REPORT No. 4960

DATE 8/12/40

VOUGHT-SIKORSKY AIRCRAFT

STRATFORD, CONNECTICUT

DIVISION OF UNITED AIRCRAFT CORPORATION

TITLE

INFORMAL PROPOSAL FOR ARMY TWO-SEATER SERVICE OBSERVATION-TRAINER HELICOPTER VS-316

SUBMITTED UNDER

MODEL

CONTRACT

PREP. [signature] CH'KD. [signature] APPR.

REVISIONS

DATE	REV. BY	PAGES AFFECTED	REMARKS	NO. OF PAGES

TABLE OF CONTENTS:

FOREWORD

This proposed Helicopter, to be known as the VS-316, shall be similar to the VS-300 Experimental Helicopter which was produced in 1939, gradually improved, and which gave extremely promising results during tests conducted this summer.

The proposed aircraft shall be a true helicopter with all lift and control being based on the action of the air on its rotating surfaces only. The machine shall be completely independent of speed for its lift and control. It shall be capable of rising vertically from small places surrounded by obstacles; hover motionless over one spot for indefinite periods; travel forward at any speed from zero to about one hundred miles per hour, and travel backwards and sideways at a reduced speed. With these characteristics it shall be possible to operate the aircraft from any place large enough to swing the rotors.

The proposed helicopter may be used and will be able to render valuable service under conditions which would not allow the use of existing types of aircraft.

\- - -

GENERAL DESCRIPTION

This aircraft shall be a two-place side-by-side helicopter.

Welded steel tubular construction shall be used throughout.

Fabric shall be used except for metal covering at the engine section and at the cockpit.

The blades shall be constructed of built-up material that will afford the utmost efficiency and safety for the job intended.

Maximum vision forward, up and down and sideways shall be obtained. Every effort will be made to obtain maximum rearward vision consistent with the design of the aircraft.

The power plant shall be located near the center of gravity of the aircraft. Power shall be transmitted to the main rotor and rear blades by a gear and shaft transmission system.

The main rotor, consisting of three blades, shall be located just forward of the center of gravity.

The three auxiliary rotors, one mounted vertically and two mounted horizontally, shall control the airplane. Two horizontal propellers shall be located on both sides of the centerline of the fuselage behind the disc of rotation of the main lifting rotor.

The third auxiliary propeller shall be located in a vertical plane near the end of the fuselage in a direction transverse to the centerline of the fuselage.

The two rear horizontal propellers shall be controlled by the main control stick. The motion of the stick fore and aft shall change the pitch of both propellers in the same direction producing a longitudinal control of the aircraft. Moving the stick laterally shall change the pitches of the propellers in opposite directions providing means for lateral control of the aircraft and acting in a way similar to the ailerons on an airplane.

The rear vertical propeller shall furnish forces to compensate the torque of the main lifting rotor.

Conventional rudder pedals in the cockpit shall control the pitch of the propeller which in turn shall control the direction of the aircraft.

All controls shall depend only upon the aerodynamical forces caused by the rotation of the auxiliary propeller. Therefore control shall be completely independent from the rate of speed of the machine, that is, the controls shall be fully active with the machine moving slowly or hovering over one spot.

The whole system of auxiliary propellers shall be mechanically connected to the main lifting rotor and shall be operated from the same power source.

In the event of engine failure, an automatic device shall change the pitch of the main rotor so as to create auto-rotation. The control propellers shall then rotate through power from the auto-rotating main rotor and control of the aircraft permitting normal gliding and landing similar to the gliding and landing of the autogyro aircraft shall be possible.

A lever in the cockpit controls the pitch of the main rotor.

The setting of the two horizontal propellers and the throttle control shall be linked to this rotor control lever. This shall allow synchronization in such a way that during maneuvers close to the ground, the pilot will be able to use this lever to change the altitude of flight without adjusting the power of the engine or the relative pitch setting of the rear propellers. The action of all controls shall be positive.

SUMMARY OF ANTICIPATED PERFORMANCE BASED ON CALCULATIONS

Gross Weight	1700 lbs.
High speed at sea level	102 mph
Operating speed at sea level	83 mph
Endurance at operating speed (two-seater)	1.62 Hrs.
Endurance at operating speed (single-seater) .	5.5 Hrs.
Service ceiling (at zero forward speed)	6,000 ft.
Absolute ceiling (at zero forward speed)	7,000 ft.
Service ceiling (with forward motion)	14,000 ft.
Minimum speed	0 MPH
Rate of climb at S.L. (zero forward speed) ...	600 ft/min.
Best rate of climb at S.L.	1200 ft/min.
Free rate of descent (vertical)	1650 ft/min.
Takeoff over 50' obstacle, distance	0 ft.
Landing over 50' obstacle, distance	0 ft.

REPORT No. 4960

WEIGHTS

Gross Weight - 1700 lbs. Useful Load 525 lbs.

I. ROTOR

Blade structure (3 blades)	105#
Hub and fittings	20#
TOTAL	125#

II. FUSELAGE

Steel tubings, frame and tail boom	170#
Plexiglass windows	25#
Fabric and fairing	25#
TOTAL	220#

III. TAIL GROUP

Blade structure (3 sets 2 blades each) TOTAL	30#

IV. LANDING GEAR

Main Gear	70#
Front Gear	15#
TOTAL	85#

V. ENGINE MOUNT (weight is included in fuselage)

VI. POWER PLANT

Engine Weight	250#
Engine Controls	5#
Exhaust	5#
Cooling System	25#
Fuel System	15#
Starting System	15#
TOTAL	315#

VII. TRANSMISSION GROUP

Main and rear shafts (including universals)	40#
Main gear box complete	115#
Rear propeller box complete (3) ..	40#
Fluid clutch and free wheeling ...	56#
Transmission oil	10#
TOTAL ..	261#

VIII. INSTRUMENTS	TOTAL ..	10#
IX. CONTROLS	TOTAL ..	35#

X. FURNISHINGS

Two (2) seats	25#
Floor	5#
TOTAL ..	30#

XI. ELECTRICAL

Battery	17#
Generator	15#
Wires, conduits, etc.	8#
TOTAL ..	40#

TOTAL WEIGHT EMPTY .... 1151#

USEFUL LOAD

Crew (2) with parachutes	400#
Fuel (14 gals.)	84#
Oil (2 gals.)	15#
Provision for radio	50#
TOTAL ..	549#

TOTAL GROSS WEIGHT .... 1700#

PHYSICAL CHARACTERISTICS

DESIGN GROSS WEIGHT, W	1700 lbs.
FUEL	
Normal (14 Gals.) (Provision for 50 gals.)	84 lbs.
MAIN ROTOR	
Airfoil Section	NACA 23012
Diameter of Rotor, D	34 ft.
Disc Area, A	908 sq. ft.
Number of Blades	3
Total Blade Area	3 x 14 - 42 sq. ft.
Solidity Ratio, ...	.0463
Twist	5^{o}
Gear Ratio	1:12
Taper Ratio	2.5:1
CONTROL PROPELLERS	
(Two Horizontal and One Vertical)	
Airfoil Section	NACA 0012
Diameter	7 ft. 8 in.
Disc Area (per Propeller)	46 sq. ft.
Number of Blades	2
Solidity Ratio	.0543
Twist	3.5^{o}
Gear Ratio	1:2.71

PHYSICAL CHARACTERISTICS (continued)

TYPE OF ALIGHTING GEAR

Fixed

One Nose Wheel, Two Main Wheels and Tail Skid

Tread of Main Gear	13' 4"
Main Wheels	16" x 7"
Nose Wheel	12" x 5"

POWER PLANT DATA

Number of Engines	One
Manufacturer	Aircooled Motors Corporation
Manufacturer's Designation	Franklin 6AC-296
Displacement, cu. in.	296
Compression Ratio	7:1
Fuel	Socony 80 Octane
Oil	SAE #20
Gear Ratio	D.D.

ENGINE PERFORMANCE:

Normal Power 150 BHP at 2800 RPM at Sea Level

METHODS OF PERFORMANCE CALCULATION

I. Analysis was made for the following conditions:

1. Hovering
2. Vertical ascent
3. Horizontal flight and climb with forward velocity
4. Ceilings
5. Power off descent

II. Distribution of lift and power required between the rotor and control propellers.

1. Hovering and Vertical Climb

The distribution of lift between the main rotor and horizontal control propellers is done in such a way as to balance all forces and moments acting on the aircraft at any given attitude.

In hovering and vertical climb the forces acting on the helicopter are lift and weight. Therefore, the lift on each horizontal propeller depends on the distance of the axis to c. g. of the aircraft.

The force acting on the vertical control propeller is determined in such a way as to give a couple which balances the torque from the main rotor. The torque influence of the rear control propeller on the balance of the aircraft is neglected.

The power required on each propeller is determined in accordance with their respective lift distribution.

2. Climb with longitudinal motion.

In writing the equations of balance, because of the multitude of propellers, the determination of the force components acting on the aircraft becomes quite difficult because of the number of unknowns involved for a given number of equations. Therefore, certain reasonable assumptions and simplifications have to be introduced.

At the moment the most reasonable procedure seems to be to isolate the main rotor and the body drag from the control propellers. This is done in the following manner.

(a) Determine the power required in hovering on each rotor.

(b) Assume that, in motion, the percentage of total power taken by the main rotor is the same as in hovering.

(c) Assume that the distribution of body drag acting with each horizontal rotor is proportional to their respective thrusts in hovering.

III. Performance

Performance calculations are based on the information taken from the given list of references as follows.

1. Hovering - ref. 1, 2, 12 (page 401, Corr. to Slipstream Rot.)

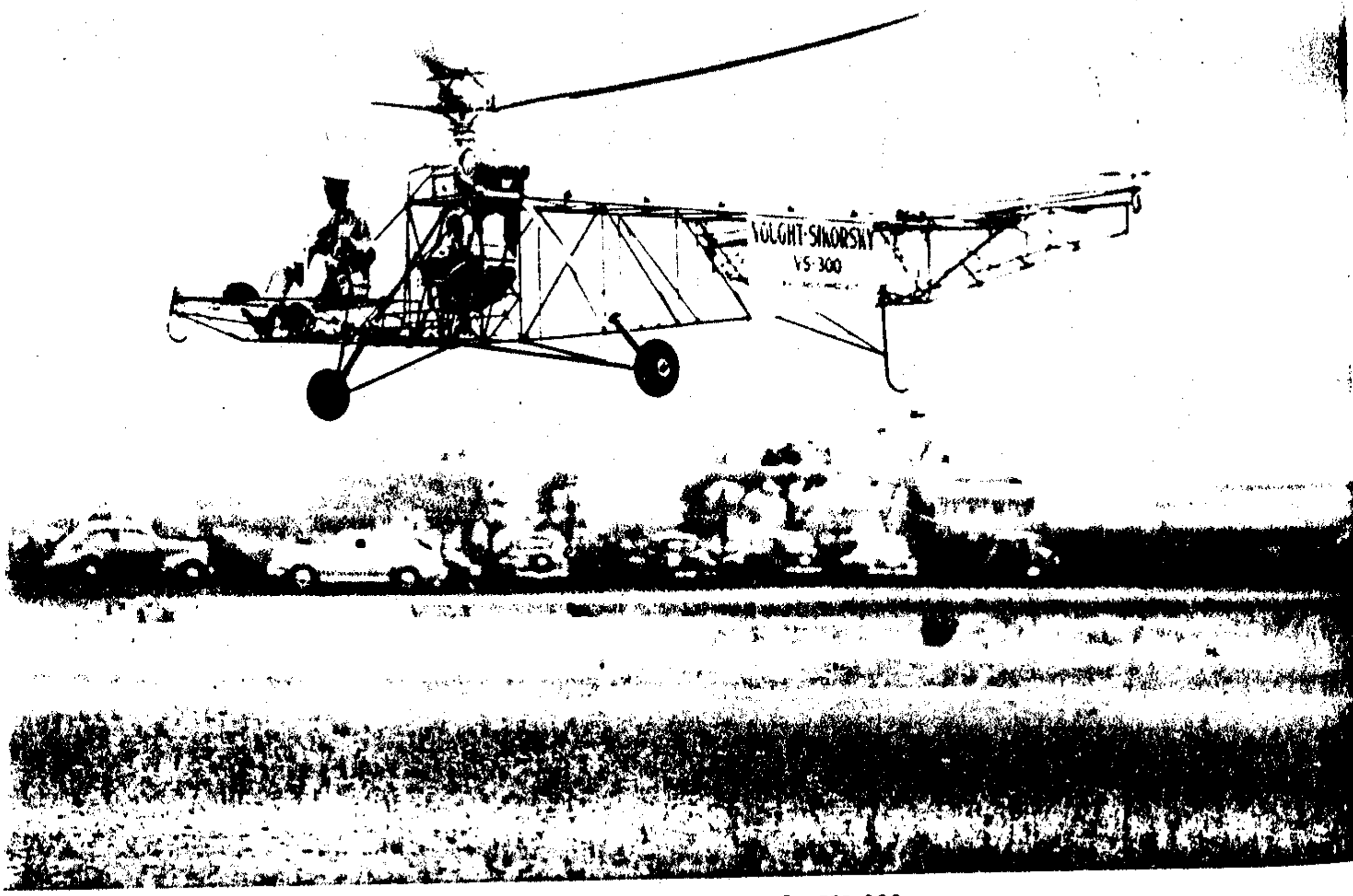
2. Vertical ascent - ref. 3, 4, 5.
3. Horizontal flight and climb with forward velocity, ref. 3, 4, 5, 6.
4. Ceilings, ref. 3, 4, 5, 6.
5. Power off, descent, ref. 8, 11.

It is believed that the performances given are conservative.

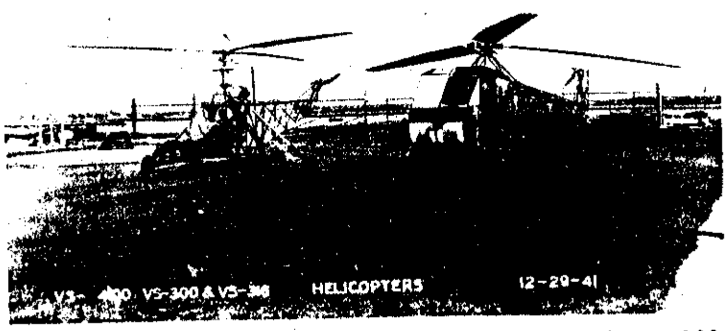
The final results compare favorably with performance of a hypothetical helicopter similar to the C-30 "Autogyro" (example given in refer. 3, pages 2, 18-22, Ref. 1, page 30-31 and Ref. 15).

REFERENCES:

1. Static Thrust Analysis of the Lifting Airscrew, by M. Knight and R. A. Hefner, NACA T.N. #626 (1937).
2. The Hafner Gyroplane by R. Hafner, Journal of the Royal Aeron. Society, Feb. 1938.
3. The Flight of a Helicopter by H. B. Squire, R. & M. #1730 (1936).
4. Handbook of Aeronautics (British) Vol. I, 1938 Edition.
5. Vertical Ascent of a Helicopter by Glauert, R. & M. #1132 (1927).
6. Horizontal Flight of a Helicopter by Glauert, R. & M. #1157.
7. Flight on Rotating Wing by W. L. Le Page (reprint from Journal of the Franklin Institute, Vol. 222, No. 3, Sept. and No. 4 Oct. 1936).
8. Vertical Descent of the Autogyro by J. A. J. Bennett, NACA T. M. #673, (1932).
9. Performance of Rotating Wing Aircraft, by F. Hohenemser, NACA T.M. #871 (1938).
10. Aerod. Theory, W. F. Durand, Vol. IV, pages
11. A General Theory of the Autogiro, by Glauert, R. & M. #1111 (1926).
12. The Helicopter: Propulsion and Torque by H. H. Platt, Journal Aeron. Sc., Sept. 1936.
13. Analytical Comparison of Helicopter and Airplane in Level Flight, by M. Knight, Journal Aeron. Sc., Sept. 1938.
14. Vought-Sikorsky Report #4948 (April 20, 1940) Aerod. Rep., Rotating Wing Aircraft.
15. Avro C-30 Direct-Control Autogiro by C. N. Colson, NACA Aircr. Circular #196 (1934).



Frank Gregory's first flight in the VS-300.



XR-4 as she was rolled out for the first time beside VS-300.

of the
The
strut-b
at nin
craft o
suppo
Thi
It t
to ma
copter.
prope
weight
craft k
brough
not b
on th

XR-4 (left) and VS-300 (final configuration) in formation.

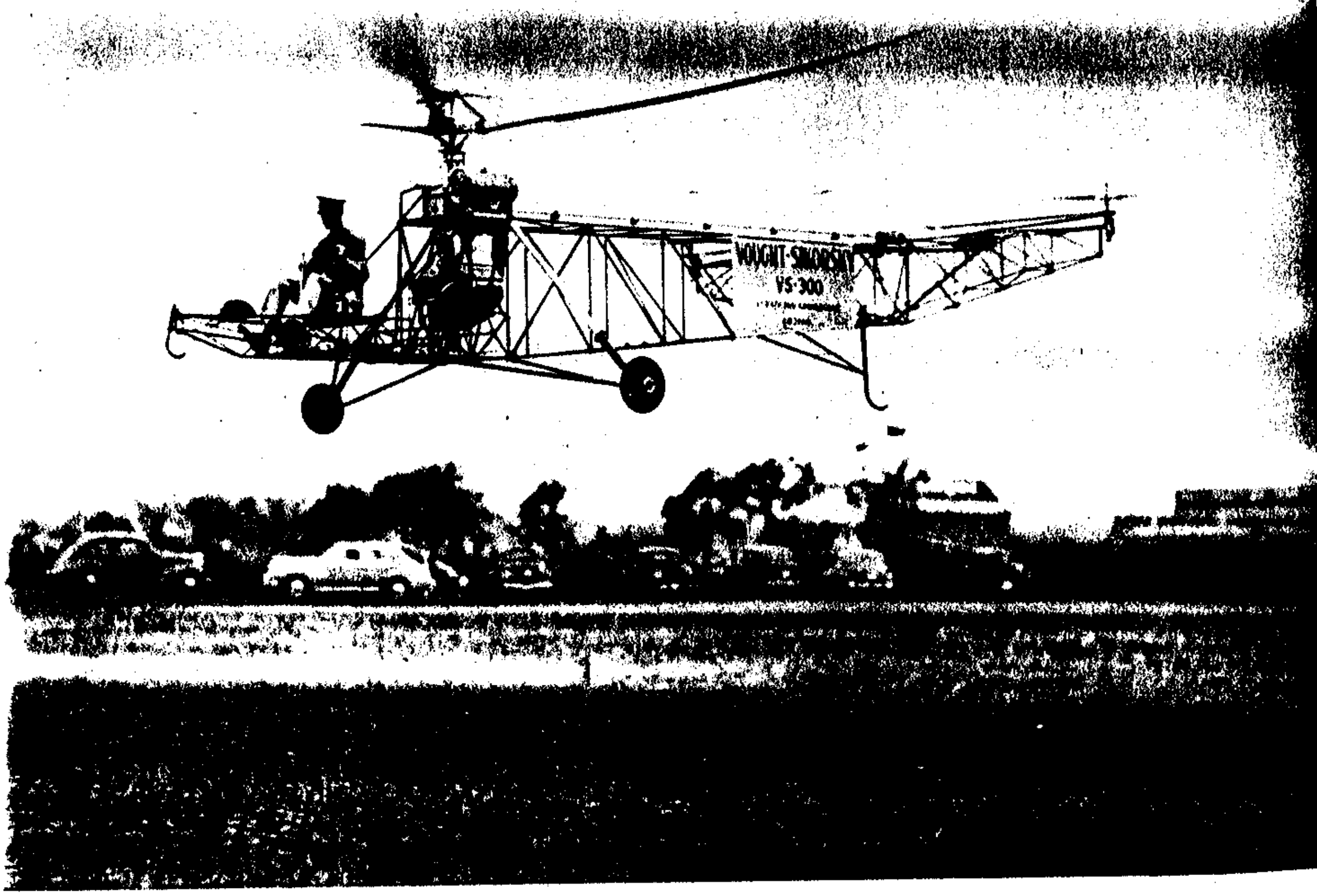
f the craft.

The landing gear—vertical hydraulic shock struts which were trut-braced and extended to the left and right sides of the craft t ninety-degree angles to the engine mount—supported the air-raft on two small balloon-tired wheels. A tiny wheel in the tail upported the craft from that position.

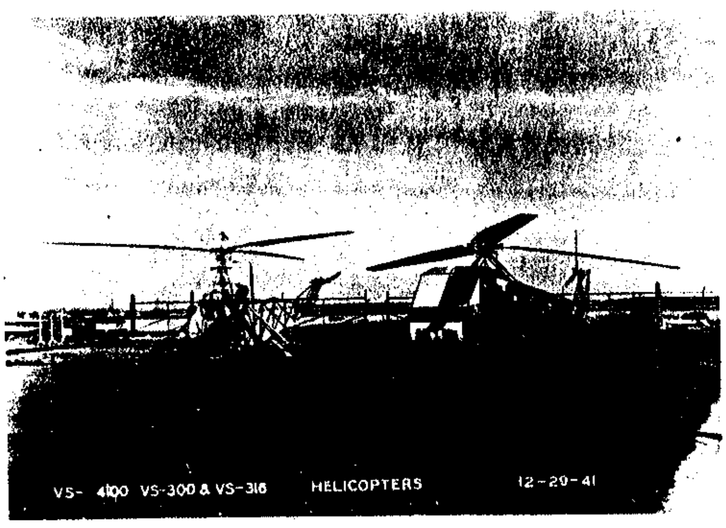
This was the XR-4.

It took Sikorsky mechanics and test engineers about a month to make ground tests and preliminary runs with the new heli-copter. They tested the engine thoroughly and got the blades properly balanced and controlled. A few structural changes and weight changes were effected here and there, but generally the craft kept its same shape and weight as it had the day they first brought it out in the open. They did, however, feel that it would not be wise to fly it without putting some additional cushioning on the nose and as a result of this a makeshift fourth wheel arrangement was devised. A pair of small dolly wheels were rigged up on a two-by-four plank which was bolted to the bottom of the craft to protect it in case of a nose-over.

Sikorsky's chief test pilot, Les Morris, who had flown most of the tests with the VS-300 during the elimination of the horizontal rotors and who had been with the company since the XR-4 was started, was nominated to fly the Army's vertical-flight craft. Morris flew the ship on the morning of January 14, 1942. He made a total of six test flights that day, the longest of which lasted for seven minutes and twenty seconds. Total flying time was twenty-five minutes and six seconds for all the flights—a short period, but a milestone in the development of the helicopter in this country. While there were many changes to be made, the flights indicated definitely that the craft would be successful. The Army could claim a new first with its initial flight of the XR-4.



Frank Gregory's first flight in the VS-300.



XR-4 as she was rolled out for the first time beside VS-300.

of the
The
strut-b
at nin
craft o
suppor
Thi
It t
to mal
copter
proper
weight
craft k
broug
not b
on th