UNITED STATES DEPARTMENT OF THE INTERIOR

GEOLOGICAL SURVEY

Preliminary Airworthiness and Operational Evaluation of an Ultralight Aircraft as a Geological Reconnaissance Vehicle

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ABSTRACT

A preliminary airworthiness and operational evaluation was performed on a Rotec Engineering Rally 3 (military version) ultralight aircraft to gather qualitative baseline airworthiness data and to determine its mission suitability as a geologic reconnaissance vehicle. The aircraft's flying qualities and performance are adequate for the proposed mission although several deficiencies were noted.

INTRODUCTION

The rapid evolution of ultralight aircraft has revolutionized general aviation by making available inexpensive easy-to-fly recreational aircraft to a large segment of the public. Powered ultralight aircraft are defined by Federal Aviation Administration Regulation (FAR Part 103) as those single-occupant vehicles intended for sport or recreational use, weighing less than 254 pounds empty, having a maximum fuel capacity of five U.S. gals, and incapable of exceeding 55 knots, with a power-off stall speed of 24 knots or less. Such vehicles are not required to meet FAA airworthiness certification standards, need not be registered, and their operators are not required to meet any aeronautical knowledge, age, or experience requirements or have airman or medical certificates. Their low cost, ease of operation, and freedom from licensing restrictions therefore makes them appealing as personal utility vehicles and potentially useful as observation platforms for geological reconnaissance and surveying.

In the summer of 1983, the U.S. Army acquired three two-seat and one single-seat Rotec Engineering Rally* ultralight aircraft for evaluation for surveillance, mapping, and flight training. The military specifications were: 500-lb useful load (crew + fuel + equipment), 10,000-ft ceiling, 45 mph maximum cruise speed, 200-nautical mile range with 16 gal of fuel, rough field takeoff and landing capability, and capability for assembly in the field by two persons in 30 min. These specifications are quite appropriate for geological applications and in the fall of 1983 a military version of the Rally 3 was acquired for test and evaluation as a geological field vehicle. The two-place aircraft comes from the manufacturer as an FAA-approved kit for home construction, is certified by the FAA as an experimental aircraft, and must be flown by a licensed pilot. The two-seater was selected for the advantage of its payload, enabling subsequent installation of geophysical equipment, and for the second seat which allows an instrument operator or observer to be carried. The flight characteristics and performance of the single- and two-place Rotec versions are essentially comparable.

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*Mention of a proprietary or commercial product does not constitute recommendation or endorsement by the U.S. Geological Survey and does not imply its approval to the exclusion of other products that also may be suitable.

Guard, in making available the facilities of the Navajo Army Depot. Their contribution is warmly acknowledged.

OBJECTIVES

Stability and control (flying qualities) and performance determine the mission suitability for any aircraft. The objectives of this evaluation were to assess qualitatively the flying qualities as a general measure of pilot workload, subjectively evaluate the pilot workload while performing representative low-level geologic reconnaissance tasks and to gather qualitative base line data prior to modifying the aircraft with the addition of geophysical sensors. An ancillary objective was to evaluate the flying qualities to provide a basis for estimating the ease with which a geologist without prior flight training might gain piloting proficiency and to anticipate difficulties. Additional objectives were to define a reasonable operating envelope and evaluate safety-of-flight considerations.

SCOPE AND METHODS

The test and evaluation flights were conducted at Duncanville, Texas, and the Navajo Army Depot, west of Flagstaff, Arizona, intermittently between August 24 and November 1, 1983. Twelve flights were performed for a total flight time of 9.5 hours of which 8.5 hours were productive. Pre-test checks and preliminary evaluation flights were flown in the manufacturers aircraft (Rally 3B and 2B; see Table 1) at Duncanville and the final test and evaluation flights were in the USGS aircraft (Rally 3B) at the Navajo Army Depot; the tests were conducted in accordance with the Test Plan in Table 1. Standard flight test techniques were employed (Roberts, 1980; 1981; USAF, 1980) and qualitative ratings of handling qualities are based on the Cooper-Harper Handling Qualities Rating Scale (HQRS) (Cooper and Harper, 1969, Fig. 1).

DESCRIPTION

The Rally 3 is a side-by-side 2-place, single-engine ultralight aircraft (Fig. 2, Table 2). The airframe is constructed of aluminum tubing and channels, supported by steel cables and an aluminum king post. Lifting surfaces are covered with Dacron fabric. The aircraft is powered by a 48 hp ROTAX, 2-cycle engine which drives a 60-in wood, fixed pitch, pusher propeller. Gear reduction is 2.18:1. Mixture control is effected by replacing the carburetor main jet with one of appropriate size for anticipated altitude. Pitch control is provided by counter-balanced elevators and spoilerons installed on the upper wing-surface provide roll control. Wing tip end-plates enhance roll stability and increase spoileron-induced roll control. Yaw and additional roll control power are furnished by a large counter-balanced rudder. The aircraft has conventional landing gear; the main landing gear are independently suspended on swing arms mounted with dual wheels. The small tail gear is non-steerable. An overhead control stick and rudder pedals provide conventional 3-axis control. Control lines are constructed of Kevlar covered with Dacron and are routed from the cockpit controls to the control surfaces through a system of pulleys. A motorcycle-type twist-grip throttle is installed at the base of the control stick immediately below the ignition kill switch. Engine starting is accomplished with an overhead pull starter. The pilot normally occupies the left seat.

RESULTS AND DISCUSSION
Airworthiness Evaluation

General. The overall handling qualities of the Rally 3B ultralight aircraft are pleasant and satisfactory. However, its handling qualities and design present several moderate to minor deficiencies which limit its potential capabilites:

Moderate Deficiencies
- (1) Inadequate lateral control power (roll control).
- (2) Limited capability to handle crosswinds and gusty winds.

Minor Deficiencies
- (3) Lack of pilot operated trim control and throttle friction lock which prohibit any hands-off flying capability.
- (4) High noise levels which make crew communication impossible.
- (5) Lack of pilot-operated mixture control which precludes large excursions in density altitudes.

Although the aircraft was originally designed as a recreational vehicle, correction of the above deficiencies would markedly enhance its utility. Items (1) and (2) warrant improvement; items (3)-(5) would be desirable to correct. The aircraft should not be operated in wind conditions greater than 10 mph with a zero gust spread.

Ground Handling Characteristics. Taxiing with one and two pilots and with one pilot and 70 lbs of ballast in the right seat was performed over rough ground covered with low grass and weeds. The independently-suspended landing gear performed adequately. Low-to-moderate throttle power furnished sufficient propeller wake across the rudder for adequate directional control. Brakes are not provided or required. In calm wind conditions the ground handling characteristics are satisfactory. Taxiing in crosswinds and in gusty wind conditions was difficult because there was not always sufficient spoileron roll-control to prevent the upwind wing from rising (HQRS 5). This deficiency warrants that caution be exercised when taxiing in crosswind or gusty wind conditions and mitigates against safe operation when wind speeds exceed about 10 mph.

Takeoff Characteristics. Maximum available power was used in all takeoffs. The standard sea level carburetor jet was replaced with a high attitude jet for tests flown at 8000-8500 ft density altitudes to assure optimum fuel/air mixture. Takeoff roll at 2000 ft density altitude with two pilots was less than 100 feet and about 200-250 feet at 8000 ft density altitude. Roll distance was influenced by field roughness. Takeoff characteristics were conventional: application of full power, slight forward longitudinal control movement to raise the tail, slight aft longitudinal control movement at 25 mph resulted in liftoff. The aircraft accelerated rapidly in the liftoff attitude; climb was established at 30 mph. Rudder was effective immediately with the application of power and was required for both directional control and to keep a wings level attitude during windy conditions. The takeoff characteristics are satisfactory.

Trimmability. There is no pilot-operated trim control or throttle friction lock to enable complete hands-off flying. Single pilot operation, without ballast, required moderate forward stick pressure to maintain level, constant airspeed (30 mph) flight and is a fatigue factor (HQRS-3).

Longitudinal Static Stability. Stick-fixed longitudinal static stability was evaluated with the aircraft stabilized at 30 mph. Varying the airspeed ±5 mph with the longitudinal control at constant power indicated positive stability: forward movement resulted in increased airspeed and aft movement resulted in decreased airspeed. Breakout forces were nominal and control forces were light and appear linear. Longitudinal static stability is satisfactory.

Lateral-Directional Static Stability. Lateral-directional static stability of the aircraft was evaluated at 30 mph in level flight and during slips to landing in a power approach. The aircraft was placed in sideslips while maintaining a steady heading using approximately one-half and full rudder pedal deflections left and right. Positive stability was indicated by rudder pedal control opposite to the sideslip. The dihedral effect was also positive as indicated by lateral control held into the side slip. Negligible bank angle was required to hold a sideslip indicating no sideforce. Lateral-directional static stability is satisfactory.

Short-Period Longitudinal Stability. Longitudinal short-period stability was evaluated in level flight at 30 mph. The aircraft pitch attitude was monitored after both a longitudinal control doublet impulse and a frequency sweep to excite an aircraft oscillation in phase with control input. Short period responses were deadbeat. The short-period longitudinal stability is satisfactory.

Dutch Roll. Dutch roll characteristics were evaluated in level flight at 30 mph. The aircraft was disturbed from the trim condition by a sinusoidal rudder doublet. The response was deadbeat. The dutch roll characteristics are satisfactory.

Spiral Mode Stability. Spiral mode stability was evaluated at 30 mph in level flight. The aircraft was stabilized in steady left and right turns of 10° bank angles and the controls neutralized. The spiral stability was convergent; the aircraft returned to wings level in less than 10 sec. The spiral mode stability is satisfactory.

Maneuvering Stability. Maneuvering stability was evaluated in steady turns of 30 mph at bank angles of approximately 45°. There is an asymmetrical overbanking tendency at low gross weight with more opposite lateral control required in left turns than in right turns (HQRS-3); the deficiency improved with increased weight. Increased aft longitudinal control and pull force was required with increased bank angle. The maneuvering stability characteristics are satisfactory.

Lateral Control Power. Lateral control power (roll response) was evaluated by monitoring bank angle and roll rate resulting from left and right lateral control imputs of approximately one-quarter, one-half, and full deflection. Control inputs of one-quarter and one-half deflection produced no noticeable roll response. Full control deflection resulted in a slow roll response which achieved a steady state roll rate in less than 5 sec. No adverse yaw was noted. Roll rates appear slightly faster to the left than to the right. The roll rates induced by spoileron deployment are inadequate and adequate roll control can only be effected through use of rudder control. The lateral control power is deficient (HQRS-5).

Longitudinal Control. Longitudinal control was evaluated by monitoring pitch attitude and rate resulting from fore and aft incremental control inputs. Pitch control and damping of pitch motion are adequate. The longitudinal control is satisfactory.

Stalls. Normal power-on and power-off stalls were performed from 30 mph by reducing airspeed approximately 1.0 mph/sec with aft longitudinal control. No pre-stall-buffet or stall break was observed. Stalls are pleasant with no loss of control effectiveness. The normal stall characteristics are satisfactory.

Trim Change with Power. Trim changes with power addition and reduction were evaluated in level flight at 30 mph. Trim changes from the trim condition were effected by increased power to full throttle or reduced power to engine idle. Increased power resulted in a mild pitch up attitude (~10°) and a stabilized climb of 25 mph. Decreased power to idle resulted in an abrupt pitch down (20°) and a stabilized descent of 40 mph. The trim changes with power are satisfactory.

Approach and Landing Characterists. Approach and landing characteristics were evaluated during normal, crosswind, and gusty wind conditions (≤10 mph, gusts 3-5 mph). All landings were on unimproved fields of varying roughness. Approaches were flown with and without power and all landings were wheel landings.

Power approaches were flown at 30 mph. Pitch attitude was approximately 20° down. Glide path was controlled by coordinated application of power and longitudinal control. Coordinated lateral and directional control were used for roll attitude but as noted above, adequate roll response was primarily effected by rudder control (HQRS-5). Descent rate was a function of airspeed and needed constant monitoring as did the maintenance of a wings level attitude in weakly turbulent air.

Landing flair was begun using gradual aft longitudinal control input at approximately one-half wing span height above ground so as to achieve level flight at about 3 feet. Descent and touch down were controlled with coordinated power and longitudinal control changes. Touch down occurred at approximately 25 mph. Under crosswind and gusty wind conditions constant attention was required to keep the wings level necessitating the use of power to maintain the touchdown attitude while establishing wings level prior to actual touchdown (HQRS-5). A wing-down landing would most likely result in a ground loop. During crosswind and variable wind conditions, the aircraft tended to weathercock into the wind after landing. The landing characteristics in calm winds are satisfactory.

Operational Evaluation

General. To the extent possible, the approach taken during the operational evaluation was to consider the aircraft as a generic state-of-the-art model, representative of present day ultralight capabilites as a whole. However, caution should be exercised because of wide differences in design, structural integrity, and performance among U.S.-manufactured ultralight aircraft.

Cockpit Environment. Entering and exiting the aircraft was awkward but not difficult, requiring agile maneuvering between cockpit tubes and over rudder control lines. The field of view from the cockpit was essentially unrestricted in all directions except overhead where the wing and engine obstruct the view. Pilot and observer stations consist of cushioned, plastic bucket-seats. Lap-type safety belts are provided. Noise levels were extremely high and require ear-protection; for overall safety, protective head gear with noise-attenuating ear cups is recommended. The high noise levels precluded voice communication without the aid of a radio. Radio usage was not evaluated. Because the crew is exposed to the inflight airstream, eye protection (goggles or visor) should be worn at all times.

Rough Field Capability. Rough field handling characteristics were evaluated throughout the test. A mowed pasture, a plowed, weed-covered field, and a low-grass covered dry-lake were used for take off and landing evaluations. These were chosen to simulate field conditions that might be expected during a geological reconnaissance project. One mishap occurred during an attempted landing in 2-feet high wet weeds when rapid deceleration resulted in the aircraft nosing over, damaging the king post and control stick. Installation of factory-supplied "training wheels" on the forward cockpit tubes (Fig. 2) are recommended for rough field operations. Rough field handling characteristics are satisfactory.

Simulated Geologic Reconnaissance. Simulated geologic reconnaissance missions were performed from the Navajo Army Depot. Typical maneuvers included S-turns across a ground track, turns about a point, and an evaluation of handling qualities during tracking. The inherent dynamic stability (longitudinal, dutch roll mode, and spiral mode stability) enables the pilot to maintain flight path easily or to maneuver the aircraft while attention is diverted to observational tasks. However, ground tracking such as in following a geologic contact in turbulence and light gusty wind conditions at low altitude required constant pilot attention (HQRS-5), emphasizing the need for an observer in the crew station. Similarly, the aircraft was susceptible to rotor-turbulence on the lee side of obstructions which required constant pilot attention. In calm wind conditions the aircraft was sufficiently stable to serve as a hand-held camera-platform. Control harmonization and handling qualities during tracking in calm wind conditions are satisfactory.

The spring-loaded twist-grip throttle, and the lack of pilot-controlled trim capability require that the aircraft be flown "hands-on," thus precluding ready note-taking or map annotation by the pilot.

Finally, lack of a cockpit mixture control requires that the main carburetor jet be changed on the ground to accomodate wide variations in density altitude. This may be an annoying deficiency in mountainous terrain.

SUMMARY

The stability, controlability, and performance of the Rotec Engineering Rally 3 (military version) ultralight aircraft were evaluated and found to be satisfactory for use as a geologic reconnaissance vehicle. Its handling qualities make it suitable as a trainer for geologist-pilots who have no previous flight training. Prudence dictates, however, that training be done with a certificated flight instructor well versed in ultralight aircraft

operations and include thorough coverage of Federal Aviation Regulation Part 91 (General Operating and Flight Rules), meteorology, micrometeorology, and other safety-of-flight considerations. The rapid development of ultralight aircraft suggests they may find real utility in a variety of geologic applications.

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TABLE 1. TEST PLAN, CONDITIONS, AND SUMMARY

	TEST	GROUND HANDLING	TAKEOFF CHARACTER-ISTICS	TRIMMABILITY	LONGITUDINAL STATIC STABILITY	LATERAL-DIRECTIONAL STATIC STABILITY	SHORT PERIOD LONGITUDINAL STABILITY	DUTCH ROLL CHARACTER-ISTICS	SPIRAL MODE STABILITY	MANEUVERING STABILITY
Conditions	AVERAGE DENSITY ALTITUDE (FT)	2000 (1) 8000 (2)	2000 (1) 8000 (2)	8500	3000 (1) 8500 (2)	3000 (1) 8500 (2)	8500	8500	8500	8500
	AVERAGE GROSS WEIGHT (LBS)	680 (1) 530 (2) 600 (2) 700 (2)	680 (1) 530 (2) 600 (2) 700 (2)	530 595 695	675 (1) 525 (2) 595 (2) 695 (2)	675 (1) 525 (2) 595 (2)	525 595	525 595	595	525 595 695
	INDICATED AIRSPEED (MPH)	0 TO 20	0 TO 30	25 TO 35	30	30	30	30	30	30
	REMARKS	SATISFACTORY DEFICIENT IN CROSSWIND AND GUSTS (HQRS-5)	SATISFACTORY MINOR DEFI-CIENCY NOTED (HQRS-3)	SATISFACTORY MINOR DEFI-CIENCY NOTED (HQRS-3)	SATISFACTORY	SATISFACTORY	SATISFACTORY	SATISFACTORY	SATISFACTORY	SATISFACTORY MINOR DEFI-CIENCY NOTED (HQRS-3)

TABLE 1. TEST PLAN, CONDITIONS, AND SUMMARY (CONTINUED)

	TEST	LATERAL CONTROL POWER	LONGITUDINAL CONTROL RESPONSE	STALLS	TRIM CHANGE WITH POWER	APPROACH AND LANDING CHARACTERISTICS	OPERATIONAL EVALUATION
Conditions	AVERAGE DENSITY ALTITUDE	3000 (1) 8500 (2)	3000 (1) 8500 (2)	3000 (1) 8500 (2)	3000 (1) 8500 (2)	3000 (1) 8500 (2)	8500
Conditions	AVERAGE GROSS WEIGHT	675 (1) 530 (2) 595 (2) 695 (2)	675 (1) 530 (2) 595 (2) 695 (2)	675 (1) 530 (2) 595 (2)	675 (1) 530 (2) 595 (2) 695 (2)	675 (1) 530 (2) 595 (2) 695 (2)	530 595 695
Conditions	INDICATED AIRSPEED (MPH)	30	30	30	30	30 TO 0	
	REMARKS	DEFICIENT (HQRS-5)	SATISFACTORY	SATISFACTORY	SATISFACTORY	SATISFACTORY, DEFICIENT IN CROSSWIND AND GUSTS, (HQRS-5)	SATISFACTORY, DEFICIENCY NOTED (HQRS-5)

TABLE 2. DESCRIPTION OF THE ROTEC ENGINEERING RALLY 3 (MILITARY VERSION)

Specifications

Powerplant	ROTAX 503, 48 hp, 2 cycle
Propeller	Rotec, 2-blade, laminated wood, fixed pitch pusher, 60-in diameter
Length	17 ft, 4 in
Height	10 ft, 8 in
Wingspan	38 ft
Wing area	190 ft^2
Wing loading	3.2 lb/ft^2
Power loading	15.6 lb/hp
Seats	2
Empty weight	330 lb*
Gross weight	750 lb
Useful load	420 lb
Payload with full fuel	389 lb
Fuel capacity (50:1 gas/oil mixture)	31 lb (5 U.S. gal)

Performance

(Note: Performance figures provided by manufacturer for 350 lbs useful load, 75% power, no wind, sea level)

Takeoff distance, ground roll	100 ft
Rate of climb, sea level	450 fpm
Cruise airspeed	40 mph
Maximum range	100 miles
Maximum endurance	2.5 hr
Fuel consumption	2.0 gph
Service ceiling	10,000 ft
Glide ratio	7:1
Landing distance, ground roll	80 ft

Limiting Airspeeds

Never exceed speed (V_{ne})	45 mph
Stall speed (100% power)	20 mph
Stall speed, power off	22 mph

*USGS determined weight

Figure 1.

HANDLING QUALITIES RATING SCALE

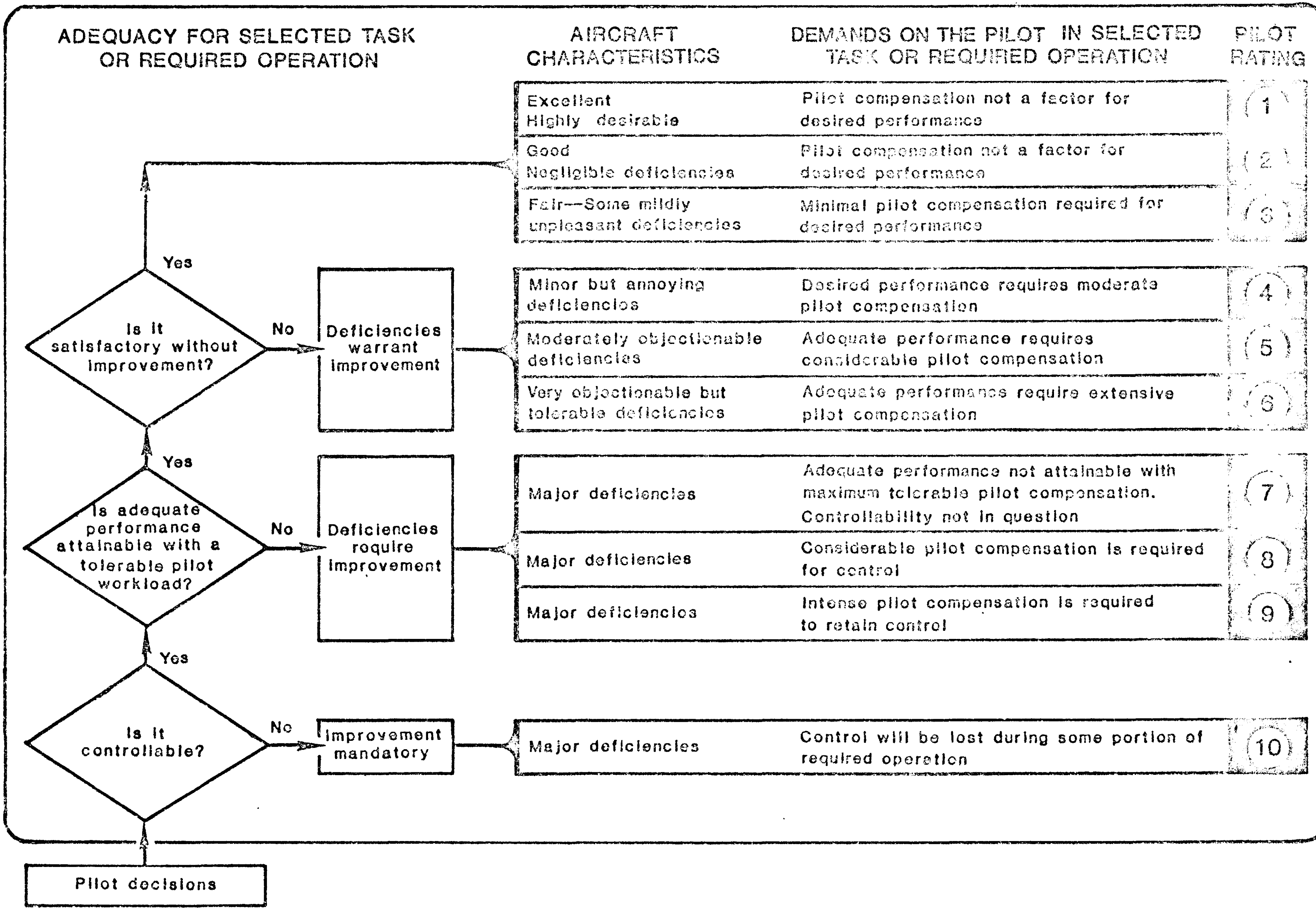

Figure 2. 13
Rotec Rally 3 Ultralight Aircraft