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DEVELOPMENT OF IMPROVED CARGO SLING SYSTEM INCORPORATING LOAD STABILIZATION
FINAL REPORT ON PHASE I - ENGINEERING ANALYSIS (U)

R-186

U.S. Army Transportation Research Command
Fort Eustis, Virginia

Project No. 9R38-01-017-52
Contract No. DA 44-177-TC-587
Code Identification No. 77272

March 1960

VERTOL AIRCRAFT CORPORATION
Morton, Pennsylvania
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I. INTRODUCTION

The U.S. Army CONARC determined that a need existed to provide a means of minimizing the effects of external loads on helicopter flight characteristics and to provide means of stabilizing sling loads in order to more fully exploit the benefits of transporting loads externally at high speeds. Accordingly, Contract DA 44-177-TC-587 was awarded to Vertol Aircraft Corporation for an improved external cargo sling system incorporating load stabilization.

The results of the Phase I study for the contract are presented in this report. The investigations covered the following areas for H-21C, YHC-1A, H-34A and H-37A cargo helicopters:

a. External cargo systems which will allow the load line of action to pass near the c.g. of the helicopter;

b. Means of stabilizing the attitude of the load with respect to the helicopter;

c. Problems involved in providing internal pyramids in the four helicopters to provide a support near the aircraft c.g. for external loads.

A configuration of suspension system and load stabilizer is recommended for design and testing on an H-34 during Phases II and III of this program.

During the conduct of this study, discussions were held with the activities listed below in order to obtain comments from operating personnel and to maintain liaison with work being done in parallel areas:

Transportation Research Command, Ft. Eustis, Va.
Army Aviation Board, Ft. Rucker, Ala.
Airborne and Electronics Board, Ft. Bragg, N. C.
A study was made of various means of improving the effective pivot point of helicopter external cargo suspension systems and of stabilizing the load in flight. Successful flights of a "cargo swing" system under another contract provided a criterion for evaluating the systems considered.

The results of the study were:

1. For concentrated, heavy loads pivot point improvement is required to permit operation up to Vmax, but load stabilization may not be required for all loads.
2. Internal cabin space should not be taken up for the external load device.
3. For bulky, aerodynamically dirty loads stabilization will be required.
4. Rapid cargo pick-up is important, so the stabilizer must be out of the way for pick-up and quickly engaged thereafter.

The configuration which best meets the above requirements for the H-34 to be used in Phases II and III of this program is:

1. External hatch cover removed but floor above left in place;
2. Folding, double-axis cargo swing;
3. Fuselage-mounted stabilizer forward, with two degrees of freedom.

The work required to install an appropriate hatch for cargo slinging in the bottom of the H-21 was investigated. In essence, there would be required:

1. Removal of the keel and floor frame;
2. Installation of a hatch frame and doors;
3. Relocation of control cables and searchlight.

The H-34 has provisions for a hatch, which may be incorporated at SCAMP overhaul; the YHC-1A and H-37 have existing hatches. All the above hatches are somewhat smaller than those required to meet the criteria for both pivot point improvement and range of motion, so some compromise must be accepted in using them.
1. Requirements

The design requirements to be met by the equipment recommended in this study are to be the best compromise of the factors listed below. The contract specified certain requirements, and other recommendations were made during discussions at the Army Aviation Board, Ft. Rucker, Alabama.

A. Contractual Requirements:

(1) Devise external load supporting equipment which will prevent the stability and controllability of the basic helicopter from being materially penalized by the sling and load.

(2) The lifting device to allow the line of action of the sling load to pass through or near the c.g. of the helicopter.

(3) The load stabilizer to operate in hover and forward flight to prevent excessive swinging, pitching and yawing of all configurations of external loads that are likely to be transported by Army cargo helicopters.

(4) The weight of the systems to be kept to a minimum.

(5) The support and stabilizing devices to be compatible with each other, with standard helicopter hooks, with the hook being developed under Contract DA 44-177-TC-560, with slings having the characteristics specified in AD 207201, and with the static electricity elimination program.

(6) Maintenance requirements to be minimum.

(7) Configuration to provide greatest general utility.

(8) The study to include analysis of the weights and stresses in the recommended systems and an analysis of their aerodynamics.

(9) The analysis to consider the feasibility of modifying existing fuselage structures to allow attachment of the sling near the c.g.
B. Operational Features:

In addition to the above, other desirable operating features of cargo slinging equipment were pointed out in meetings held at the Army Aviation Board and the Army Airborne and Electronics Board and are included here for completeness.

(1) Equipment should be as inexpensive as possible.

(2) Installation should require only ordinary tools used in the field.

(3) Stowage should be accomplished readily in a position offering minimum drag.

(4) Operation may be conducted by a crew chief because he will be aboard for cargo slinging operations.

(5) Equipment should be immediately adaptable to all aircraft of a type and should not result in special mission aircraft.

(6) All operations of equipment should be performed from within the aircraft.

(7) Load pick-up and engagement of the stabilizer should be rapid.

(8) Internal cabin space should not be taken up by external load devices.

(9) Instantaneous release of the load should be provided.

(10) Capability of night operation should be provided.

(11) Equipment should provide single point load suspension.

(12) Equipment should be air transportable in detached form.

(13) Operation should present no hazard to ground crew.

2. Criteria

A. Pivot Point:

Under Contract DA 44-177-TC-578, tests were flown on the H-21 with a "cargo swing" device, which raises the effective pivot point of an external load from 124 in. below the c.g. of the aircraft to 30 in. below. This system is shown on Drawing 242, page 1-3, and the photo
on page 1-2. Pilot comments on this configuration are summarized in the statement that "qualitatively, the control and stability characteristics... very closely resemble the flying qualities of the basic aircraft." The helicopter was maneuvered with alacrity and flown at speeds up to Vmax during the test program. See Reference I.

Since use of the cargo swing with external loads afforded fully satisfactory controllability and stability in all flight regimes, the pivot point geometry it affords is used in the present study as a criterion. The effective pivot point is 30 in. below the helicopter c.g.

The principle effect of the raised pivot point is to improve dynamic stability of the helicopter with load, especially in hover. The results of an analog study of lateral dynamic stability of the H-21 in hover are presented in Figure 1 for loads on the standard cargo sling, on the cargo swing and on the cabin floor. This plot confirms the pilot evaluation discussed above by showing that the accelerations toward normal attitude for the internal load and cargo swing start at the same time, about 1 second (deflection point). But for the standard sling this acceleration does not occur until 2 seconds. This is the effect felt by the pilot and is the one upon which his evaluation of stability is based. Note that the coupling of the helicopter-plus-load with the cargo swing creates positive dynamic stability which is not present in the basic aircraft.

In order to establish criteria for the YHC-1A, H-34 and H-37 equivalent to that flown successfully in the H-21, dimensionless constants for the factors affecting dynamic stability were selected.

Geometric dimensionless constant = \( \frac{r}{h} \)

Weight dimensionless constant = \( \frac{L}{W} \)

where 
- \( r \) = vertical distance from c.g. to load effective pivot point - in.
- \( h \) = vertical distance from plane of rotors to c.g. - in.
- \( L \) = rated payload - lb.
- \( W \) = flying weight of helicopter alone for cargo mission - lb.
COMPARISON OF EXTERNAL LOAD CARRYING DEVICES

Roll Angle vs Time
H-21

Figure 1
Thus, for equivalent effects on basic aircraft dynamic stability,

\[
\frac{r_1}{h_1} \times \frac{L}{W_1} = \frac{r_2}{h_2} \times \frac{L}{W_2}
\]

and solving for \( r_2 \),

\[
r_2 = \frac{r_1 h_2}{h_1} \times \frac{L}{l_2 W_1}
\]

Computations for equivalent \( r_2 \)'s are tabulated below:

<table>
<thead>
<tr>
<th></th>
<th>( h )-in.</th>
<th>( L )-lb.</th>
<th>( W )-lb.</th>
<th>Cargo Swing ( r_1 )-in.</th>
<th>Equivalent ( r_2 )-in.</th>
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<td>10300</td>
<td>30</td>
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<td>3786</td>
<td>10899</td>
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<td>2083</td>
<td>8779</td>
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<tr>
<td>H-37A</td>
<td>81.</td>
<td>6045</td>
<td>23437</td>
<td>--</td>
<td>24.0</td>
</tr>
</tbody>
</table>

TABLE 1.

B. Angle of Motion:

In the H-21 cargo swing installation the lateral angle of motion of the load with respect to the helicopter was 30°, before contacting stops. This value was chosen to permit safe operations not only in extreme flight maneuvers but also during pick-up when the aircraft may not be perfectly centered over the load. Accordingly, the 30° criterion of motion from the vertical when hovering was retained for this study.

3. Configurations

A. Load Pivot Point Improvement:

(1) All feasible configurations of devices which improve the actual or effective pivot point of external cargo were investigated in this study. Their characteristics are compared in Table 2 up to the points at which various ones are disqualified.
The systems are classified by their mechanics as kinematic or fixed devices, or by application to nonhatched or hatched helicopters.

(2) The first two kinematic devices are one- and two-axis versions of the cargo swing successfully tested under Contract DA 44-177-TC-578. For tandem rotor helicopters pivot point improvement is only required for the roll axis because of the powerful pitch control available in the aircraft by use of differential collective pitch. The cargo swing, nevertheless, offers approximately 30% pitch plane improvement with respect to the standard cargo sling. For single-rotor helicopters, it is necessary to provide substantial improvement of pivot point about both pitch and roll axes, as with the double-axis swing. Both units provide effective pivot points 2-1/2 to 3 feet below the c.g., which has been found to be quite satisfactory. Drawing #242 and Sketches 9571 and 9504 show these concepts.

The cargo swing provides higher effective pivot points as the W-frame is made deeper. But, depth of the W-frame also poses ground clearance, retraction, weight, and drag problems so a practical compromise between these factors must be selected. One method of reducing weight and providing ready retraction is to design the legs and base of the W-frame of cable so that the unit can be folded easily for retraction into the helicopter or along its belly. This flexible construction is also desirable for preventing damage in case the swing should contact the load during operations in turbulent weather. The cable supporting the hook should be long enough to place the hook below the in-flight horizontal plane of the nose wheel on the H-21 or other aircraft having a nose wheel.

With the cargo swing system, adequate torsional rigidity can be provided to the cargo hook to orient and hold it in position for automatic hook-ups. The swing is also compatible with all of the means of load stabilization and it avoids interference with internal cargo space.

(3) The second kinematic device is the radius rail, which is a trolley-on-beam, formed to an arc about a selected center near the helicopter c.g. The aircraft not having a hatch or those with too small a hatch to provide adequate trolley motion would have the rail mounted externally. For helicopters with large hatches the rails would be mounted in the area between the belly and the cabin floor,
thus providing ready accessibility, easy stowage and low aerodynamic drag. Since the effectiveness of this system depends on smooth operation of the trolley as the load swings, it is important that the rolling surfaces be kept free of fouling by blowing dirt or freezing precipitation. For the external application this hazard presents a major drawback, but for the unit in the hatch protection from the elements is feasible. See SK's 9424 and 9501.

(4) Another possible configuration is a hanger extending through the sides of the aircraft and meeting at the hook beneath the fuselage. The hanger would be universally supported near the c.g. by a tripod mounted on the cabin floor. The kinematics of such a device could be very good, and structural rework of the fuselage would only be required in the sides, which are usually uncongested. However, many obvious difficulties appear to disqualify the design: Weight would be prohibitive; some rework of the aircraft would be required; handling and stowage of the device would be difficult; cabin space for internal loading would be compromised; and, aerodynamically, the installation would be dirty.

(5) External kinematic motion could be provided by use of interconnected hydraulic cylinders hung below the helicopter. The hydraulic connections would keep the total length of the system from fuselage to cargo hook to fuselage constant, giving an effect equivalent to a pulley traveling along a cable slung beneath the aircraft, as discussed in the next paragraph.

Although both of these concepts raise the effective pivot to a point near the c.g. when the angle of motion is small, the effective pivot descends rapidly as the angle increases, thus giving negative stability. This is an unacceptable condition because the pilot must apply unproportionately large corrections as the magnitude of the disturbance increases.

(6) The pulley-on-cable system has unsatisfactory kinematics as mentioned above. A further problem is presented by exposure to blowing dirt and ice which disturb or even prevent pulley motion.
(7) In an attempt to overcome the kinematic deficiency of the pulley-on-cable, a design study was conducted of a system incorporating two coaxial cams which would provide true circular motion to the cargo hook about the helicopter c.g. However, requirements of the cam motion became mechanically impractical, so the concept was discarded.

(8) Several versions of fixed devices for supporting the cargo were considered. The first was based on the concept of holding the load rigidly below the helicopter to prevent any relative motion. The aircraft plus cargo would then in effect be a single mass with the c.g. somewhat lower than when unloaded. Controllability would be satisfactory though somewhat reduced below that of the basic helicopter because of the higher moment of inertia with the external load. The principal difficulties with this system are encountered during hook-up to the load. If the load restrainer is fixed to the bottom (SK 9505) before lift-off, the aircraft must be lowered onto the load, which is considered too critical a maneuver for normal field operations, especially in gusty weather. If the restrainers are adjustable, excessively complicated controls are required to position them, and the time to position them will be too long. The requirement for hydraulic power is a further minor drawback. Local structural reinforcement of the airframe would be required at the points where the restrainers are attached. Also this system might not be satisfactory for certain delicate loads like radar antennae.

(9) Two other fixed configurations having higher attachment points than the cargo sling have been built. The first was a ventral beam hung from the aft cargo sling attachment points of the H-21. The second is the YHC-1A installation of a fixed beam below the cabin floor, SK 9426.

Although these two approaches yield improvements proportional to the reduction of the distance from c.g. to hook, neither can be considered to direct the load line of action "through or near the c.g.".

(10) For hatched helicopters, the most obvious device for pivot point improvement is an internal pyramid having its apex at the desired height. The hook is suspended from a cable or bar which is universally mounted at the pyramid apex. The height of the pivot is selected as a compromise between distance from c.g. and angle of load motion permitted by the hatch. For the YHC-1A, H-34 and
H-37, use of the 30° load motion criterion results in the following pivot distances below the c.g., respectively: 27.3 in., 41. in. and 51.4 in. Comparing these with the equivalent *R*'s computed in Table 1, 20.6 in., 26.4 in. and 24 in., it is apparent that either the hatches are not large enough or the motion criterion must be narrowed in order to retain the effect produced by the cargo swing on the H-21. The internal pyramid nevertheless provides a simple, effective, easily stowed device for performing the required function in hatched helicopters without modification. Its principal drawback is that it requires internal cabin space. Modifications required to install a hatch in the H-21C are discussed in Section 4. Internal pyramid installations are shown in SK's 9469, 9502, 9503, and 9504.

(II) A pivot point suspended by cables from the upper legerons, as shown in SK9505, produces the same effect as the internal pyramid and may be lighter. Structural support must be provided in the fuselage at the cable attachment points. The possibility of recoil of this cable system after release of a heavy load should be checked by means of a mock-up to determine whether a recoil prevention device is required.

B. Load Stabilization:

(I) Most Army loads for external transport by helicopter may be slung satisfactorily in hover and forward flight. However, a few items such as rotor blade boxes and conex boxes have presented difficulties, either because of swinging under the aircraft or because they assume a maximum-drag attitude. So if flight at maximum speed is required when slinging these problem loads, stabilization would have to be provided.

The advisability of providing external load stabilization was quite thoroughly discussed with personnel of the Airborne and Electronics Board and the Army Aviation Board. These discussions point out that there is relatively little requirement for providing such equipment inasmuch as only a few of the loads present a problem. In these problem cases, the loads could be satisfactorily handled by reduction in speed rather than compromising the performance of the helicopter by installing special equipment for those special loads. As a result of the above, further action on load stabilization was discontinued, however, those stabilizing devices investigated during the initial phase of this contract are presented and discussed.
(2) If stabilization should be required in some future program, the stabilizer should hold the desired yaw, pitch and roll attitudes of the load with respect to the helicopter during all normal maneuvers without in any way interfering with instantaneous release in case of emergency jettisoning. Safety in this situation is predicated on the use of a single cargo hook. The device should also be adaptable to a wide variety of cargo sizes by control from within the helicopter. The requirement for stabilizing equipment to be installed on the load at the time of its preparation is undesirable. Compatibility with the automatic hook-up system developed under Contract DA 44-177-TC-560 is required.

Characteristics of the various stabilizer configurations are compared in Table 3. Asterisks indicate the points at which configurations were eliminated.

(3) The first stabilizer category investigated in this study is multiple-attachment. Three configurations include: Two separately supported cargo hooks in tandem; a cargo hook holding both the load and a stabilizing line from the forward end of the load, through a fixed ring; and a cargo hook plus a separately attached stabilizing line forward on the cargo. These concepts were discarded because of the multiple attachments, which compromised safety in emergency release, made automatic hookup difficult and required more specialized preparation of the load by ground crews. Further, a simple lifting force at the forward end of a load would not provide satisfactory yaw restraint. See SK's 9421, 9422 and 9426.

(4) In the second category, helicopter-mounted stabilizers, four configurations were considered. The fixed ventral yoke could be made to operate with certain long loads, but was not very universal in application, especially when observing ground clearance requirements of the helicopter. The adjustable stabilizer mounted on the bottom of the fuselage appeared to be the best compromise of the devices conceived. Adjustability gave the opportunity of retracting the unit for ground clearance and of giving the operator selection of the points at which to engage the load. For delicate cargos, such as radars, it is often desirable to avoid contact with the load and to contact the slinging straps instead. This approach was also desirable in that it afforded a good point of engagement for yaw restraint and permitted contacting
the straps at a variety of distances below the aircraft. Accordingly, the contact area on the stabilizer was designed as a transverse bar having a series of slots capable of engaging the straps of the load sling. The hydraulic actuator of the extension unit is kept moderately pressurized when in use in order to maintain engagement with the load. The stabilizer is also spring loaded to the retracted position for safety in the event of hydraulic failure. A positive up-latch is provided. See SK's 9448, 9571 and 9574.

Undesirable features of this installation are its weight, drag, and requirements for hydraulic power and structural reinforcement.

Development testing would be required to provide a configuration that would not chafe the nylon straps or ropes supporting the load.

(5) The ventral bumper concept is equivalent to the multiple-stabilizer system discussed in paragraph II13A(8), in that the load becomes part of a single mass with the helicopter as far as controllability is concerned. This system is the only one which satisfies the requirements both of pivot point improvement and of stabilization. However, the operational difficulties associated with pick-up and deposit of the cargo are considered excessive, so the concept was not recommended. See SK 9505.

(6) An integral cargo swing and stabilizer was investigated using the concept shown in SK 9530 in order to provide stabilization with no compromise in the effect of the kinematic motion. This approach could be made feasible for the single-axis swing by making it sufficiently rigid torsionally to give a natural frequency higher than the six-per-rotor-revolution. However, with the flexible, folding double-axis cargo swing adequate torsional rigidity cannot be provided, and interference problems arise during retraction of the swing and stabilizer.

(7) The last category of stabilizing equipment is that which is attached to the load at the time of preparing the cargo. Included are aerodynamic devices such as fins or drogues, a gyroscope, and special spacing of the load with respect to the fuselage to avoid rotor downwash. In general, these approaches are unsatisfactory because they either require that the loading crews have special equipment on the ground or they do not provide stabilization in hover, maneuvers and forward flight.
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<tr>
<th>Configuration</th>
<th>Sketch</th>
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<th>Application</th>
<th>Pivot Point Distance Below C.G. (in.)</th>
<th>Reliability</th>
<th>Compatibility with Load Stabilization</th>
<th>Automatic Hookup</th>
<th>Weight Estimate, Less Hook ( lb. )</th>
<th>Aerodynamic Drag ( % )</th>
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<td>SK 9468 SK 9556 SK 9558</td>
<td></td>
<td></td>
<td>H-21: 36 to 32</td>
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<td>Fair</td>
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<td>Moving Cable With Cam Action</td>
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Point at which configuration was eliminated.
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<th>AUTOMATIC MOORUP</th>
<th>HEIGHT ESTIMATE, LESS MOOR 1b.</th>
<th>AERODYNAMIC DRAG Gt. ts.</th>
<th>GROUND CLEARANCE</th>
<th>EASE OF RETRACTION</th>
<th>AIRCRAFT MODIFICATION REQUIRED</th>
<th>EASE OF INSTALLATION AND REMOVAL</th>
<th>ADAPTABILITY TO 1- AND 2-AXIS INSTALLATIONS</th>
<th>FEASIBILITY OF MOORUP ON GROUND</th>
<th>ORIENTATION OF MOOR FOR MOORUP</th>
<th>INTERFERENCE WITH INTERNAL LOADS</th>
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<td>46</td>
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<td>ADD ELECTRICAL RELEASE</td>
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<td>REFERENCE</td>
<td>CLASSIFICATION</td>
<td>EFFECTIVENESS IN HOVER</td>
<td>EFFECTIVENESS IN FORWARD FLIGHT</td>
<td>STABILITY IN YAW, ROLL, PITCH</td>
<td>CREW MAN REQUIRED IN AIRCRAFT</td>
<td>NUMBER OF CONNECTIONS TO CARGO</td>
<td>AUXILIARY EQUIPMENT REQUIRED AT LOAD</td>
<td>APPLIANCE TO ALL TYP OF LOAD</td>
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<td>------------------------------</td>
<td>---------------------------------</td>
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<tr>
<td>DOUBLE CARGO SWING TWO HOOKS</td>
<td></td>
<td>SK 9421</td>
<td></td>
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<td>2</td>
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<td>DOUBLE CARGO SWING HOOK AND RING</td>
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<td>STABILIZING LINE AND CARGO SWING</td>
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<td>FAIR</td>
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<td>FIXED VERTICAL YOKE</td>
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<td>STABILIZING EQUIPMENT ON HELICOPTER</td>
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<td>SK 9400</td>
<td></td>
<td>GOOD</td>
<td>GOOD</td>
<td>YAW ROLL FAIR PITCH GOOD</td>
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<td>NONE</td>
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<td>FIN TAIL</td>
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<td>SK 9505 H-3</td>
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<td>YAW ROLL FAIR PITCH POOR</td>
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<td>FIN AND ATTACHMENTS GOOD</td>
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<td>SPOOL CHUTE</td>
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<td>SK 9505 H-2</td>
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<td>YAW ROLL FAIR PITCH POOR</td>
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<td>SPINDLE AND ATTACHMENTS FAIR</td>
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<td>GYROSCOPE ON LOAD</td>
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<td>FAIR</td>
<td>IN SPACE ANY TWO AXES FAIR</td>
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<td>CARGO LONG DISTANCE TOW HELICOPTER</td>
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<td>POOR</td>
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* POINT AT WHICH CONFIGURATION WAS ELIMINATED
<table>
<thead>
<tr>
<th>APPLICABILITY TO ALL TYPES OF LOADS</th>
<th>LIFT MECHANISM</th>
<th>AUTOMATIC HOOKUP</th>
<th>WEIGHT ESTIMATE (lb)</th>
<th>AERODYNAMIC DRAG (ft²)</th>
<th>RELIABILITY</th>
<th>SAFETY</th>
<th>GROUND CLEARANCE</th>
<th>EASE OF RETRACTION</th>
<th>AIRCRAFT MODIFICATION REQUIRED</th>
<th>EASE OF INSTALLATION AND REMOVAL</th>
<th>ADAPTABILITY TO HATCHED &amp; NONHATCHED AIRCRAFT</th>
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<td>STRUCTURAL INSTALLATION FOR FORK</td>
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<td>GOOD</td>
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<td>35</td>
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<td>GOOD</td>
<td>FAIR</td>
<td>FAIR</td>
<td>FAIR</td>
<td>NOT REQUIRED</td>
<td>PROVISION TO RAISE LIFTING CABLE THROUGH BELLY</td>
<td>GOOD</td>
<td>GOOD</td>
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<td>FAIR</td>
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<td>6.0</td>
<td>GOOD</td>
<td>FAIR</td>
<td>POOR</td>
<td>GOOD</td>
<td>LOAD ROD STRUCTURAL INSTALLATION</td>
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<td>HATCHED GOOD</td>
<td>FAIR</td>
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<td>5</td>
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<tr>
<td>FAIR</td>
<td>GOOD</td>
<td>1</td>
<td>0.8 X AREA</td>
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<td>GOOD</td>
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<td>N.A.</td>
<td>NONE</td>
<td>GOOD</td>
<td>GOOD</td>
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</tbody>
</table>

- 15 -

TABLE 3
Fins have been used in the field by Army crews with the ensuing comment that they are undesirable because ground crews would not normally have the material with the cargo, and each load needs a special size fin to be effective.

The gyroscope, even if it were heavy enough to stabilize a heavy load in forward flight would tend to maintain the cargo's attitude in space rather than with respect to the aircraft and so would be useless in maneuvers.

Special location of the load either very close to or far below the fuselage may prevent the cargo from feeling the influence of the rotor downwash in hover, but in maneuvers and forward flight, no stabilization is offered.

4. Hatch and Internal Pyramid

A. Modification for Hatch:

A contractual item of this study called for determination of the work required for installing a hatch in the floor under the c.g. of the aircraft. Of the four helicopters under study here, only the H-21 does not have an existing hatch. A summary of the structural modifications required to install such a hatch in the H-21 is presented below.

**H-21C Hatch**

**Size:** 28.0 x 34.5 (Fus. Sta. 319.5 to Sta. 354.0 Sym. about & ship at B.L. 14.0)

**Structure Modifications**

1. Remove Keel Sta. 319.5 to Sta. 354.0
2. Remove Floor Frame from R&L B.L. 14.0 at Sta. 339.5
3. Add Hatch Frame (28.0 x 34.5)
4. Add Hatch Doors
5. Add Removable Internal Pyramid. (Provide Stowage Space)
6. Modify Cabin Floor
   a. At Hatch
   b. At Sta. 311.81 - Control Cables
EQUIPMENT MODIFICATIONS

1. Relocate Search Light and Support Installation
2. Modify Troop Seat at Sta. 311.81 (Control Cables)
3. Add Control Cable Guard - Floor to Ceiling Sta. 311.81

CONTROLS MODIFICATIONS

1. Modify Flight Control Cables
   a. Move Pulley Brackets & Pulleys at Sta. 354.0
      fwd. to Sta. 311.81 - (Maintain same W.L. Dim.)
   b. Add 6 Pulleys and Brackets at Sta. 311.81 at Side and Ceiling
   c. Length of Cables will increase

B. Kinematics of Internal Pyramid:

An analysis of the kinematics available by use of a hatch and internal pyramid is presented here for the four subject helicopters because this simple system obviously places the load pivot point near the aircraft c.g., as in the HU-1A. However, for other reasons discussed earlier, this configuration is not recommended for Phases II and III of the present contract.

Using the geometry of existing hatches in the YHC-1A, H-34 and H-37, a study was made of the angle of motion permitted when using the criterion r's, or distance from c.g. to pivot point, from Table I. Also, the r's available when using the ±30° motion criterion were determined.

The results of the above study are summarized in Table 4. For all the helicopters the hatches are somewhat smaller than would be required to meet the criteria for both pivot point improvement and range of motion, so some compromise must be accepted in using them.
# Pivot Height and Motion Limits for Present or Recommended Hatches

<table>
<thead>
<tr>
<th>Helicopter</th>
<th>Criterion</th>
<th>Motion Angle for Criterion</th>
<th>Per Cent of Criterion Motion ($\pm 30^\circ$)</th>
<th>$r$ Obtainable with $\pm 30^\circ$ Motion Criterion</th>
<th>Per Cent of Criterion</th>
</tr>
</thead>
<tbody>
<tr>
<td>H-21, pivot at belly; $r = 70$ in.</td>
<td>30 in.</td>
<td>$\pm 90^\circ$</td>
<td>300%</td>
<td></td>
<td>233%</td>
</tr>
<tr>
<td>H-21, hatched</td>
<td>30 in.</td>
<td>$\pm 21$</td>
<td>70%</td>
<td>42 in.</td>
<td>140%</td>
</tr>
<tr>
<td>YHC-1A, hatched</td>
<td>20.6 in.</td>
<td>$\pm 25$</td>
<td>83%</td>
<td>27.3 in.</td>
<td>133%</td>
</tr>
<tr>
<td>H-34, hatched</td>
<td>26.4 in.</td>
<td>$\pm 17$</td>
<td>57%</td>
<td>41 in.</td>
<td>155%</td>
</tr>
<tr>
<td>H-37, hatched</td>
<td>24.0 in.</td>
<td>$\pm 19$</td>
<td>63%</td>
<td>51.4 in.</td>
<td>214%</td>
</tr>
</tbody>
</table>

**Table 4**
IV. CONCLUSIONS AND RECOMMENDATIONS

The configurations of pivot point improvement and stabilizing systems recommended by this contractor for application to the H-34 in Phases II and III are: The folding double axis cargo swing and the hydraulic actuated stabilizer, which are shown in SK-9574. These two devices represent the best compromise of the features outlined in the "Requirements" section. They are applicable with minor modification to the four helicopters considered in the study and afford a system requiring no internal cabin space.

It is, therefore, recommended that the above conclusions be approved for detail design and flight test on the H-34 during Phases II and III of this contract.
APPENDIX I

Photo
H-21 In Flight with Cargo Swing Installation and Load

Drawing
#242 Cargo Swing Installation and Assembly - H-21

Sketches
SK-9421 Fore and Aft Cargo Swings - H-21 and H-34
SK-9422 Cargo Swing and Stabilizing Line - H-21
SK-9424 Radius Rail - H-21
SK-9426 Beam in Floor and Stabilizing Line - YHC-1A
SK-9448 Cargo Swing and Stabilization Yoke - H-21
SK-9468 Double Axis Cargo Swing, Telescoping - H-34
SK-9469 Integral Cargo Hook and Stabilizer - YHC-1A
SK-9501 Double Axis Radius Rail - H-34
SK-9502 Internal Pyramid - H-21
SK-9503 Internal Pyramid - YHC-1A
SK-9504 Double Axis Cargo Swing and Internal Pyramid - H-37
SK-9505 Ventral Bumper Stabilizer - H-37
SK-9506 Retracting Double Axis Cargo Swing - H-37
SK-9530 Integral Cargo Swing and Stabilizer - H-21
SK-9571 Cargo Swing and Hydraulically Operated Stabilizers - H-21
SK-9574 Folding Double Axis Cargo Swing and Hydraulically Operated Controllable Stabilizer - H-34

Computation
Yaw Loads Imposed by Blade Boxes
APPENDIX II

Reference

1. Vertol Aircraft Corporation Report R-177, Flight Test Evaluation of an Improved External Cargo System for Helicopters
1. REMOVE CARGO SLING EYE BOLT AT 6A AND REPLACE WITH 6A-4.
2. REMOVE PRINT ASSY, PRIMARY FUEL TUBE AND CONNECTOR-SEE MIN A-179.
3. LUBRICATE ALL JOINTS WITH GRAPHITE GREASE PER MATHW-318 AT ASSY.
Effective Suspension Point

Fuselage Contour

Cargo Swing Assy

Sec. A-A

Phantom lines illustrate the cargo swing Assy 15° from normal position. Interconnecting bar (2 b.d.d.)

Arrow illustrates direction of the LOA in this position.

Configuration 1

M-21 Installation
STANDARD AERIAL SUSPENSION SLING
(MULTIPLE THICKNESS)
(ASSUMED BAILED EQUIPMENT)
CARGO SWING ASSY

STANDARD AERIAL SUSPENSION SLING
(MULTIPLE "THICKNESS"
(ASSUMED BAILED EQUIPMENT))

CONFIGURATION I-a
H-3A INSTALLATION

PRINT REDUCED
ONE-THIRD
INDICATED SCALE

FIGURE 4
(SHEET 1)
Configuration I-6

Print reduced one-third indicated scale

Figure 1
(Sheet 2)
SECTION A-A
SHOWN WITH SLING REMOVED

EXPLOSIVE CABLE CUTTER
CONTROLS TO PARALLEL CARGO HOOK NORMAL & EMERGENCY RELEASE
PRINT REDUCED
ONE-THIRD
INDICATED SCALE

FIGURE II

STD AERIAL SUSPENSION SLINGS (MULTIPLE THICKNESS)
(ASSUMED BAILED EQUIPMENT)
SECTION A-A

SHOWN WITH NET REMOVED
FIGURE IV

PRINT REDUCED ONE-THIRD INDICATED SCALE
EXPLOSIVE CABLE CUTTER
(Controls to parallel
Cargo Hook Normal &
Emergency Release)
STABILIZING LINE

EXTERNAL LOADING SYSTEM

STANDARD AERIAL SUSPENSION SLING (MULTIPLE THICKNESS)

YHC-1A ROTOR BLADE BOX

PRINT REDUCED ONE-THIRD INDICATED SCALE

FIGURE V
CARGO SWING AND STABILIZATION YOKE
FOR USE WITH H-21 HELICOPTER

PRINT REDUCED
ONE-THIRD
INDICATED SCALE
ALLOWABLE CG TRAVEL

G.G. CALCULATED UNDER THE FOLLOWING CONDITIONS:

- WT EQUITY 7938 lb
- CREW 400 lb
- FUEL 1121 lb
- TRAPPED / KEL 14"
- ENGINE OIL 57"
- ESCAPED OIL 33"
- TRANSMISSION OIL 56"

PHANTOM LINES ILLUSTRATE THE CARGO SWING ASSY IT" FROM NORMAL POSITION. ARROW ILLUSTRATES DIRECTION OF THE LOAD IN THIS POSITION. (SEE PHANTOM LINES IN SEC. 4.4)
ALLOWABLE CG TRAVEL

CG CALCULATED UNDER THE FOLLOWING CONDITIONS:

WT EMPTY       7438 lbs
CREW           405 lbs
FUEL           1121 lbs
TRAPPED FUEL   14 lbs
ENGINE OIL     5 lbs
DROPPED OIL    3 lbs
TRANSMISSION OIL 5 lbs

PRINT REDUCED ONE-THIRD INDICATED SCALE

GROUND LINE: FLAT TIRE STRUTS BOTTOMED

PHANTOM LINES ILLUSTRATE THE CARGO Sling ASSY AT 90° FROM NORMAL POSITION. ARROW ILLUSTRATES DIRECTION OF THE LOAD IN THIS POSITION. (SEE PHANTOM LINES IN SEC A A)}
VIEW LOOKING AFT
CHARGE SWING RETRACTED
ALLOWABLE CG TRAVEL

C.G. CALCULATED UNDER THE FOLLOWING CONDITIONS:

- WT EMPTY: 7430 lb
- CREW: 680 lb
- FUEL: 1121 lb
- TRAPPED FUEL: 14 lb
- ENGINE OIL: 37 lb
- TRAPPED OIL: 33 lb
- TRANSMISSION OIL: 34 lb

PHANTOM LINES ILLUSTRATE THE CARGO S WING ASSEMBLY FROM NORMAL POSITION. ARROW ILLUSTRATES DIRECTION OF THE LOAD IN THIS POSITION. (SEE PHANTOM LINES IN SEC. A-A)
G.G. calculated under the following conditions:

- Wt Empty: 7438 lbs
- Crew: 400 lbs
- Fuel: 1131 lbs
- Trapped Fuel: 10 lbs
- Engine Oil: 57 lbs
- Trapped Oil: 37 lbs
- Transmission Oil: 24 lbs

Ground line: Flat Tire Struts Bottomed

Phantom lines illustrate the cargo sling axis from normal position. Arrow illustrates direction of the load in this position. (See phantom lines in Sec. A)
SECTION A-A SHOWING STABILIZER INDEXED 45° TO ACCOMMODATE CARGO SLING ON CONEX BOX.

VIEW OF YHC-1A HATCH & CARGO STABILIZING DEVICE.
C.G. Calculated under the following conditions:

- Weight Empty: 9000 lb
- Creek (0): 600 lb
- Fuel: 1800 lb
- Trapped Fuel: 12 lb
- Trapped Oil: 10 lb

Effective Suspension Point based 24.5" from C.G.

Arrow illustrates direction of load at 1st deflection.

Between Rotors
CABLE SHUGGING DEVICE (supports full load)

HATCH

BUMPER CAN BE SWUNG INTO (HATCH WHEN NOT IN USE)

ROTOR BLADE BOX

CONEX BOX

PRINT REDUCED
ONE-THIRD
INDICATED SCALE
SWING CAN BE RETRACTED MANUALLY OR BY EXISTING HOIST

PHANTOM LINES ILLUSTRATE SWING IN THE RETRACTED POSITION

HATCH

EXISTING FITTINGS

CABLE

DOUBLE AXIS CARGO SWING - COLLAPSIBLE
PHANTOM LINES ILLUSTRATE SWING IN THE RETRACTED POSITION
HATCH

EXISTING FITTINGS
CABLE

CARGO SWING - COLLAPSIBLE

PRINT REDUCED ONE-THIRD INDICATED SCALE
PRINT REDUCED
ONE-THIRD
INDICATED SCALE
1. Available roll control about horizontal through c.g. for H-21
   \[ \ddot{x} = 0.3 \text{ rad/sec}^2 \text{ per inch lateral stick travel} \]
   Total stick travel = 4 inches

   Roll inertia of the helicopter about c.g. = 60,000 \# sec\(^{-2}\)-in.
   Available restoring moment in roll = \[ I_e \ddot{x} = 60,000 (0.3 \times 4) \]
   = 72,000 in.\#

   Available lateral corrective force at A:
   \[ F_A = \frac{72,000}{150} = 480\# \]

2. % of lateral stick travel to counteract a rudder-excited yaw excitation of the cargo
   Yaw control \[ \ddot{\gamma} = 0.1 \text{ rad/sec}^2 \text{ per inch rudder} \]
   Total rudder travel = 3.25 inches
   \[ \ddot{\gamma} = 0.1 \times 3.25 = 0.325 \text{ rad/sec}^2 \]

   \[ \ddot{y} = 66 (0.1 \times 3.25) = 21.5 \text{ inches/sec}^2 \]
Find force, $F$, due to applied acceleration, $a$

\[ \sum F_{cg} = F = M\ddot{x} \quad \sum \tau_{cg} = I\dddot{\xi} \]

\[ \dddot{x} + A\ddot{x} = a \]

Solving these three equations simultaneously,

\[ \ddot{x} = a - A\dddot{x} \]

\[ F = m(a - A\dddot{x}) \]

\[ F = \frac{I}{A}\dddot{\xi} \]

\[ F = m(a = A\dddot{x}) = \frac{I}{A}\dddot{\xi} \]

\[ ma - mA\ddot{x} - \frac{I}{A}\dddot{\xi} = 0 \]

\[ \dddot{\xi} = \frac{ma}{mA + I/A} \]

\[ \ddot{x} = a - A\frac{ma}{mA + I/A} = \left[ 1 - \frac{mA}{mA + I/A} \right] a \]

\[ F = m\ddot{x} = ma \left[ 1 - \frac{mA}{mA + I/A} \right] = ma \left[ \frac{I/A}{mA + I/A} \right] \]

Check

\[ F = \frac{I}{A}\dddot{\xi} = \frac{Ia}{A} \left[ \frac{m}{mA + I/A} \right] \]
\[ a = 21.5 \text{ in/sec}^2 \]

\[ \text{Weight} = 3 \text{ boxes} \times 500\# = 1500\# \]

on cargo sling

\( (3 \text{ H-21 blade boxes}) \)

\[ m = \frac{1500}{386} = 3.88 \]

Inertial \( I_{cg} = \frac{1}{12} m l^2 \)

\[ = \frac{1}{12} \frac{1500}{386} (288 \text{ in.})^2 \]

\[ I_{cg} = 26,900 \# \cdot \text{sec}^{-2} \cdot \text{in.} \]

\[ F = \frac{I a}{A} \left[ \frac{m}{mA + I/A} \right] = \frac{26,900(21.5)}{66} \cdot \frac{3.88}{66} + \frac{3.88(66.0) + 26,900}{66} \]

\[ F = 51.2\# \]

Required lateral stick travel = \( \frac{51.2}{480} = 10.7\% \)

3. \% of lateral stick travel to counteract a stick-excited lateral excitation of the cargo.

Assume 1" stick excitation in maneuvering helicopter

\[ a = (150 \text{ in})(0.3 \text{ rad/s}^2) = 45 \text{ in/sec}^2 \]

\[ F = \frac{I a}{A} \left[ \frac{m}{mA + I/A} \right] \]

\[ = \frac{26,900(45)}{66} \cdot \frac{3.88}{3.88(66) + 26,900/66} \]

\[ F = 107.2\# \]

\% of lateral stick travel = \( \frac{107.2}{480} = 22.3\% \)
CARGO SWING AND STABILIZATION YOKE
FOR USE WITH H-21 HELICOPTER

SK 9448

Lateral Wind Center of Pressure Offset from Hook e, in

Lateral Force at Forward Support, lb.

- d -
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