hughes' Anti-Submachine Warfare Concept



# *Hughes' Commercial Transport Concept*

The efficiency, simplicity and low empty weight of the Hot Cycle Compound Helicopter provide it with outstanding potential for commercial VTOL application.

The 275 MPH city-center transport design shown here would carry 50 passengers over stage lengths up to 350 miles.

It promises direct operating costs comparable with the most economical fixed-wing short-haul aircraft, and highly superior to other proposed or existing VTOL types. In addition to the benefits this aircraft offers to the traveling public, a commercial fleet would provide a valuable military reserve in times of international crisis.

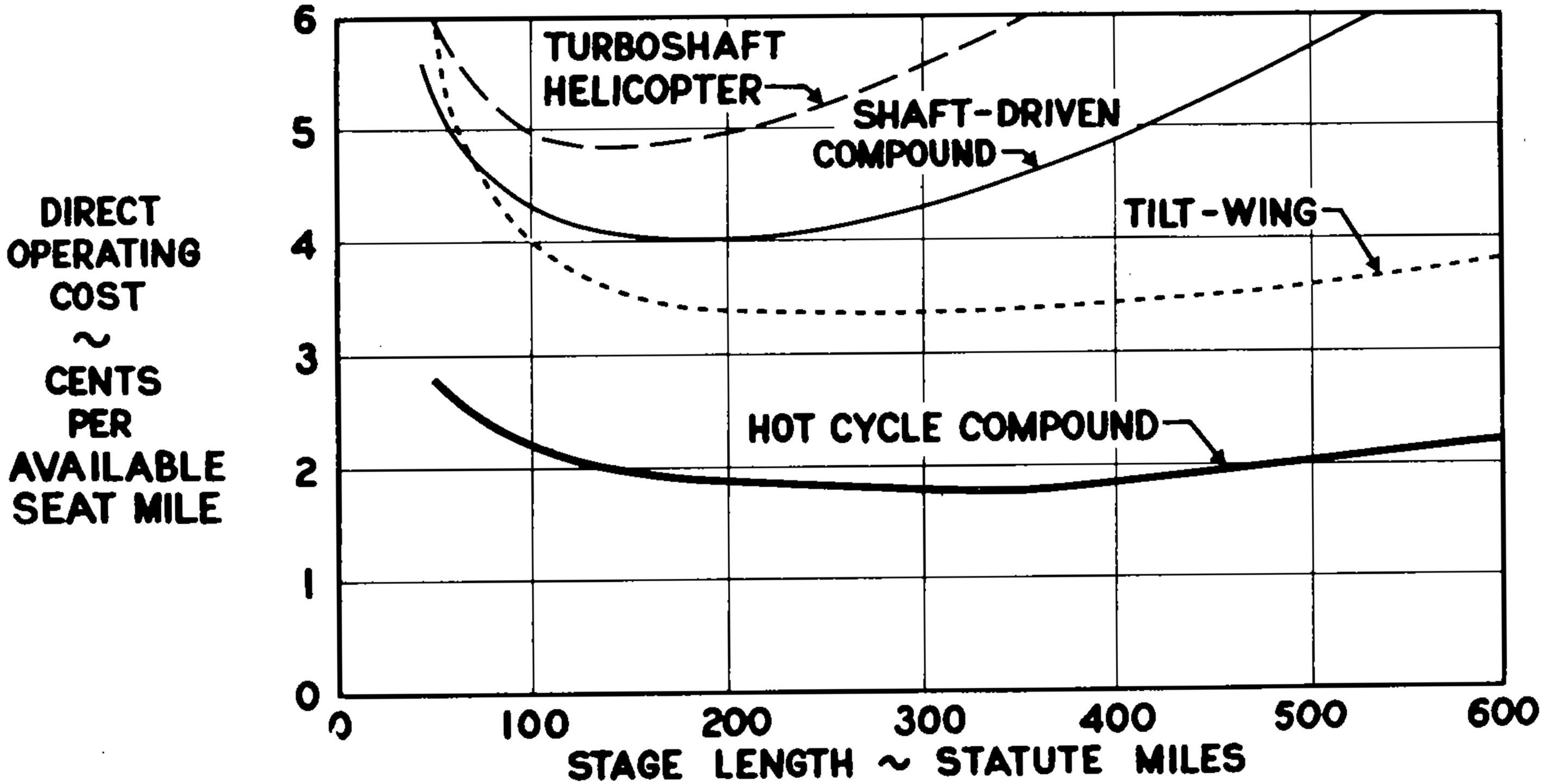
# HUGHES' COMMERCIAL TRANSPORT CONCEPT

# COMMERCIAL ECONOMY

The attractive economies of the Commercial Hot Cycle Compound are illustrated in the operating cost comparisons shown here and on page 49. The cost data for other than the Hot Cycle have been taken from information published by proponents of the systems.

Again, the unique simplicity and light weight, and the resulting high payload account for the 2 to 1 superiority of the Hot Cycle Compound.

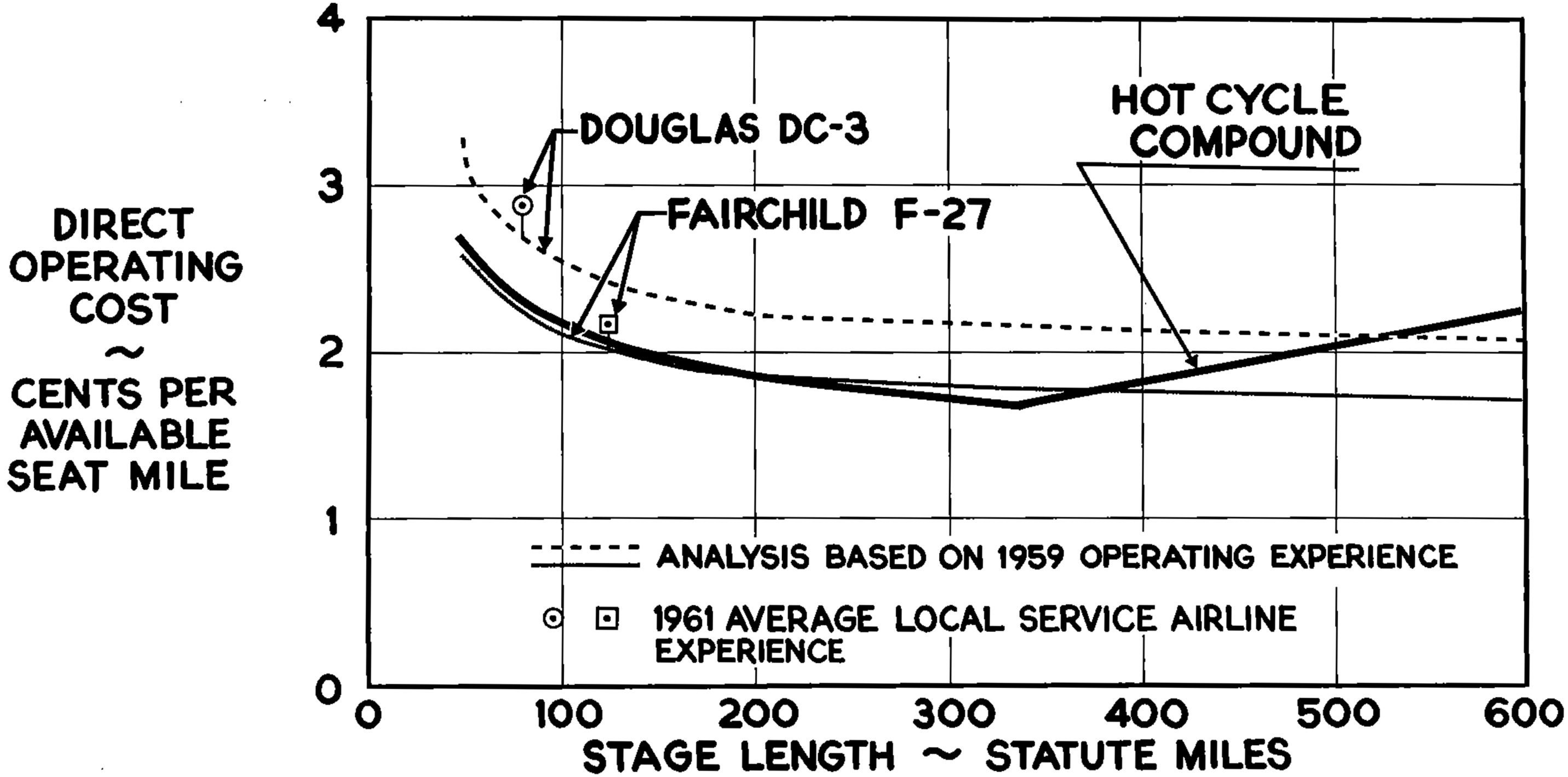
# Operating Cost Comparison, Vtol Aircraft



# COMMERCIAL ECONOMY

This chart further illustrates the economic potential of the Hot Cycle Compound by reference to two outstanding short-haul airplanes in current use. The Hot Cycle Compound promises operating cost lower than those of the fully amortized DC-3's in current use, and quite comparable with the Fairchild F-27. The potential of providing economical downtown VTOL service in place of current, short-haul airplane service could provide a major improvement in convenience to the traveling public. This should stimulate increased air traffic and thus make possible more frequent and more economical service between small cities now providing small numbers of passengers.

# Operating Cost Comparison, Short Haul Aircraft



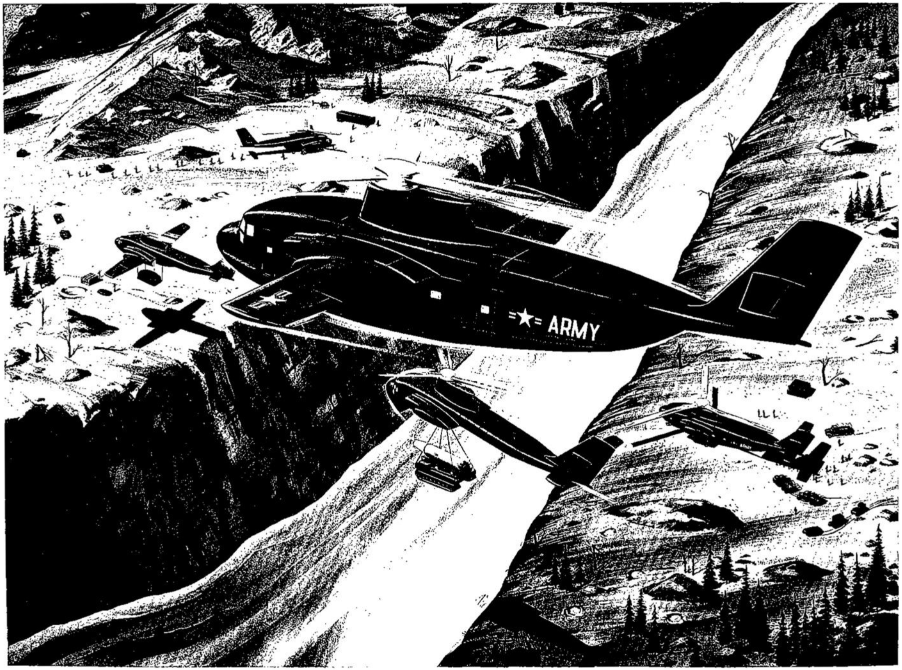
# HUGHES' HOT CYCLE
# MULTI-PURPOSE AIRCRAFT CONCEPT

# A SINGLE AIRCRAFT CAPABLE OF PERFORMING ALL INTRA-THEATER MISSIONS INVOLVING THE TRANSPORT OF LARGE PAYLOADS

Basic design and performance characteristics are presented here for a proposed Multi-purpose Hot Cycle Heavy-Lift helicopter. The design is based on a flying crane configuration which could readily be converted to a high-speed vertical-lift transport.

This Multi-Purpose aircraft could quickly ferry itself to any point in the world and could perform the full spectrum of intra-theater logistics and heavy lift missions with outstanding effectiveness and unparalleled economy. This unique combination of flexibility, high performance and economy results from the simplicity and light weight of the Hot Cycle propulsion system and its application in an aircraft capable of efficient operation as a flying crane, as an internal loading helicopter and as a 300 mph compound helicopter transport. In addition to the large economic and tactical advantages offered by the Multi-Purpose Hot Cycle Heavy-lift helicopter, significant operational and logistics benefits would result from the reduction in number of aircraft types made possible by its multi-mission flexibility.

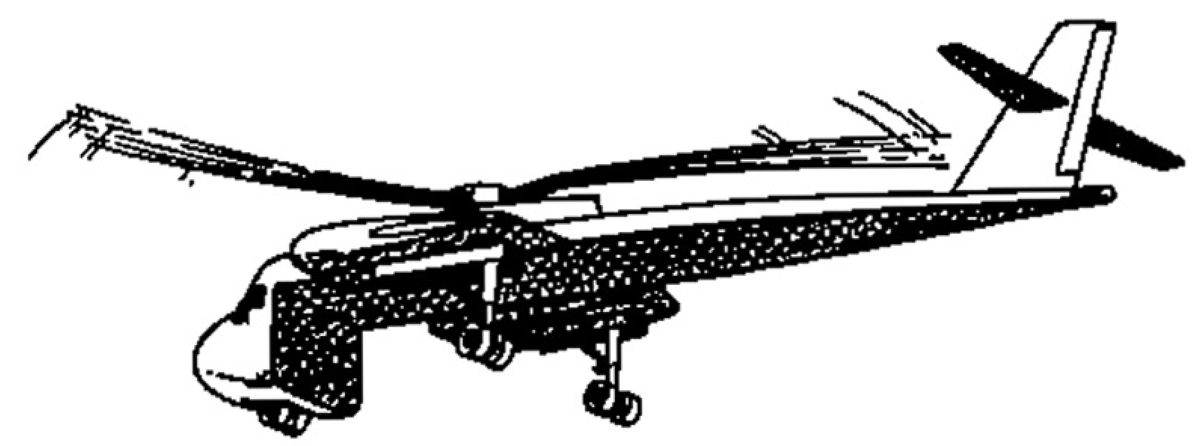
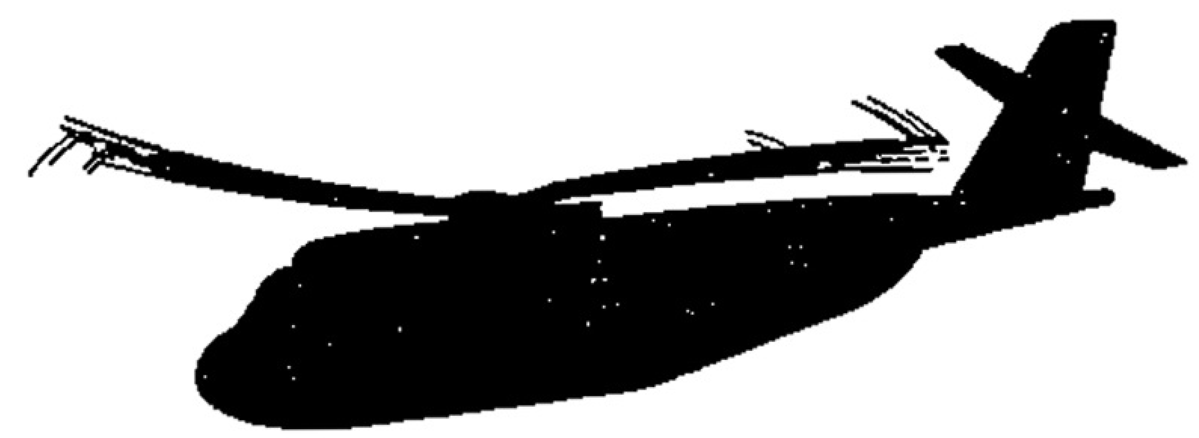
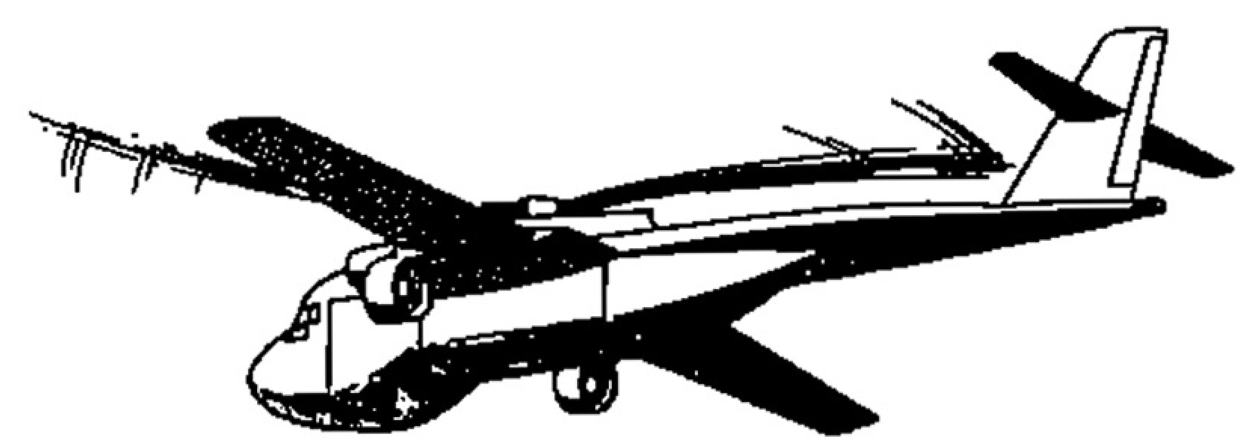
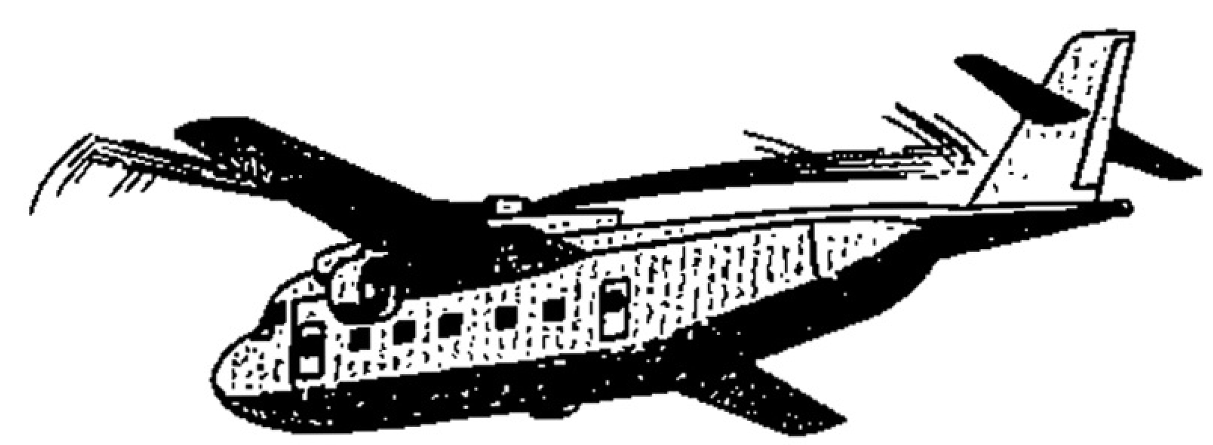
# Hughes' Multi-purpose Aircraft Concept



# CONFIGURATIONS

The basic aircraft is a flying crane helicopter using four advanced General Electric T64 gas generator engines powering a Hot Cycle rotor. This configuration would provide unparalleled capability and economy for carrying sling loads, vans, containers, etc. By the addition of a streamlined container or fuselage pod plus wing panels and tip-turbine-driven propulsion fans for cruise flights, the aircraft becomes a 300 mph vertical take-off transport. It operates in this mode as a Hot Cycle Compound helicopter, providing outstanding productivity and economy coupled with the ability to operate effectively in the field.

# Configurations

| | |
|---|---|
| ***CRANE***<br>24 TONS, 50 MILES AT 115–150 MPH |  |
| ***HELICOPTER***<br>20 TONS, 100 MILES AT 170 MPH |  |
| ***FUEL/AMMO RESUPPLY***<br>16 TONS, 500 MILES AT 300 MPH |  |
| ***HIGH SPEED TRANSPORT***<br>125 TROOPS, 500 MILES AT 300 MPH FERRY RANGE 3,200 MILES |  |

# HUGHES' CONCEPT OF A TYPICAL MISSION

For the extremely important mission of aerial re-supply of fuel, ammunition, and other high-density cargo, a configuration is shown which provides maximum payload and operational flexibility. The load (fuel cells, pallets, or containers) is carried from the mounting points on the basic aircraft strong-back. A light fairing streamlines the load and aircraft, permitting efficient cruise at 300 mph. The fairing can be opened remotely for rapid loading and unloading using the basic aircraft winch system.

For high-speed VTOL operation carrying typical bulk cargo or troops, a fuselage pod would be added to the basic flying crane configuration. This pod would provide a cargo space 9 x 10 x 40 feet and would incorporate doors and a ramp for straight-in rear loading. It would be attached to the strong-back of the basic aircraft at four mounting points provided for this purpose.

In addition to outstanding mission performance and flexibility, this Multi-purpose aircraft promises operating costs one-third that of present inventory helicopters and one-half that of the best competing VTOL concept.