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A STOL AIRWORTHINESS INVESTIGATION USING A SIMULATION OF A DEFLECTED SLIPSTREAM TRANSPORT

Volume I – Summary of Results and Airworthiness Implications

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16. Abstract

A simulator study of STOL airworthiness criteria was conducted using a model of a deflected slipstream transport. This study covered the approach, flare and landing, go-around, and takeoff phases of flight. The three volumes of this report document the results of that investigation.

Volume I (NASA TM X-62,392; FAA-RD-74-143-I) summarizes the results and discusses possible implications with regard to airworthiness criteria. The results provide a data base for future STOL airworthiness requirements and a preliminary indication of potential problem areas. Comparison of the simulation results with various proposed STOL criteria indicates significant deficiencies in many of these criteria.

Volume II (NASA TM X-62,393; FAA-RD-74-143-II) contains a detailed description of the simulation and the data obtained. These data include performance measures, pilot commentary, and pilot ratings. This volume also contains a pilot/vehicle analysis of glide slope tracking and an analysis of the flare maneuver.

Volume III (NASA TM X-62,394; FAA-RD-74-143-III) documents the aircraft model used in the simulation.

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FOREWORD

The research reported here was done under NASA Contract NAS2-6433 as part of a joint NASA/FAA program. The FAA Project Monitor was Jack E. Cayot, the NASA Project Monitor was Charles S. Hynes, and the STI Project Engineer was Robert L. Stapleford. The work was accomplished in the period June 1972 through August 1973.

Successful completion of this project was due to the contributions and cooperation of many individuals besides the authors. Major contributions were made by: Richard S. Bray (NASA), Ralph Bryder (CAA, United Kingdom), Jack E. Cayot (FAA), Samuel J. Craig (STI), and Gilles Robert (CEV, France). Special thanks are due the pilots for their patience through many long simulator sessions and their many helpful suggestions. They were: John A. Carrodus (CAA, United Kingdom), LTC. Robert A. Chubboy (USA and FAA), Richard M. Gough (FAA), Gordon H. Hardy (NASA), Michel Jarriges (CEV, France), and Robert J. Kennedy (FAA).

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LIST OF ABBREVIATIONS

AEO	All Engines Operating
BR	Breguet
CTOL	Conventional Takeoff and Landing
FAA	Federal Aviation Administration
FSAA	Flight Simulator for Advanced Aircraft
ILS	Instrument Landing System
NASA	National Aeronautics and Space Administration
OEI	One Engine Inoperative
PIO	Pilot Induced Oscillation
SAS	Stability Augmentation System
STOL	Short Takeoff and Landing
VASI	Visual Approach Slope Indicator

LIST OF SYMBOLS

C_L	Lift coefficient
$C_{L_{max}}$	Maximum value of lift coefficient
n_Z	Vertical load factor
S	Reference wing area (ft^2)
$\bar{q}$	Dynamic pressure (lb/ft^2)
T	Transparency
T'_c	Thrust coefficient, $\frac{\text{total thrust (lb)}}{\bar{q}S}$
V_{APP}	Target approach airspeed on the glide slope (kt)
V_{LOF}	Lift-off speed (kt)
V_{min}	Minimum possible speed at given power setting (kt), at V_{min} $\frac{\partial\gamma}{\partial V} = \infty$
V_{MU}	Minimum unstick speed (kt)
V_R	Target rotation speed (kt)
V_S	Stall speed (kt)
V_1	Critical-engine-failure speed (kt)
V_2	Takeoff safety speed (kt)
α	Angle of attack (deg)
δ_e	Elevator deflection
δ_T	Throttle deflection
γ	Flight path angle
θ	Pitch attitude (deg)
τ	Time constant

SECTION I

INTRODUCTION

A. BACKGROUND

It has been widely recognized that some portions of the CTOL airworthiness and operational criteria are not generally appropriate for STOL aircraft. Therefore the FAA has undertaken a long range program to develop STOL airworthiness standards. Included in that program is a series of simulation experiments using models of different STOL concepts such as deflected slipstream, augmentor wing, and externally blown flap. This report covers the first simulation of that series---the simulation of a deflected slipstream aircraft.

The simulations were conducted under a joint NASA/FAA program. They were done at the NASA Ames Research Center on the Flight Simulator for Advanced Aircraft, FSAA. The simulated aircraft was the French Breguet 941S, which is a four-engine, turbo-prop, deflected slipstream, STOL transport in the 50,000 lb gross weight class. The simulator model which was used was developed as part of this project. The model was based on available flight test data, wind tunnel data, and French estimates of the aerodynamic characteristics. While an effort was made to fairly accurately match the existing data, there were frequent conflicts between various data sources. The final model was, in the opinion of the pilots, quite representative of the airplane, however there are two flight regimes where the model may have been somewhat inaccurate. There were little or no data for extreme angles of attack (those well beyond maximum C_L) and for aerodynamic characteristics during takeoff and landing ground roll. The model in these areas was based primarily on engineering judgment and extrapolation of the model from other regimes.

The general objectives of the overall program include:

- Evaluating the operating characteristics of promising powered-lift STOL concepts
- Establishing airworthiness criteria and required performance margins

- Determing appropriate flight test procedures and techniques.

The specific objectives of the simulation exercise described here included:

- Establishing the minimum acceptable approach speed for the BR 941S with and without transparency*. Aircraft characteristics at these speeds would provide a data base useful in developing potential airworthiness criteria
- Determining which factors (e.g., performance, stability, or controllability) limit the approach speed
- Obtaining approach and landing performance as functions of approach speed
- Investigating the effects of using speed or angle of attack as the approach reference
- Obtaining go-around performance data
- Investigating potential safety problems in takeoff.

All of the specific objectives were accomplished.

B. ORGANIZATION OF THE REPORT

This report is in three volumes. This volume summarizes the results and interprets them with regard to airworthiness criteria. Section II presents the results in a summary form and briefly discusses possible implications relative to airworthiness criteria and operational problems or restrictions. Section III is a review of some STOL airworthiness criteria which have been proposed by various authors. These criteria are compared with the characteristics of the simulated aircraft at the minimum acceptable approach speeds. Also included in Section III are some ideas on alternative criteria which are based on the simulator results and accompanying analyses.

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* Transparency is a differential pitch between the inboard and outboard propellers. The differential is an automatic function of flap position.

Detailed information on the simulation results is presented in Volume II. This volume provides a detailed description of the simulation and an analysis of the data. The data include performance measures, pilot commentary, and pilot ratings. The data presentation is divided into four flight phases: ILS tracking, flare and landing, go-around, and takeoff. One appendix describes a pilot/vehicle analysis of the glide slope tracking problem. Another appendix contains an analysis of the flare maneuver.

Volume III of this report is a documentation of the aircraft model used in the simulation. This contains a complete description of the aerodynamic, propulsion, control system, and landing gear models.

SECTION II

SIMULATION RESULTS

This section presents the results of the two Breguet 941S simulation programs*. Some of these results are based on the detailed data analyses which are presented in Volume II. Other results presented here are based not on performance data but simply on observations made by the participating pilots. In each case, the finding is first stated in a concise form and then it is discussed in more detail.

Part A deals with results pertaining to validation of the simulation. These results substantiate the use of the simulator in an investigation of airworthiness criteria and problems. Part B presents the findings regarding piloting technique. These describe the techniques which were found to be the most appropriate for this particular aircraft. The last three parts, C, D, and E, present the results for three different flight phases---approach and landing, go-around, and takeoff. It is in these three parts that results directly relevant to the establishment of airworthiness criteria are presented. In each of these three parts, the implications of the findings relative to airworthiness criteria or operational problems and restrictions are also presented.

A. SIMULATION VALIDATION

Finding: With practice, the pilots were able to make consistent, well-controlled landings. Landing performance was similar to that obtained in flight.

Discussion: In the 1972 simulation there was some concern because the pilots were not able to land as well on the simulator as they could in the real airplane. Such discrepancies between flight and simulation cast some doubt on results obtained in the simulation experiments. To address this problem, special efforts were taken in the 1973 simulation. These included improvements in some of the simulation features and substantial increases in pilot training (the changes are detailed in Volume II). As a result of these factors, pilot landing consistency improved considerably,

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* The first simulation exercise was in October/November 1972 and the second in April/May 1973.

although the simulator training greatly exceeded that required in flight for comparable performance. Examination of the flare maneuver itself also showed strong correlations between flight and simulation. Both showed a nearly linear variation in pitch attitude with altitude once the flare had been initiated.

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Finding: The pilots had a definite feeling of being able to trade off touchdown sink rate and longitudinal position.

Discussion: During the 1973 simulation the pilots noted that they were able to make this trade. This indicates a higher level of pilot control over the touchdown conditions; a level more associated with the flight situation. The flare was at least partially a closed loop task rather than merely a precognitive maneuver.

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Finding: The pilots were able to detect and counteract large wind shears.

Discussion: In the 1972 tests, the pilots had a great deal of difficulty in detecting large wind shears until it was too late to effect a reasonable landing. This problem seemed to disappear, or at least be greatly reduced, in the 1973 tests. Pilots were generally able to counteract the effects of the wind shears, sometimes without even being consciously aware of it, whereas in 1972 they felt that their ability to handle the shears was unrealistically poor.

B. PILOTING TECHNIQUE

Finding: Basic longitudinal piloting technique in approach was throttle to control flight path and pitch attitude to control airspeed.

Discussion: The pilots found that active control of both angle of attack and airspeed was not possible because they would frequently get conflicting indications from the two. It thus became necessary to control one and monitor the other. The preferred technique was to control airspeed while monitoring the angle of attack. No corrections for angle of attack were made unless it got dangerously large. Neither angle of attack nor airspeed was controlled directly but corrections were made by adjusting pitch attitude.

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Finding: The crosswind landing technique was a crabbed approach going to wing-low at or near flare.

Discussion: In this simulation, the pilots preferred to make crabbed approaches in a crosswind. Transition to wing-low was made at flare initiation or a few seconds prior to that point. Wing-low was used because of inadequate rudder power for a rapid decrab maneuver and the difficulties in precisely predicting touchdown in the simulator.

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Finding: Removing the transparency* instead of adding power was not an acceptable method of correcting for a low approach.

Discussion: A brief test was made of the feasibility of removing transparency to correct for being low on the glide slope. The pilot found that this was not an acceptable technique. Removing the transparency or putting it back in produced a large step input to the aircraft and changed the trim power setting. The pilot could easily get confused as to whether the transparency was in or out.

C. APPROACH AND LANDING

Finding: Minimum acceptable approach speed was 60 kt, transparency in, and 60 - 65 kt, transparency out.

Implication: The aircraft characteristics at these speeds provide data to test against potential airworthiness criteria.

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* This was done by raising the flaps slightly.

Discussion: Minimum acceptable approach speed is the slowest target approach speed which the pilots considered acceptable for airline operations. The comparison of the aircraft characteristics at the minimum acceptable speeds with potential airworthiness criteria is covered in Section III. A variety of proposed STOL criteria are considered and the comparison serves to either support or refute these ideas.

With regard to the minimum acceptable speed evaluations, several factors are worth noting. First, the pilot ratings are based on the simulated task and conditions. For actual airline operation an increased speed margin might be required because of additional pilot workload (e.g., radio communications) and the possibility of more severe atmospheric conditions. Second point is that the speed was primarily limited by the pilots' subjective evaluation of workload not by pilot/aircraft performance. This is in agreement with a number of handling quality studies which show that pilot ratings generally degrade as workload increases before pilot/aircraft performance changes substantially. Third, the workload increase at lower speeds is confirmed by the pilot/vehicle analysis which shows an increased requirement for pilot lead in the flight path feedback. The analysis also supports the slightly higher minimum acceptable speed for the transparency out configuration.

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Finding: The approach speed limits based on glide slope tracking or on flare/landing problems were nearly the same.

Implication: The comparison referred to above includes limiting conditions for both approach and landing.

Discussion: The pilot comments clearly indicated the degradations in glide slope tracking ability and flare control as approach speed was reduced. At the limiting speeds, glide slope tracking had become difficult and, in the flare, a slight power addition was necessary for an acceptable landing. The pilots considered this an acceptable flare technique. Without the power addition, the minimum approach speed would have been increased because of the flare/landing problems.

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Finding: Pilot ratings of the flare characteristics correlated with the potential for sink rate reduction without adding power. This characteristic in turn was correlated with the speed margin above V_{min}.

Implication: Speed margin above V_{min} may be a convenient criterion for adequate flare capability.

Discussion: Over the range of test conditions, it was found that pilot rating of the flare maneuver correlated with the potential reduction in sink rate without the use of power. For this particular model and the approach speeds tested, the potential sink rate reduction was in turn correlated with the speed margin* above V_{min}. Either of these correlations might be changed for a different STOL aircraft. The first correlation, if it can be shown to be universal or nearly so, could form the basis for a flare criterion, such as the ability to reduce sink rate by a specified amount without adding power. If both correlations hold up, even simpler criterion based on speed margin above V_{min} might be adequate.

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Finding: A predetermined power addition to assist the flare was an acceptable technique.

Implication: Allowance for the addition of power at flare initiation should be considered in STOL airworthiness criteria.

Discussion: At the minimum approach speeds, the pilots found that good landing performance was not obtainable without the addition of power. Without the power addition, hard landings were impossible to avoid; however, a slight (1 - 2 percent) open loop addition of power was acceptable to the pilots. Just prior to the flare maneuver, the pilots would simply make the small power addition and then leave the power alone for the rest of the flare. While they rated it acceptable, some pilots were uncomfortable

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* V_{min} is a function of power setting. In making this correlation, the power setting and V_{min} for a no wind condition was used.

with this technique because it was difficult to judge if they were adding the right amount of power. Conditions (slower speeds) which required simultaneous closed-loop control of pitch and power were considered very difficult and unacceptable.

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Finding: Pilot/aircraft performance degraded significantly when turbulence and wind shears were added.

Implication: Operation under adverse conditions should be considered in certification.

Discussion: The pilots felt that the performance degradations due to turbulence and wind shears were more severe than for CTOL transports. Configurations which were relatively easy to control in calm air became quite demanding under the adverse test conditions. The pilots concluded that airworthiness evaluations done in calm air would not be valid for operation in adverse conditions. The simulated turbulence level should be met or exceeded 10% of the time.

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Finding: Recognition of V_{min} was very difficult for the pilots without an angle of attack display but recovery was easy if excessive angles of attack were avoided.

Implication: Even though there were no sharp breaks in the lift curve at V_{min}, adequate warnings must be provided to the pilot.

Discussion: The lift versus angle of attack characteristics of this aircraft are considerably different than those of most CTOL aircraft. At approach power there is no sharp break in C_L with angle of attack but rather a gradual rounding over (see Figure II-1). As a result, aircraft behavior in the region of maximum C_L is somewhat unconventional.

If we start with a normal approach condition and gradually raise the nose, the airspeed decreases initially and the sink rate increases.

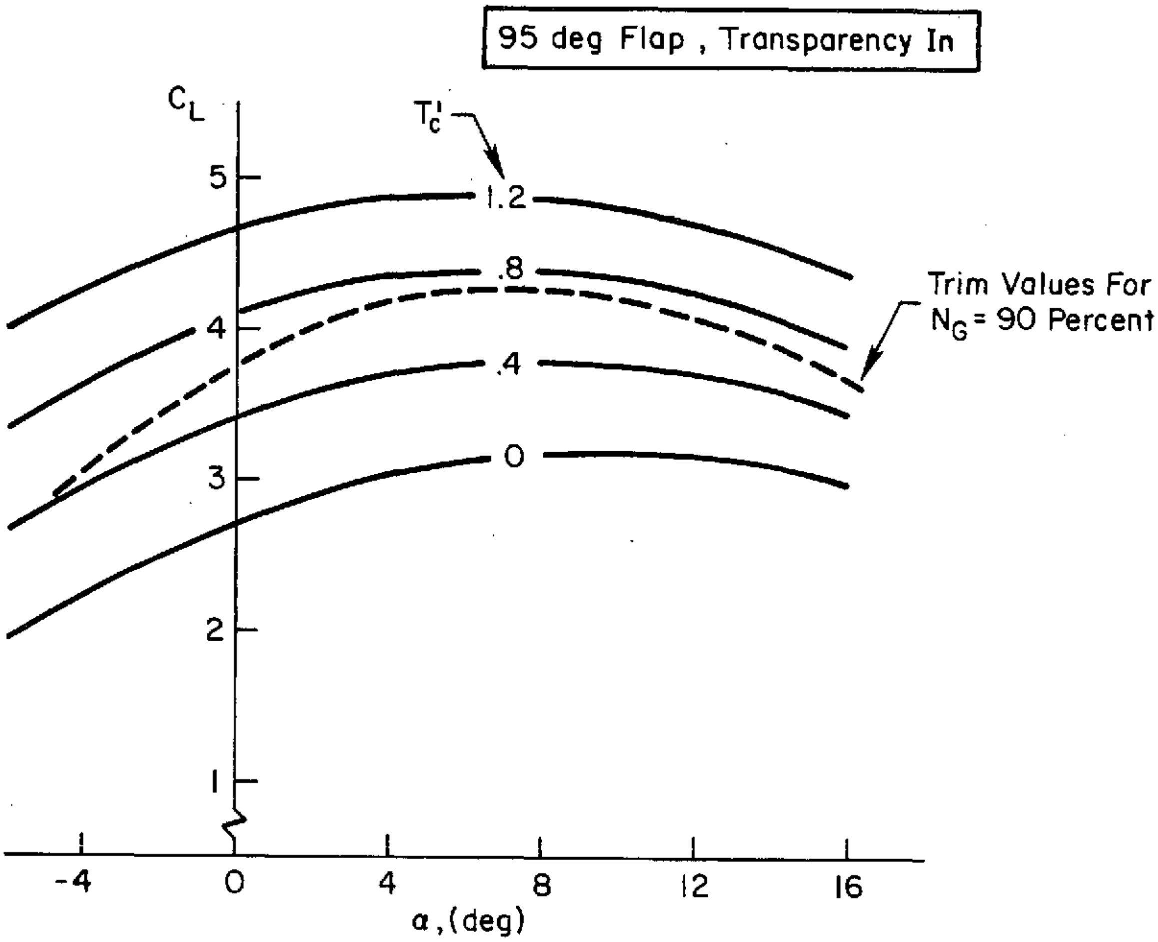

Figure II-1. Lift Characteristics

As $C_{L_{max}}$ is reached the airspeed decrease stops. Airspeed reaches an absolute minimum for that power setting, V_{min}. Additional attitude increases will cause the airspeed to increase and the rate of descent to grow quite rapidly.

While the aircraft is basically well behaved in this condition, it is a dangerous situation to have in an approach. Increasing pitch attitude would cause a rapid increase in airspeed and rate of descent, both of which are opposite to what the pilot would except and would certainly confuse him. Therefore the speed margins must be large enough or some warning device must be provided to prevent the pilot from getting into this situation.

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Finding: An angle of attack display did not reduce pilot workload but helped him avoid dangerously high angle of attack situations.

Implication: The use of an angle of attack display will not allow significant reductions in minimum approach speeds.

Discussion: The pilots felt that the angle of attack information did not reduce their workload and workload was a primary factor in limiting approach speeds. Therefore the pilots felt that the angle of attack display would not result in any significant reductions in approach speeds. Nevertheless, the display is useful and may improve safety because it helps the pilot avoid getting to excessive angles of attack. However, if such a display is used the pilots must be carefully trained not to close a tight angle of attack loop, i.e., chase the angle of attack. To do so results in a severe degradation in flight path control as demonstrated in the pilot/vehicle analyses of Volume II. This was confirmed during early familiarization flights when flight path PIO's resulted from pilot concentration on angle of attack.

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Finding: The chevrons were a poor type of angle of attack display because of a lack of rate information.

Implication: The angle of attack display, if used, should be a continuous, rather than discrete, type.

Discussion: Pilots complained about the lack of rate information from the angle of attack chevrons. Without the rate information the pilots did not know how serious a high angle of attack indication was. They would respond more rapidly if the angle of attack was increasing than if it was steady or decreasing. The pilots felt the continuous displays were generally more useful than the chevrons. However, the chevrons were especially useful after the pilots went visual. Because of the chevron's location the pilots were able to monitor it with their peripheral vision.

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Finding: Flare with power alone may be an acceptable technique if the thrust response is sufficiently rapid.

Implication: Consideration should be given to the possibility of power alone flare and of defining criteria for acceptable thrust lags.

Discussion: The pilots found that they could make acceptable landings using power alone to flare when the thrust lag was reduced to 0.5 sec. Pilot acceptance of this technique varied for different pilot backgrounds. A pilot with considerable helicopter experience considered it an acceptable technique. Another pilot, who had no helicopter background, initially evaluated it as unacceptable. On re-examination and after some discussion with the first pilot, he modified his position to possibly acceptable. Extrapolating from the preceeding finding we would also hypothesize that the flare maneuver could include an open loop pitch change, such as that to avoid landing on the nose gear, if the accompanying lift change were sufficiently small.

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Finding: Variations in the approach attitude did not affect the pilot's ability to judge the flare.

Implication: Restrictions on approach attitude will be set by other factors.

Discussion: There was some concern that approaches with a large nose-down attitude might adversely affect the pilot's judgment of the flare maneuver. Tests were made with the pitch attitude varied from 10 deg nose down to 2 deg nose up with all other parameters fixed. Over this range of attitudes there was no effect on the pilot's judgment of the flare.

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Finding: Ground-based (e.g., VASI) or heads-up glide slope guidance may be necessary for consistent, accurate approach and landing.

Implication: Runway length requirements might be somewhat reduced for runways which have ground-based guidance or for aircraft which have heads-up glide slope guidance.

Discussion: The 1973 tests were conducted with a VASI-type system in addition to the standard ILS instrumentation. The pilots felt that the VASI contributed to the consistent landing performance which was obtained. Data on the separate effects of the ground-based guidance were not obtained; however, it should reduce touchdown dispersions. If the reduction were significant, it would seem reasonable to compensate for reduced touchdown dispersions by reducing runway length requirements.

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Finding: The offset localizer made crosswind landings under low visibility conditions more difficult.

Implication: It may be necessary to increase runway length requirements when an offset localizer is used.

Discussion: In both simulations the glide slope and localizer transmitters were co-located off to one side of the runway. The localizer was angled back so that it crossed the runway center line prior to the threshold. The pilots felt that the offset localizer made the cross-wind landings more difficult when operating with a low ceiling, such as 200 ft. After breakout, they had to make a heading change to get lined up with the runway; then as they got down to the flare they had to perform the de-crab maneuver. The extra heading change may have, in some cases, contributed to situations in which the landing was long because the pilot had to delay his touchdown until he got the lateral conditions under proper control. Thus the offset localizer may cause more long touchdowns. If this possibility is true, it may be necessary to increase runway length requirements where an offset localizer is used.

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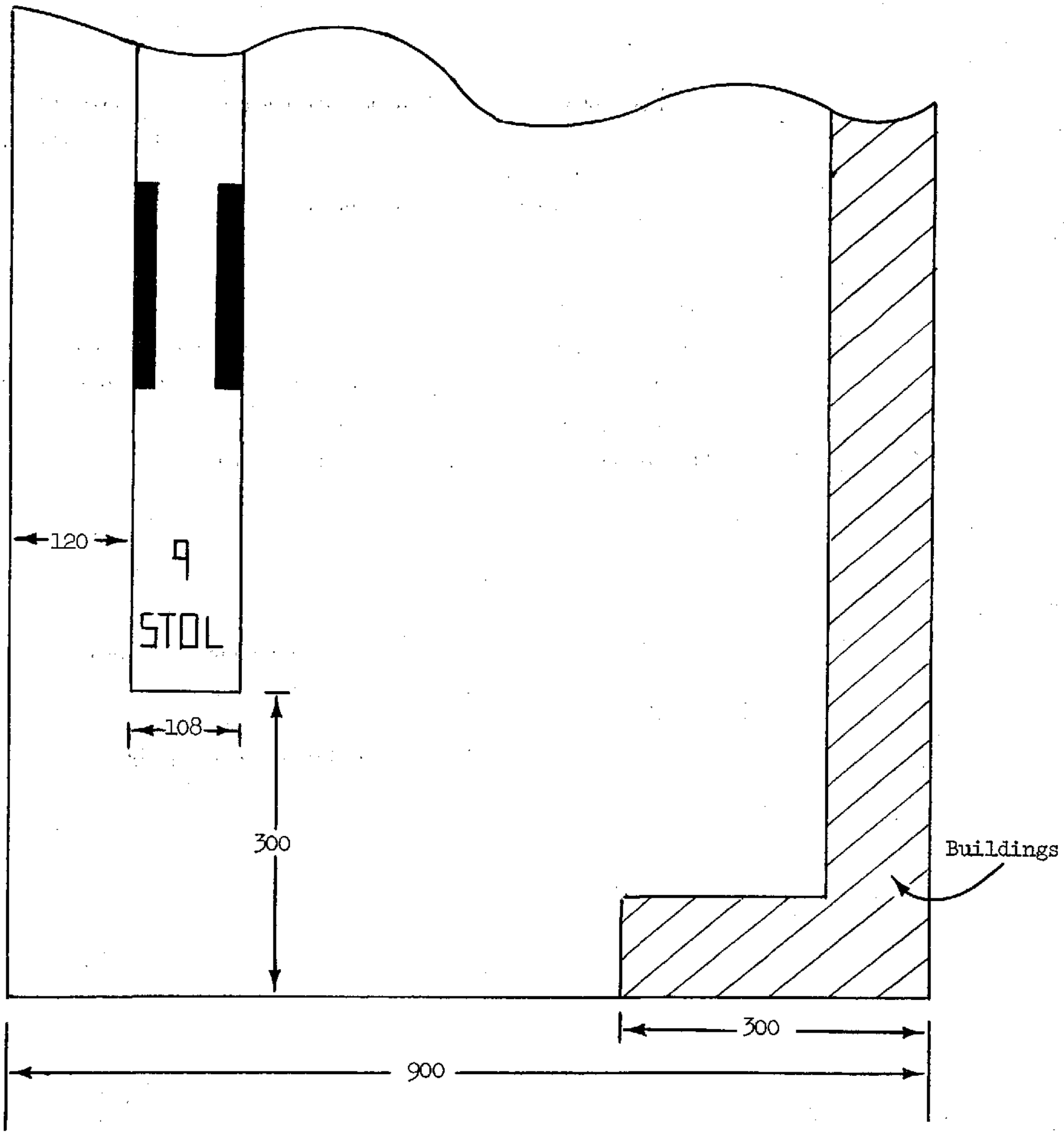
Finding: There were no adverse psychological reactions to landing on the model of an elevated STOL port.

Implication: No additional requirements for landing on an elevated STOL port may be necessary.

Discussion: A number of landings were made using a model of an elevated STOL port. The pilots found no adverse psychological reactions and felt just as comfortable as landing on the usual STOL runway. However, it should be noted that the model used in these tests was quite wide relative to some proposed designs (see Figure II-2). Pilot reactions could be considerably more adverse with a minimum width STOL port.

D. GO-AROUND

Finding: The go-around sequence used in these simulations did not present any piloting problems.



NOTES: 1. All dimensions in feet (full scale)

2. Surface is elevated 100 ft above surrounding terrain

3. Runway length is 1800 ft

Figure II-2

Elevated STOL Port

Implication: Regulations should allow flap changes for go-arounds, at least if the flap controls are as convenient as they are on the Breguet 941S.

Discussion: The go-around sequence used in the simulation involved two flap changes. The first flap change was made at the initiation of go-around and was done with a switch on the throttle lever. Activating the switch caused the flaps to retract at a rate of 7 deg/sec until they reached 70 deg. Thus with one hand motion the pilot could apply full power and raise the flaps to 70 deg. After he had established a positive rate of climb, he then raised the flaps to 45 deg using a conventional flap lever. The pilots found no problems with this go-around sequence. It was simple and easy to accomplish.

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Finding: With a decision height of 200 ft, the aircraft occasionally got to altitudes of less than 100 ft on go-arounds.

Implication: To avoid ground contact, decision height should be on the order of 150 to 200 ft or more.

Discussion: Throughout both simulations a decision height of 200 ft was used. If the pilot did not have ground contact at that point he was instructed to initiate a go-around. Numerous runs were made with a ceiling less than 200 ft. Data were not obtained which allow partitioning the height loss into that due to the basic aircraft performance and that due to pilot delays in making the go-around decision. However, the combination resulted in minimum wheel heights of less than 100 ft in roughly 5 percent of the cases, with the worst case getting down to 85 ft. Assuming these results to be realistic and typical of STOL operations, and allowing for normal altimeter errors, it can be seen that minimum decision heights should be on the order of 150 to 200 ft to avoid ground contact in the event of a go-around. The possibility ground contact is especially bad if an offset localizer is being used as the ground contact would probably be off the runway.

E. TAKEOFF

Finding: This aircraft was very forgiving of takeoff abuses. No dangerous situations were encountered.

Implications: Takeoff criteria might be simplified, e.g., requirement for margin between V_{LOF} and V_{MU} might be eliminated.

Discussion: For this aircraft, none of the abuse conditions which were examined resulted in a dangerous situation. The aircraft could not be forced off the ground until it had attained satisfactory flying speed and even with one engine out it could then accelerate to V_2. To the extent that these characteristics are typical of STOL aircraft, takeoff criteria might be considerably simplified.

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Finding: Early rotation abuses with one engine out greatly increased the takeoff distances relative to all engines operative.

Implication: Early rotation and one engine out abuses must be considered in takeoff performance standards.

Discussion: While rotation abuses with one engine out did not result in dangerous situations, they did greatly increase the takeoff distances relative to the all engines operating case. Data were not obtained which would allow separation of the engine out effects and those due to the early rotation. However, the effects of the combination were very large, up to 45% increase in distance to 35 ft, even though this is a four-engine aircraft with no asymmetries due to the engine failure.

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Finding: Takeoff performance OEI was quite insensitive to V_1.

Implication: It may be possible to use a combined decision/rotation speed.

Discussion: The effects of V_1 on OEI takeoff performance were measured in a series of takeoffs with an engine failure at V_1. The distance to an altitude of 35 ft increased only 300 ft (1900 to 2200 ft) going from $V_1 = V_R = 65$ kt to $V_1 = 0$. One contributing factor that reduced sensitivity in this case is, of course, the fact that it is a four-engine aircraft. Another factor is the propeller cross-shafting which eliminated any asymmetries.

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Finding: Climb performance in turbulence was as much as 1.4 deg less than the ideal takeoff flight path.

Implication: These data provide an indication of reasonable margins between actual obstacle planes and climb performance standards.

Discussion: For all takeoffs the steepest obstacle clearance plane which would have been cleared was measured. These later were compared to theoretical values based on the aircraft performance characteristics. In the worst case measured, the climb performance in turbulence and OEI was 1.4 deg less than the theoretical value for OEI. The measured decrements between theoretical and obtained performance should provide guidance as to margins which should be provided between real obstacles and the aircraft climb capability. These margins must provide tolerances for the effects of turbulence and for typical pilot/aircraft performance, such as that obtained in the simulation.

Reference 12 uses an "assumed worst flight path" equal to 0.625 times the nominal flight path angle. They consider this a conservative estimate and it is based on CTOL experience (1 deg error for a nominal path of 2.5 - 3 deg). For the worst simulator case noted above, the achieved flight path was 0.72 (3.6/5.0) times the theoretical value. Thus, the Reference 12 factor of 0.625 may not be overly conservative.

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Finding: Climb-outs at speeds near V_{min} were dangerous (1 "crash"). Speed margins on the order of 10% were necessary.

Implication: Margin between V_2 and the one engine out V_{min} should be on the order of 10% or more.

Discussion: One series of takeoff tests were conducted with $V_2 = 67$ kt. As can be seen from Figure II-3, that speed is very near the OEI V_{min}. This was found to be a dangerous situation and resulted in one "crash". After an engine failure, the pilot got to angles of attack beyond that for $C_{L_{max}}$. He found his airspeed was high and so raised the nose to slow up. This just caused the airspeed to increase and the rate of climb to decrease. The pilot and observer (acting as co-pilot) both became quite confused and were sure the computer had malfunctioned. Subsequent pilot evaluations were that a margin on the order of 10% was necessary to avoid this situation.

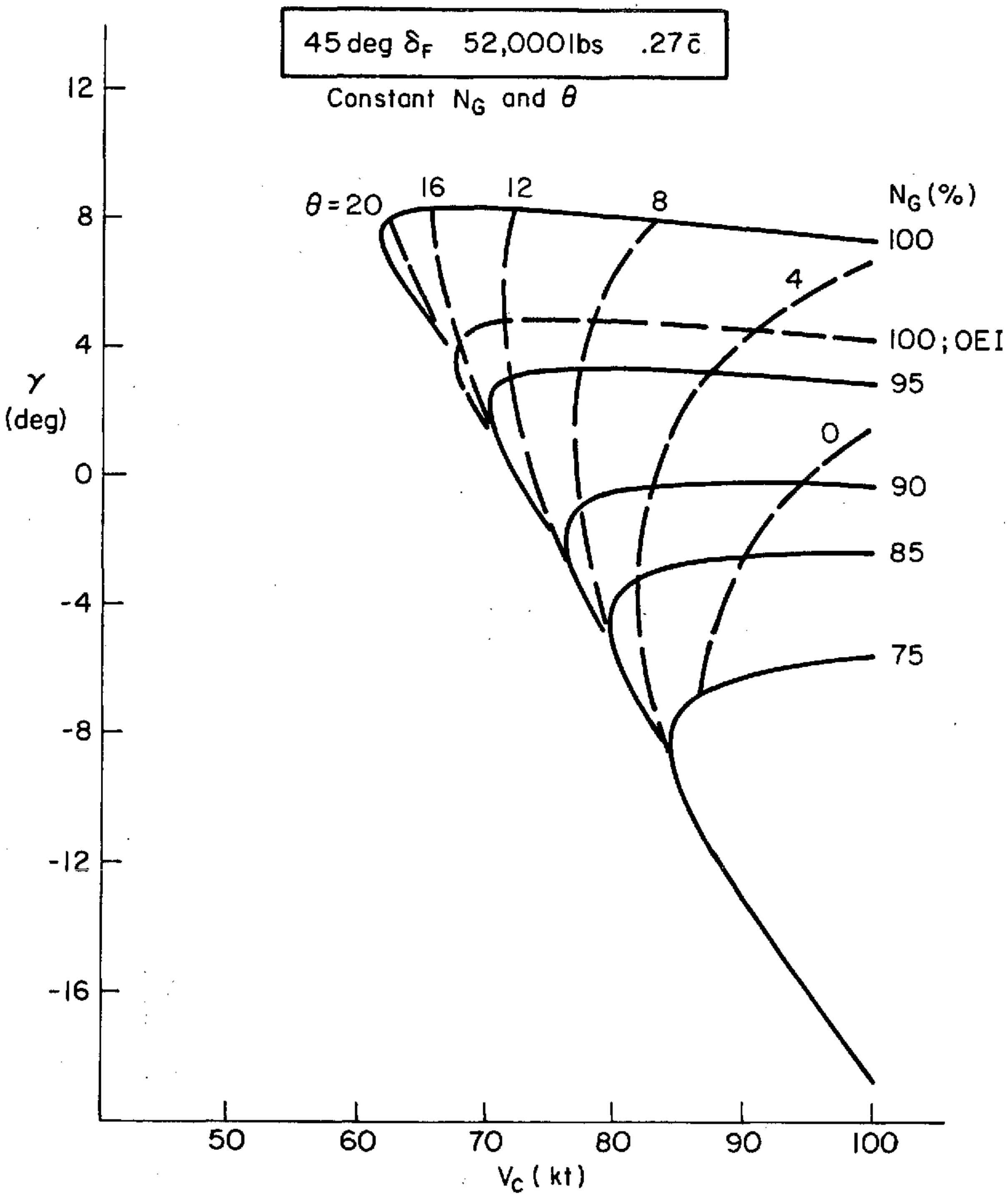


Figure II-3. Takeoff Performance Curves

SECTION III

AIRWORTHINESS CRITERIA

This section deals with potential airworthiness criteria for STOL aircraft. It includes an evaluation of several proposed criteria by comparing them with the characteristics of the simulated Breguet 941S. The comparison shows a number of instances where there are significant discrepancies between the criteria and the simulation results. Also included in this section are some ideas on possible alternative criteria forms which are based on the simulation results and accompanying analyses.

While reading this section the reader should keep in mind that the minimum acceptable approach speeds which were selected in the simulation were 60 kt, transparency in, and 60 - 65 kt, transparency out. In the comparison tables the BR 941S characteristics are given for both 60 and 65 kt, transparency in and out. For the transparency in cases, 60 kt represents the minimum acceptable speed and is therefore a key case for comparison with the criteria. The 65 kt case is included in the table to provide a condition which is somewhat better than the minimum. For transparency out, the 60 and 65 kt cases bracket the minimum acceptable approach speed. Therefore the data for these two cases should bracket at least some of the requirements.

A. SPEED MARGIN

Speed margin requirements for STOL and CTOL are fundamentally different. With a CTOL aircraft speed margin directly implies a maneuver capability. In STOL aircraft the relationship between speed and maneuverability is different and depends on the type of STOL aircraft. Thus it is necessary to separate STOL speed margin and maneuverability requirements. The latter are considered in Part B.

The approach taken here is to consider the speed margin requirements independent of other factors, such as maneuverability, flight path control, and control power considerations. There are few fundamental factors which dictate requirements for a speed margin. Real requirements for speed margin are to provide protection from the effects of gusts, wind shears, and inadvertent airspeed deviations caused by the pilot. The speed margin must be sufficiently large so that speed variations due to these factors do not result in dangerous flight situations.

Obviously the size of the margin depends strongly on the severity of the safety problem when the margin is exceeded. One extreme would be if this condition were catastrophic. This would correspond to an aircraft which had some speed or angle of attack limit beyond which the aircraft suffered a complete loss of control. If exceeding this limit would result in a crash, then the margins must be large enough so that the probability of exceeding the limit is extremely small. For another aircraft there could be a minimum speed or maximum angle of attack beyond which the aircraft characteristics were unknown. This is the case with the actual Breguet 941S aircraft. While it has been flown to very large angles of attack, no one knows for certain what might happen at slightly higher angles of attack. In this event the most prudent approach would be to assume that catastrophe awaits just beyond the known conditions and margins would be established on the same basis as discussed above.

The simulated Breguet 941S was somewhat different. At the minimum speed the aircraft was quite controllable although high sink rates were generally present. While the aircraft was controllable this condition really represented a dangerous situation because of the difficulty in controlling flight path. At V_{min} the throttle is ineffective in changing the flight path and raising the nose causes a rapid increase in airspeed and rate of descent. This represents a dangerous situation but is not catastrophic in that the pilot could easily recover if he recognized the situation. The recovery technique was to add power and lower the nose. Thus, the minimum margins obtained in the simulation may be too small for other STOL aircraft.

Let us now compare the speed margins that were in effect selected by the simulation pilots with proposed criteria. This comparison is summarized in Table III-1. As a point of departure the first entry in the table is the criterion from FAR Part 25 (Ref. 1), that is, approach

TABLE III-1

MINIMUM APPROACH SPEED CRITERIA

SOURCE	CRITERION	BR 941S (δ_f = 95 deg)			
		T in		T out	
		60 kt	65 kt	60 kt	65 kt
FAR Part 25	>1.3 V_s (flight idle power)	0.97 V_s	1.05 V_s	1.01 V_s	1.09 V_s
Breguet Special Conditions NASA TN D-5594 NASA CR-114454	>1.15 V_{min} AEO and approach power	1.06 V_{min}	1.15 V_{min}	1.06 V_{min}	1.15 V_{min}
Breguet Special Conditions	>1.3 V_{min} OEI and maximum power	1.14 V_{min}	1.23 V_{min}	1.30 V_{min}	1.40 V_{min}
NASA TN D-5594	>1.15 V_{min} OEI and maximum power	1.14 V_{min}	1.23 V_{min}	1.30 V_{min}	1.40 V_{min}
NASA CR-114454	Step vertical gust to stall wing > 20 kt OEI	8.0	12.2	7.8	12.5

V_{min} for BR 941S is assumed to be minimum possible speed at given power setting ; $\left(\frac{\partial\gamma}{\partial V}\right)_T = \infty$ at V_{min}

speed greater than 1.3 times the stall speed. The table shows that acceptable approach situations for the BR 941S were very close to the flight idle stall speed. The first real STOL criterion shown in the table is for the approach speed to be greater than 1.15 V_{min}. We see that acceptable approach conditions for the BR 941S resulted in smaller margins, down to 1.06 V_{min} for transparency in. Pilot acceptance of such low margins is apparently due to the lack of catastrophic conditions at V_{min} as discussed earlier. Another contributing factor may have been the relatively low airspeed deviations the pilots experienced. RMS airspeed deviations were typically about 2 kt even in moderate turbulence.

The next two entries in the table define speed margins relative to the OEI and maximum power V_{min}. The simulation results indicate that the 1.3 factor may be too conservative and the 1.15 factor may be more reasonable.

The last entry in the table is not really a speed margin criterion directly but is very closely related. The requirement (to not stall the wing with a 20 kt step vertical gust) was not satisfied by the BR 941S. While the gust protection might seem relatively small it is apparently adequate since gusts somewhat larger than those shown in the table would not result in extreme losses in lift. This requirement might be better stated in terms of a maximum lift loss for a given size gust.

Overall we see that the simulation indicates the pilots' willingness to fly with considerably smaller speed margins than have been proposed. The low margins are obviously partly due to the rather innocuous aircraft characteristics at V_{min}. In this regard the BR 941S may or may not be representative of most STOL concepts.

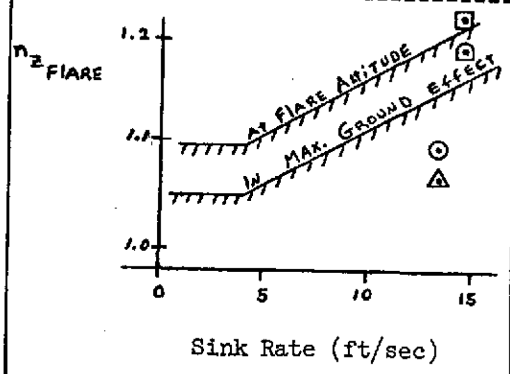
B. LOAD FACTOR

In a STOL aircraft both the elevator and throttle can be effective in producing load factor changes. This dual capability must be considered in establishing load factor requirements. Several proposed load factor criteria are presented in Table III-2 along with values for the BR 941S.

TABLE III-2. LOAD FACTOR CRITERIA

SOURCE	CRITERION	BR 941S ($\delta_f = 95$ deg)			
		T in		T out	
		60 kt	65 kt	60 kt	65 kt
Breguet Special Conditions	$\Delta n_Z > .25$ g AEO, approach power, elevator input	.10	.22	.07	.19
NASA CR 114454	$\Delta n_Z > .35$ g AEO, approach power, elevator input	.10	.22	.07	.19
	$\Delta n_Z > .5$ g AEO, maximum power, elevator and throttle inputs	.29	.43	.40	.52
CAA, Section P	$\Delta n_z \geq .6$ g AEO, maximum power, elevator and throttle inputs	.29	.43	.40	.52
NASA TN D-5594 AGARD R-577-70		Maximum Δn_Z			
	When maximum $\Delta n_Z < .15$ g with elevator alone:	.15	na	.19	na
		Time to $\Delta n_Z = .1$			
	$\Delta n_Z = \pm .1$ g in 0.5 sec for throttle input at constant attitude	1.1	na	1.0	na
		Maximum Δn_Z			
	When maximum Δn_Z is .15 - .3 g with elevator alone:	na	.16	na	.18
		Time to $\Delta n_Z = .1$			
	$\Delta n_Z = \pm .1$ g in 1.5 sec for throttle input at constant attitude	na	1.2	na	1.1

TABLE III-2. (Concluded)

SOURCE	CRITERION	BR 941S (δ_f = 95 deg)			
		T in		T out	
		60 kt	65 kt	60 kt	65 kt
NASA CR 114454	$\tau_{n_Z} < 1$ sec τ_{n_Z} is time from flight path input until n_Z reaches 63% of first peak	1.6	1.3	1.3	not measured
	$\tau_{\dot{h}} < 0.8$ sec $\tau_{\dot{h}}$ is time to achieve a positive change in vertical speed following a climb command	1.4	1.0	1.2	not measured
	n_Z available at stall warning shall not be less than values shown in figure to the right. Requirement applies at approach speed and thrust not exceeding that required for constant speed in the flare.	Data are for free air and constant thrust Symbols			
		⊙	⊡	△	⌂
					

The first two entries in the table specify load factor requirements for elevator inputs. One source has a requirement of .25 g and the other .35 g. The BR 941S does not meet even the lower requirement. At the minimum acceptable speeds, BR 941S load factor capability is only about .1 g. Thus both requirements seem overly severe.

The third and fourth criteria in the table call for .5 and .6 g using both elevator and throttle and again these requirements are not met by the BR 941S, particularly for the transparency in configuration. In the simulation a capability of only .3 g was acceptable.

The next two entries present a requirement for load factor due to the throttle input. The requirement is .1 g in either .5 or 1.5 sec, depending on the load factor available from the elevator alone. For both 60 kt cases, the criterion is not met because the response time is too long. Also for both cases, the criterion is met at 65 kt. Thus the transparency in results do not agree with the requirement since 60 kt was an acceptable speed.

For general maneuvers, excluding flare for the moment, it seems that the most logical criterion would be the total load factor available from both elevator and throttle inputs. The simulation results indicate that a capability on the order of .3 g should be acceptable. A time limit should probably be specified in addition to guard against excessive thrust lags.

The next two entries of Table III-2 deal with response time rather than magnitude requirements. Neither criterion is supported by the simulation results as neither is met for an acceptable approach condition.

The last item in the table refers specifically to a flare requirement. A direct comparison of the criterion with the BR 941S was not possible as data were only available for constant thrust. The requirement allows thrust inputs up to those required for constant speed. The constant speed provision of this requirement is especially troublesome. In many cases, constant speed cannot be maintained even when power is added. The power addition will just postpone or reduce the speed loss.

It is important to establish load factor criteria to insure adequate flare capability. In considering flare requirements one must consider two possible flare techniques. In the first (conventional) technique, sink rate control is primarily through attitude. Throttle inputs, if any, are precognitive. This was the technique generally used in the simulator program. It is shown in Volume II of this report that pilot acceptance of the flare characteristics correlated quite well with a potential touchdown sink rate. This potential sink rate is the best touchdown sink rate which could be achieved without adding power. Acceptable flare characteristics were obtained when the touchdown sink rate could be reduced to approximately 7 ft/sec without adding power. Such a requirement would make a good flare criterion as it is relatively easy to evaluate. It remains to be seen if this metric provides as good a correlation with pilot acceptance for other types of STOL aircraft.

It is also shown in Volume II that this potential sink rate for the BR 941S correlated very well with the speed margin above V_{min}. This correlation plus the one noted above infers that speed margin could be used to insure good flare characteristics. This approach would be satisfactory only if other STOL aircraft showed the same relationship between speed margin and potential sink rate. This would seem to be an unlikely situation.

The other flare technique which should be considered is one in which the throttle becomes the primary control. Pitch changes, if any, would be done only to establish the proper touchdown attitude. The simulation results regarding the acceptability of this technique are not conclusive. However, it seems to be a reasonable possibility and deserves further consideration. A potential touchdown sink rate might also be an acceptable criterion for this flare technique. It would probably be necessary to add a time constraint to avoid problems due to excessive thrust lags.

C. FLIGHT PATH CONTROL

With regard to flight path control, it is necessary to have requirements on the magnitude of flight path changes which can be obtained, but the path control dynamics must also be considered. The dynamics must be such that the pilot can maintain adequately precise control of flight path during his approach and the $\Delta\gamma$ capability must be large enough to allow for winds and recovery from reasonably large disturbances. Flight path control criteria from several sources are presented in Table III-3.

Let us first examine the $\Delta\gamma$ requirements. These are specified in Table III-3 with a variety of constraints, including constant airspeed, constant attitude, and approach speed plus or minus a given increment. In terms of upward corrections, that is, $\Delta\gamma$ positive, the BR 941S generally meets the various proposed criteria. This is an encouraging result as the pilots did not complain about the ability to make upward corrections for these four conditions. For downward corrections, the BR 941S also meets all of the criteria. However, for the 60 kt, transparency out configuration there were pilot complaints about the ability to make downward corrections. With transparency out, if power is reduced to increase the flight path from 7.5 to 9.5 deg while holding 60 kt, one would now be operating right at V_{min}. In other words, with the power set for a 9.5 deg approach, V_{min} is 60 kt. Thus, when the pilots tried to make large downward corrections they found they were operating in the region around V_{min} and this made the control task quite difficult.

The pilots had difficulty even though, as noted earlier, the aircraft characteristics at V_{min} were relatively gentle and no catastrophic conditions existed. This implies that the requirement for downward capability must include an additional requirement for a speed margin above V_{min}. This could take the form of the following:

> With power reduced to steepen the flight path 2 deg, the approach speed shall be greater than 1.05 V_{min}.

This condition would be just met by the 65 kt, transparency out case. If the aircraft characteristics at V_{min} were more unfavorable, such as a sharp break in the lift curve, then larger speed margins would undoubtedly be required.

With regard to criteria relating to flight path control dynamics, the bottom of Table III-3 contains criteria from NASA CR-114454 (Ref. 4). The criteria given there assume that the aircraft is flown using the

TABLE III-3. FLIGHT PATH CONTROL CRITERIA

SOURCE	CRITERION	BR 941S (δ_f = 95 deg)			
		T in		T out	
		60 kt	65 kt	60 kt	65 kt
NASA TN D-5594 NASA CR 114454	For altitude < 1000 ft, rate of descent < 1000 fpm	794	860	794	860
Breguet Special Condition	$\Delta\gamma = \pm 2$ deg (assumed constant airspeed)	+7 -5	+7.5 -8	+12.4 -2	+13 -3.8
CAA, Section P	$\gamma_{max} > 0$ $\Delta\gamma = -2$ deg (constant airspeed)	-0.5 -5	0 -8	4.9 -2	5.5 -3.8
NASA TN D-5594 AGARD R-577-70	$\Delta\gamma = -2$ deg (constant attitude)	-9	-8.5	-4	-3.5
NASA CR 114454	$\Delta\gamma = -2$ deg at V_{APP} + 10 kt	-8	-7.5	-3.5	-4
		CRITERION $\Delta\gamma$			
	$\Delta\gamma = \Delta\gamma_{STILL\ AIR} + \Delta\gamma_{HEAD\ WIND}$ $\Delta\gamma_{STILL\ AIR}$ is greater of: a) +2 deg at V_{APP} -10 kt b) 20 $(\frac{\partial\gamma}{\partial V})_T$ at V_{APP}	7.4	5.5	8.2	5.5
		941 $\Delta\gamma$			
	$\Delta\gamma_{HEAD\ WIND} = -\gamma_{APP}\frac{V_{DESIGN\ WIND}}{V_{APP}}$ (assumed $V_{DESIGN\ WIND}$ = 30 kt)	7 ⓐ V_{APP}	6.2 ⓐ V_{APP} -10	12.4 ⓐ V_{APP}	11 ⓐ V_{APP} -10
	For STOL piloting technique (throttle controls flight path and pitch attitude controls airspeed):				
	$n_z/\alpha > 0$ g/deg	.025	.039	.019	.031
	$(\frac{\partial\gamma}{\partial V})_T < 0.2$ deg/kt	.18	.079	.24	.034
	$(\frac{\partial\theta}{\partial\gamma})_V$ limit unknown; negative values undesirable but allowable	-.040	.24	-.54	-.015
	$-.6$ deg/kt $< (\frac{\partial\theta}{\partial V})_\gamma < 0$	-.62	-.43	-.85	-.68
	Effective thrust vector angle, limits unknown, 13 - 90 deg suggested	80.3	80.5	81.6	76.9

STOL technique, that is, primary control of flight path is with the throttle. The requirement for n_Z/α to be positive will not be discussed further as it simply means that there must be some load factor capability with angle of attack. The next criterion ($\partial\gamma/\partial V$ at constant throttle less than .2 deg/kt) is worth discussing. Note that the .2 limit is very close to the BR 941S values at the minimum acceptable speeds but this is felt to be more of a coincidence than a substantiation of the criterion. The derivative, $\left(\frac{\partial\gamma}{\partial V}\right)_T$, has been shown to be a significant parameter for aircraft which are controlled by the CTOL technique but there is no basis for assuming it is significant when flying the STOL technique. The derivative has been shown to be approximately proportional to the low-frequency flight path to elevator transfer function zero. This zero is important in evaluating the pilot's ability to control flight path with attitude. However, when one switches to the STOL technique that zero no longer has any direct relevance.

The $\left(\frac{\partial\theta}{\partial\gamma}\right)_V$ parameter will not be discussed as NASA CR-114454 does not propose any limiting values. The simulation results, especially for transparency out, clearly indicate that negative values of this parameter are allowable.

For the limiting approach speed, BR 941S values of $\left(\frac{\partial\theta}{\partial V}\right)_\gamma$ appear to be fairly close to the -.6 deg/kt proposed by NASA CR-114454. However, this apparent agreement is difficult to justify. As pointed out in that report, the value of -.6 was taken from Paragraph 3.2.1.1 of Reference 6. That portion of Reference 6 deals only with requirements for V/STOL aircraft at hover or low speed (less than 35 kt). The limit of -.6 was established to avoid the necessity for large pitch changes to make the vehicle translate or to hover in a steady wind. Application of that limit to a STOL aircraft seems questionable.

The last criterion in the table is on the effective thrust angle. Thrust angle has been shown by several researchers to be an important parameter, e.g., Reference 7. The data from the BR 941S simulation are of little value in establishing limits as the thrust angles were all close to 80 deg.

The problem of establishing criteria for flight path control dynamics is a very serious one. Some of the results from the pilot/vehicle analyses presented in Volume II can be used to speculate on possible criteria forms. The analytical results showed a good correlation with the simulator results when the analysis considered only the simplest case of the pilot controlling flight path deviations with the throttle and not regulating airspeed. This limiting case can show the importance of several key factors.

The major parameters are the two zeros of the pitch to elevator transfer function, the flight path zero with attitude constrained, and the engine lags. The pitch zeros are important because they become the system poles when pitch attitude is constrained by either the pilot or a pitch SAS. One of the most important effects of speed changes in the BR 941S is the change in heave damping which, in turn, significantly affects the pitch zeros. At higher speeds there are two, well separated, real zeros which represent two different dynamic modes with attitude constrained. The higher frequency mode is primarily a plunging or a flight path mode. The lower frequency mode is primarily an airspeed mode with little flight path change. With two distinct modes it is possible to separately control flight path and airspeed. At lower speeds the attitude zeros become coupled and, as speed is reduced, the damping of this mode is reduced. Now there is one oscillatory mode which involves both flight path and airspeed changes. Consequently, it is impossible to change flight path or airspeed without affecting the other one.

The flight path zero* is a strong function of the effective thrust vector angle. It has a very large effect on the flight path control characteristics, as has been demonstrated in Ref. 7. It has recently been shown in Ref. 8 that when the effective thrust vector angle is large this zero can be approximated by the following expression:

$$\frac{1}{T_{\gamma_T}} \doteq -g\left(\frac{\partial\gamma}{\partial V}\right)_\alpha = \frac{-g}{\left(\frac{\partial V}{\partial\gamma}\right)_\theta + \left(\frac{\partial V}{\partial\theta}\right)_\gamma}$$

---

* This is the zero of the flight path/throttle, γ/δ_T, transfer function with pitch attitude constrained and is equal to the zero of the γ/δ_T, θ/δ_e coupling numerator.

The analogy with the zero for elevator inputs is very strong. It seems that limitations on this zero might be imposed by a criterion based on slopes from γ - V curves.

If the throttle is being used to control flight path, obviously excessive engine lags can have detrimental effects. Restrictions could be imposed on the thrust lags per se or included in an overall requirement on the delays between throttle input and some flight path response. The latter is the preferred approach, as it is the total lag from cockpit control motion to aircraft response that is of concern to the pilot.

While it is possible to analyze a given set of dynamics to fairly well evaluate the flight path control problem, it is quite another problem to establish criteria to insure adequate characteristics. One would also like the criteria to be easily evaluated in flight. These two desires (validity and ease of flight verification) seem to generally be in opposition and it is difficult to speculate at this time as to the ultimate form of good criteria for flight path control dynamics.

There are at least three possibilities. One would be direct limitations on the pitch and flight path zeros discussed earlier, as well as on thrust lags. A second would involve limitations on the flight path to throttle frequency response with the attitude constrained. The third would be restrictions on the time responses to throttle inputs, for example, the types of parameters proposed in Ref. 9. The ordering in the above list is from parameters directly applicable to pilot/vehicle analysis to parameters less so. At the same time, the parameters go from difficult to measure in flight to relatively easy. Whatever criteria ultimately evolve, the simulation results presented in this report can provide one check of their validity.

D. GO-AROUND

Go-around requirements include a minimum climb capability and limits on the configuration changes allowed. For example, the Ref. 10 (commonly known as Part XX) requirements are: gradient > .032 and rate of climb > 250 fpm for landing configuration AEO; gradient > .027 and rate of climb > 225 fpm for approach configuration* OEI. For comparison, the go-around performance of the BR 941S for several conditions is given in Table III-4.

The table shows that the BR 941S does not have reasonable climb performance in the landing configuration (95 deg flaps). Retracting the flaps to 70 deg increases the climb performance to reasonable levels, although the transparency-in gradients are near the obstacle clearance plane proposed in Ref. 11 (14:1 slope or .071 gradient). For this aircraft, at least one flap change must be permitted for go-arounds. The change from 95 to 70 deg was no problem for the pilots as they could do it with a switch mounted on the throttle lever.

It seems reasonable to allow at least one configuration change for go-arounds, at least if the change is as easy to accomplish as it was for the BR 941S. It should also be noted that in the simulation the pilots made a second flap change. After establishing a positive rate of climb they raised the flaps to 45 deg using a conventional flap lever. This second change did not present any problems either.

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* Approach configuration limits given are those for a four-engine aircraft.

TABLE III-4

BR 941S GO-AROUND PERFORMANCE

Climb Gradient, Rate of Climb (fpm)

Engine Status	Flap (deg)	Transparency In		Transparency Out	
		60 kt	65 kt	60 kt	65 kt
AEO	95	-.009, -55	0 , 0	.084, 509	.096, 629
OEI	95	-.065, -394	-.059, -388	.012, 73	.021, 138
AEO	70	.149, 899	.140, 913	.163, 978	.156, 1015
OEI	70	.075, 455	.070, 460	.089, 539	.086, 564

REFERENCES

1. Airworthiness Standards: Transport Category Airplanes, Federal Aviation Regulations, Volume III, Part 25.

2. Special Conditions Attached to FAR Part 25 for Certification of the Breguet 941, October 27, 1969.

3. Innis, Robert C., Curt A. Holzhauser, Hervey C. Quigley, Airworthiness Considerations for STOL Aircraft, NASA TN D-5594, January 1970.

4. Allison, R. L., M. Mack, P. C. Rumsey, Design Evaluation Criteria for Commercial STOL Transports, NASA CR-114454, June 1972.

5. V/STOL Handling - Qualities Criteria, AGARD-R-577-70, December 1970.

6. Military Specification - Flying Qualities of Piloted V/STOL Aircraft, MIL-F-83300, 31 December 1970.

7. Craig, S. J., I. L. Ashkenas, R. K. Heffley, Pilot Background and Vehicle Parameters Governing Control Technique in STOL Approach Situations, FAA-RD-72-69, June 1972.

8. Stapleford, Robert L., Some Connections Between Performance and Flight Path Control Characteristics, STI TR 1035-1, August 1973.

9. Franklin, James A., Robert C. Innis, Pitch Attitude, Flight Path, and Airspeed Control During Approach and Landing of a Powered Lift STOL Aircraft, NASA TM X-62,203, December 1972.

10. Tentative Airworthiness Standards for Powered Lift Transport Category Aircraft, Federal Aviation Administration, August 1970.

11. Planning and Design Criteria for Metropolitan STOL Ports, FAA AC 150, November 1970.

12. Section P, Provisional Airworthiness Requirements for Civil Powered-Lift Aircraft, Civil Aviation Authority, United Kingdom, October 1972.