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PROGRAM SUMMARY

An experimental flight-test program was conducted with the Goodyear Mayflower I airship. The purpose was to utilize an existing airship (1) as a test bed to evaluate GFE sensors; (2) as a vehicle for the design, fabrication, installation, and test of a stern propulsion system; and (3) for an investigation of the critical parameters that will be helpful in establishing requirements for a prototype Silent Joe II vehicle.

In fulfillment of the first objective, six contract flights were conducted between 30 October 1968 and 25 November 1969, during which time the Mayflower I was used as an aerial platform to support the GFE payload. This payload consisted of a high-intensity infrared light and a TV camera, both of which were mounted on the bow of the airship. In addition, a number of acoustic sensors were strategically located along the length of the airship.

The television platform of the GFE payload was controlled and operated by Gyrodyne Corporation, while the acoustic sensor portion of the payload was operated under the jurisdiction of the Georgia Institute of Technology. Individual GFE payload contractors were responsible for documenting payload evaluation tests. During the initial six contract flights and while operating the payload, Goodyear Aerospace undertook the task of obtaining airship performance data.

The airship performance test program included:

1. Turns and reversals at various entry speeds
2. Climbing turns at various entry speeds
3. Ascents and descents at various entry speeds
4. Descent at zero airspeed
5. Measuring takeoff distance at various airship static conditions
6. Acoustic measurements at ground level with airship overhead at various altitudes and speeds

The measurement of airship performance data was recorded, reduced, and plotted in a form suitable for further analysis. A special report documented the results of these performance tests. In addition, a second report documented the results of noise measurements that were recorded on the ground during various airship fly-by conditions. The design, fabrication, installation, and testing of a stern propulsion system on the Mayflower I was a major objective of this performance test program.

The initial concept for the stern propulsion system used a geared dc motor and mechanical controls that had cables connected to the rudder and elevator surfaces. A detailed engineering analysis showed that (1) the availability of a suitable dc motor was limited and (2) when the weight of the gearing and the required acoustical silencing was considered, the airship became excessively heavy at the stern. Thus, a combination electrohydraulic system was considered with a hydraulic power supply that used a dc motor and a hydraulic pump located in the airship car. This system weighed 128 lb less than the all-electric system, which had a motor and gear box in the stern.

The final configuration of the stern propulsion system consisted of a slowly rotating rotor that had a servocontrolled pitch and yaw gimbal system for vectoring the propeller thrust in order to achieve flight-path control. The gimbal system was designed to achieve an airspeed of 15 mph and gimbal travel within a cone of 45-deg radius. The system was designed in accordance with specifications to be inaudible to the human ear from a distance of 500 ft or more.

The hydraulic hoses and electrical cables were fastened to the outside of the airship envelope from the airship car to the stern propulsion system (approximately 125 ft).

The pilot's control panel, located just above the instrument panel, contained all controls for positioning the stern gimbal and visually indicated the stern rotor position. The hydraulic power supply was located in the airship car and was a noise source that required silencing. The hydraulic power supply consisted of a piston-type hydraulic pump, dc drive motor, a fan to cool the motor, and flow and pressure controls. The system was rated to supply 5.8 gpm at 3000 psi (given a calculated airspeed of 10 mph) and was capable of supplying sufficient flow to propel the airship at approximately 15 mph. The air inlet and exhaust for the fan were routed through tuned duct work, with foam insulation used for quieting. The pump also was enclosed with foam. The entire hydraulic power then was enclosed with a leaded vinyl sheeting and was mounted on shock absorbers attached to the airship floor in order to dampen and reduce acoustic noise.

A primary task was to provide a structure capable of supporting a stern propulsion system and for distributing loads generated by a stern rotor into the airship envelope. The stern propulsion system not only would apply longitudinal and shear loads but also would apply torque and moment loads to the stern. These loads are further complicated by gimbaling the stern rotor.

Battens would distribute the loads satisfactorily into the envelope, provided they were installed to resist torque and bending moments instead of the longitudinal installation used on the airship nose. Eight battens placed in a Vee strut arrangement around the stern would provide a load path similar to an aircraft engine mount and would be able to resist all stern loads. Because the battens are curved to fit the airship contour, they would be continuously laced to the envelope to receive lateral support from the envelope and thus would prevent compression buckling. The four Vee structs formed by the eight battens were terminated at and attached to the base of the fins. The base provided another path for distributing the stern loads over a large area of the airship envelope.

At the stern, a stern cone resembling an engine mount was laced snugly around the rear of the envelope. The four Vee structs were bolted at four mounting points to the forward ring of the stern cone. This provided a structural load path for distributing all types of loads into the airship envelope. Any type of propulsion system, therefore, could be mounted to the stern cone.

The primary structural components are a three-bladed, 20-ft-diameter rotor; a rotor shaft; a rotor shaft housing (yaw gimbal); a pitch gimbal; gimbal supports; a stern cone; and a batten installation.

A structural analysis was performed to show that the Silent Joe II stern propulsion structure was adequate for the load environment anticipated during the flight test program. In addition to this analysis, ground and flight tests were conducted on the modified Mayflower I airship between 20 February and 4 April 1969 in accordance with the contract task requirements. The objectives were to:

1. Conduct a complete function test and ground checkout of the instrumented stern propulsion system on the airship
2. Perform analysis of pertinent test data to permit release of the airship for flight

3. Perform flight tests in the Akron area and evaluate the performance capability of the stern propulsion installation. Airship performance was measured and the results evaluated with respect to airship mission requirements such as speed, ascent and descent capabilities, and noise at altitudes
4. Measure and record the static and dynamic data required to determine the airship and the stern gimbal performances during flight
5. Data reduction and data analysis to determine the performance and operation of the airship

In general, the ground test program included those tests necessary to prove the readiness of the airship for flight; the flight test program consisted of the performance of various typical mission maneuvers, with the airship under stern propulsion, as a basis for evaluating the airship flight performance. In addition, airship-generated noise levels were measured at ground level with the airship flying at various altitudes and speeds under stern propulsion.

The ground test program was initiated to verify the safety of flight characteristics of the stern propulsion system prior to flight tests. The tests included the operation of the stern rotor at various blade tip angles to measure the detailed system performance and to verify the operation of the safety circuits incorporated into the system.

Initial ground tests were conducted to ensure that the system as designed would meet the flight objectives. The tests were conducted on the stern rotor at various blade tip angles to determine the effect of thrust requirements (motor torque and motor rpm as a function of blade tip angle) and power requirements on the stern propulsion system and the hydraulic power system. It was determined that the maximum propeller revolutions per minute obtainable were 270 at a 0-deg blade angle and 210 at 5 deg. The propeller revolutions per minute obtainable were 170 at 8 deg and 150 at 12 deg.

At this point, a limitation on the number of revolutions per minute was observed due to the ground tests being conducted with no airflow passing across the propeller blades. Excessive vortex shedding noise and a blade resonance were observed at 150 rpm with the higher blade tip angles. As a result, no further ground performance testing was conducted at the higher blade tip angles.

The final ground test was a series of endurance tests at various stern rotor revolutions per minute to run-in-the system. A total of 20 hr of operating time was obtained on the stern propulsion system during the laboratory and ground tests.

The first flight of the modified airship was made on 13 March 1969. A telemetry instrumentation system was used to acquire data during this and subsequent flights. The final flight was made on 3-4 April.

A separate report has been prepared that contains detailed information for the airship performance data as well as special flight test data. These data will be useful for evaluating parameters necessary to establish a basic design of the prototype Silent Joe II vehicle.

The acoustic design objective stated in Technical Requirement No. 2191, Revision 2 (Paragraph 3.9.3) was that the 35-phon curve of the Robinson-Dadson curves be met when the airship flies overhead at 500 ft and the microphone is positioned on the ground. This requirement has been satisfied.

Even though the 35-phon curve requirement was met, the airship could be heard in a very quiet environment. This was because the 35-phon curve at 125 Hz permitted a sound level of 45 db; however, observers could not hear 35 db at 125 Hz, which is the experience of those engaged in a similar study (Reference 1). Theoretically, a very good ear could hear anything greater than the 5-phon curve in an anechoic chamber. Such a quiet environment probably does not exist outside an anechoic chamber due to wind, insects, and birds; therefore, the 20-phon curve was considered adequate.

With the present design, the airship should not be audible in the very quiet environment (5-phon curve) if it is flown at an altitude of from 800 to 900 ft at 140 rpm or at an altitude of 500 ft at 40 rpm. When insects are present, it is hard to hear the airship when flying at an altitude of 500 ft and at 140 rpm (rotor).

A propulsion system study was conducted as an independent effort during the Silent Joe II program. The study group that performed this three-month analysis was not considered an integral part of the Silent Joe II project team, although they had access to the data generated by the team. The fundamental objective was to synthesize and analyze a large array of alternatives to the prototype Silent Joe II vehicle, emphasizing alternative powerplant installations. The study group considered both off-the-shelf and developmental powerplants such as turbine, reciprocating, rotary, stirling cycle, and steam. Many functional prototype vehicle configurations were considered, with emphasis placed on identifying state-of-the-art configurations that met or exceeded mission performance guidelines. Six representative prototype configurations were evaluated and a suggested prototype configuration was identified together with its major design characteristics. The results of this study are given in a separate report.

A further requirement was to investigate critical design and problem areas and to establish basic design criteria for the Silent Joe II system to permit an early delivery schedule for the final prototype vehicle. The two major categories of effort were (1) the command and control system and (2) the simulation of the Mayflower I test bed airship characteristics.

The command and control system for the prototype airship was subdivided further to include the engineering required to obtain a preliminary design concept for (1) the airship flight-control system; (2) the system programmers required for the airship; (3) the airship control console, which is capable of controlling and monitoring the airship systems both from a remote location and in the airship; (4) the relay station, which may be required during drone operation if the airship is not within the line of sight of the ground station; and (5) the system cabling required to interconnect the ground station equipment with the airship systems. The phenomena known as control reversal occurred below 14 mph. The flight characteristics of the airships were studied, and several methods of eliminating the control reversal were evaluated so that the low-speed performance necessary for the Silent Joe II mission is a reality with an airship.

This study and evaluation matched several set of airship flight test data to the simulated flight test data obtained from the analog computer. The airship simulation was conducted independently for the pitch and the yaw planes. No roll plane simulation was made since the roll angular motions were small due to the large restoring moment of the airship car. The computer simulation was utilized for functionally designing a flight-control system.

The flight-control system design incorporated equipment that will allow the airship to be controlled remotely, by a pilot, or by means of predetermined stored information representing heading and altitude so that the airship can return to base in case of a malfunction. The transfer functions of the airship and the flight-control system ensure that the airship will be stable under all expected modes of operation.

A preliminary study of a relay station was conducted to determine the requirements of such a unit if the airship were operated as a drone when not within the line of sight of the ground station. RF power calculations were based on having a relay station at an altitude of 14,000 ft above the ground station and 150 mi from the airship. The equipment necessary to receive and transmit the ground commands to the airship and the equipment necessary to receive and retransmit the telemetry data from the airship to the ground station were described. The receiver and transmitter characteristics also were described. The same transmitters and receivers were to be used in the airship and in the ground station. The RF transmission will be in the S-band frequency.

The types of data transmission systems that can be used to send analog and digital commands from the ground to the airship and to transmit analog and digital performance data and telemetry data from the airship to the ground station were studied. Several data transmission systems were evaluated, and a pulse code modulation (PCM) system was selected as the most feasible for Silent Joe II. The number of command channels and the number of telemetry data channels required to operate the airship as a drone from a remote ground station was a prime factor in selecting the PCM data system format.

The airship control console, which is required by the ground operator to command the airship from the ground, incorporates meters that display the performance data of the airship and of all airship subsystems. This unit will enable the ground operator to control and monitor the airship systems remotely with the same capability the pilot has in the airship. The control console circuitry is compatible with the PCM data system in the airship so that, if the Silent Joe II airship is not operated as a drone, the control console can be installed in the airship for pilot operation with minor deletions of circuitry and equipment.

In order to convert the command signals from the airship control console to control signals for the airship subsystems, a system programmer was functionally designed. The system programmer is comprised of electronic circuitry that converts the command signals from the uplink decommutator in the airship to the various airship subsystems, such as the main and auxiliary propulsion systems, in order to control airspeed. The system programmer must functionally operate all engine functions based on monitored data and stored data when a speed increase is commanded. The system programmer also must provide the commands to the airship subsystems from stored information for the airship to return to base if any subsystem malfunctions or if the RF links are lost.

In addition, the system programmer contains the signal-conditioning equipment necessary to convert the signals from the telemetry data transducers into the correct levels for the airship downlink multicoder unit. The programmer also contains the logic circuitry for determining the proper mode of system operation based on ground commands or to switch modes of operation automatically based on the data describing the performance of the airship subsystem.

The airship multicoder system is required to convert the analog and digital telemetry signals from the system programmer. These parallel signals must be converted into serial signals coded in the PCM format for transmission to the ground.

The results of this task study showed that the airship can be controlled during a low-speed flight from a remote ground station. The equipment to achieve the required performance is available, and no long-range development programs are required.

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