The rejected takeoff (RTO), as presented in the Operations Manual, is a comprehensive procedure to accomplish any rejected takeoff. This procedure is based on the worst case situation: i.e.; field length limited with an engine failure just prior to \( V_1 \). Clearly there are legitimate reasons, other than an engine failure, for rejecting a takeoff, especially at lower speeds. As the speed approaches \( V_1 \), however, the reasons to reject become limited to an engine failure/ fire or a situation judged by the Captain to constitute an emergency that could endanger the safety of the aircraft if the takeoff were continued. The Captain is responsible by FAR for the safety of the passengers, crew, and airplane and may exercise decisions and actions as required up to the provisions of emergency authority (FAR 121.557 or .559, Atch 1) if deemed necessary.

The following information may be used to enhance simulator prebriefings. The pilot’s “mindset” concerning what \( V_1 \) actually represents in the Go/No Go decision process is of primary importance.

1. Basic Education Factors:

A. Definitions.

Certain definitions are needed to explain the concepts discussed in the training aid. Some of the definitions used are taken from the FAR’s or other references, and some are defined in the training aid. Where appropriate, the training aid definition has been written from the point of view of the pilot and may clarify or expand on the regulatory definition to the extent necessary to assure appropriate flight crew action.

1) \( V_1 \). FAR definition:

\( V_1 \) means takeoff decision speed (formerly denoted as critical engine failure speed).

2) \( V_1 \). Training Aid Definition:

The speed selected for each takeoff, based upon approved performance data and specified conditions, which represents:

a. The maximum speed by which a rejected takeoff must be initiated to assure that a safe stop can be completed within the remaining runway or runway and stopway, and

b. The minimum speed which assures that a takeoff can be safely completed within the remaining runway, or runway and clearway, after failure of the most critical engine at a designated speed, and

c. The single speed which permits a successful stop or continued takeoff when operating at the minimum allowable field length for a particular weight.

Note 1: Safe completion of the takeoff includes both attainment of the designated screen height at the end of the runway or clearway, and safe obstacle clearance along the designated takeoff flight path.

Note 2: Reference performance conditions for determining \( V_1 \) may not necessarily account for all variables possibly affecting a takeoff, such as runway surface friction, failures other than a critical engine, etc.

3) Minimum \( V_1 \): The minimum permissible \( V_1 \) speed for the reference conditions from which the takeoff can be safely completed from a given runway or runway and clearway, after the critical engine has failed at the designated speed.
4) Maximum V₁: The maximum permissible V₁ speed for the reference conditions at which a rejected takeoff can be initiated and the airplane stopped within the remaining runway or runway and stopway.

5) Reduced V₁: A V₁ less than the maximum V₁ or the normal V₁ but more than the minimum V₁ selected to reduce the RTO stopping distance required.

Note: Wet or slippery V₁ speeds are reduced V₁'s used to adjust the RTO stopping distance for the degraded stopping capability associated with these conditions. Reducing V₁ for a dry runway takeoff, when conditions permit, will provide additional stopping margin in the event of an RTO. In either case, the reduced V₁ must be determined so as to also assure the continued takeoff criteria are met (i.e. screen height, obstacle clearance and V.mcg).

6) Decision time:

The time between failure of the critical engine and/or any other event which requires the pilot to make a Go/No Go decision, and V₁.

After V₁, there is no decision time allowance provided in the airplane performance data. To stop within the predetermined accelerate-stop distance, stopping action must begin no later than V₁.

7) V₉: Rotation speed

8) VLOF: Lift off speed

9) V₂: Minimum takeoff safety speed

10) Screen Height: The height of an imaginary screen which the airplane would just clear at the end of the runway or runway and clearway in an unbanked attitude with the landing gear extended.

11) Takeoff Distance: The horizontal distance from the start of the takeoff to the point where the airplane reaches the prescribed screen height above the surface with a critical engine having failed at the designated speed or, 115% of the horizontal distance from the start of takeoff to the point where the airplane reaches the prescribed screen height above the surface with all engines operating.

12) Accelerate-Go Distance: The horizontal distance from the start of the takeoff to the point where the airplane reaches the prescribed screen height above the takeoff surface with the critical engine having failed at the designated speed.

13) Accelerate-Stop Distance: The horizontal distance from the start of the takeoff to the point where the airplane is stopped on the runway or runway and stopway, when the stop is initiated at V₁ and completed using the approved procedures and specified conditions.

14) Balanced Field length: The runway length (or runway plus clearway and/or stopway) where, for the takeoff weight, the engine-out accelerate-go distance equals the accelerate-stop distance. In more detail, it exists when the airplane performance is such that for an engine failure one second prior to V₁, the distance required to accelerate on the remaining engine(s), takeoff, climb to the prescribed screen height and reach V₂ speed, is equal to the distance required to initiate the reject at V₁ and stop. When this distance is equal to the runway length this is termed a "Balanced Field Length". The weight associated with this is termed the "Balanced Field Weight Limit". This is the speed typically given to flight crews.

15) Critical Field length: The minimum runway length (or runway plus clearway and/or stopway) required for a specific takeoff weight. This distance may be the longer of the balanced field length, 115% of the all engine takeoff distance, or established by other limitations such as maintaining V₁ to be less than or equal to V₉.

16) Derated Takeoff Thrust: A takeoff thrust level less than the maximum takeoff thrust approved for an airplane/engine for which a separate and specific set of data which complies with all of the
requirements of part 25 of the FAR's exists. When operating with a derated takeoff thrust, the thrust setting parameter used to establish thrust for takeoff is presented in the AFM and is considered an operating limit for that takeoff.

17) Reduced Takeoff Thrust: A takeoff thrust level less than the maximum (or derated) takeoff thrust. The takeoff performance and thrust settings are established by approved simple methods, such as adjustments or corrections to the takeoff performance and thrust settings defined for the maximum thrust (or derated) performance and thrust settings. When operating with a reduced takeoff thrust, the thrust setting parameter used to establish thrust for takeoff is not considered an operating limit; The thrust may be restored to the maximum (or derate) level as appropriate for the conditions of the flight at any time during the takeoff.

18) Clearway: A cleared area beyond the end of the runway, not less than 500 feet wide, centrally located about the extended centerline of the runway, that contains no obstructions and under the control of the airport authorities.

19) Stopway: An area beyond the end of the runway, at least as wide as the runway and centered along the extended centerline of the runway, able to support the airplane during a rejected takeoff without causing structural damage to the airplane, and designated by the authorities for use in decelerating the airplane during a rejected takeoff.

20) Rejected Takeoff: A takeoff that is discontinued after takeoff thrust is set and initiation of the takeoff roll has begun.

B. Reasons to reject.

Reasons to reject at low speed: System failure(s), unusual noise or vibration, tire failure, abnormally slow acceleration, engine failure, engine fire, unsafe takeoff configuration warning or the aircraft is unsafe or unable to fly.

Reasons to reject at high speed: Engine failure/fire, aircraft unsafe or unable to fly.

C. Flight Manual Margins.

To stop within the precomputed accelerate-stop distance, the first stopping action must begin by V₁. The RTO procedure must be executed accurately and expeditiously. Doing the procedure quickly and using maximum available reverse thrust give additional stopping margin.

II. Practical

A. Guidelines.

The following practical guidelines will be used in the instruction and education of pilots concerning a Go/No Go decision during takeoff:


2) A thorough understanding of the definitions/factors governing V₁ speeds and their effects on the reject process as outlined in Section I.

3) Captain’s responsibilities:

- Make all Go/No Go decisions.
- Exercise emergency authority as required.
- Ensure a departure briefing including a comprehensive takeoff plan based on gross weight, runway length, field conditions, weather, and any other factors that may affect a particular takeoff as it relates to a Go/No Go decision is made.
- Know airplane’s performance capabilities.

4) Rejected takeoffs can have an operational range from a low speed situation to a high speed balanced field length condition. The primary training goal is to recognize the variables that may affect the decision and to become proficient in the high risk, critical end of the reject scenario.

- Low speed rejected takeoffs - characterized by speeds of approximately 80 knots or less. Use normal Operations Manual reject procedures but may require less than maximum braking during deceleration to safely stop.
b. High speed/field length limited rejected takeoffs - reject decision time influenced by systematically disregarding system malfunctions up to a point approaching $V_1$. At this point, a decision to stop is recommended only for an engine failure or a malfunction where there is doubt that the aircraft will fly safely. This requires the use of operations manual reject procedures with maximum braking and deceleration techniques.

5) Because $V_1$ marks the end of the Go/No Go decision time, the FNF must complete the $V_1$ call by $V_1$ in a clear, crisp manner.

6) Discuss:

a. Tower communications, including the request for fire fighting equipment if required
b. Non-normal procedure
c. Passenger notification/evacuation
d. Brake cooling charts
e. Log book write-up
f. Clearing the runway/advisability of returning to the gate

III. Syllabus Rejected Takeoffs

The following discussion refers to Appendix 3-D which contains example simulator exercises appropriate for the specific airplane model of interest. These simulator exercises should be modified for use by each operator. The examples given are illustrative in nature and are not designed to be used by any specific operator.

During the first lesson in which RTO's are introduced to a crew, it is suggested that Exercise 1 be used to develop crew proficiency in the RTO.

More challenging RTO's should be introduced in a lesson after engine-out proficiency is attained. It is suggested that Exercises 2 through 6 be presented one after another, so the crew can compare stopping performance. Exercise 5 is only for operators who actually do make wet runway corrections to takeoff data.

In the lessons that follow this lesson, additional exercises such as a blown tire or an indicator failure/cockpit alert or advisory light can be introduced during takeoffs in which there is not a conflicting teaching point in order to enhance decision making.

Normally, the simulator lesson prior to the evaluation should include a representative sample of the type of RTO's given on evaluation flights, again emphasizing good decision making and proper procedure execution. The content of the evaluation flight is normally dictated by the regulatory agency.
§ 121.557 Emergencies: domestic and flag air carriers

(a) In an emergency situation that requires immediate decision and action the pilot in command may take any action that he considers necessary under the circumstances. In such a case he may deviate from prescribed operations procedures and methods, weather minimums, and this chapter, to the extent required in the interests of safety.

(b) In an emergency situation arising during flight that requires immediate decision and action by an aircraft dispatcher, and that is known to him, the aircraft dispatcher shall advise the pilot in command of the emergency, shall ascertain the decision of the pilot in command, and shall have the decision recorded. If the aircraft dispatcher cannot communicate with the pilot, he shall declare an emergency and take any action that he considers necessary under the circumstances.

(c) Whenever emergency authority is exercised, the pilot in command or the appropriate management personnel shall keep the appropriate management personnel shall keep the appropriate ground radio station fully informed of the progress of the flight. The person declaring the emergency shall send a written report of any deviation through the air carrier's or commercial operator's director of operations, to the Administrator within 10 days after the flight is completed or, in the case of operations outside the United States, upon return to the home base.

§ 121.561 Reporting potentially hazardous meteorological conditions and irregularities of ground and navigation facilities.

(a) Whenever he encounters a meteorological condition or an irregularity in a ground or navigational facility, in flight, the knowledge of which he considers essential to the safety of other flights, the pilot in command shall notify an appropriate ground station as soon as practicable.

(b) The ground radio station that is notified under paragraph (a) of this section shall report the information to the agency directly responsible for operating the facility.

§ 121.563 Reporting mechanical irregularities

The pilot in command shall ensure that all mechanical irregularities occurring during flight time are entered in the maintenance log of the airplane at the end of that flight time. Before each flight the pilot in command shall ascertain the status of each irregularity entered in the log at the end of the preceding flight.
Pilot Guide to Takeoff Safety Questions

Included in the following appendix are questions designed to test a pilot's knowledge of the material contained in the Pilot Guide to Takeoff Safety. The questions are all multiple choice.

The first part of this appendix is the Student Examination. Instructions for answering the questions are provided.

The second part of this appendix is the Instructor Examination Guide. This part contains the questions in the Student Examination, the correct answers to each question and the section in the Pilot Guide to Takeoff Safety where the correct answer may be found.

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Student Examination

Instructions

These questions are based on the material in the Pilot Guide to Takeoff Safety. The answers to each question can be found in that document. The questions are all multiple choice. Circle the one answer to each question which is most correct.

Questions

1) Statistically, 1 RTO occurs for every _______ takeoffs.
   
   A) 1000  
   B) 3000  
   C) 7000  
   D) 10,000 

2) Most RTO's are initiated at speeds ________.
   
   A) of 80 knots or less  
   B) between 80 and 120 knots  
   C) near V1 (within 10 knots)  
   D) above V1  

3) Every pilot must be prepared to make the correct Go/No Go decision ________.
   
   A) in the event of an engine failure or fire  
   B) if it is certain the airplane is unsafe or unable to fly  
   C) either A or B  
   D) on every takeoff  

4) Most RTO's are ________.
   
   A) engine-related events  
   B) wheel/tire events  
   C) non-engine events  

5) The majority of past RTO overrun accidents/incidents were initiated at ________.
   
   A) speeds below V1  
   B) speeds above V1
6) Of past RTO overrun accidents and serious incidents about _________ of the RTO's were initiated because of engine failures or indication warnings.
   A) one fourth  
   B) half  
   C) three fourths  
   D) all

7) Full takeoff power was available during approximately _________ of past RTO accidents.
   A) 25%  
   B) 50%  
   C) 75%  
   D) 100%

8) In a review of past accident records of revenue flights involving Go/No Go decisions, of the cases where a GO decision was made, _________ of the airplanes failed to make a safe landing.
   A) virtually none  
   B) 10%  
   C) 25%  
   D) More than 75%

9) In the majority of past RTO overrun accidents and serious incidents, if the takeoff had been continued, _________.
   A) an uneventful landing would probably have resulted  
   B) the airplane probably would have crashed

10) In a situation where the gross weight is limited by field length, ______ of the runway is typically left from $V_1$ to stop the airplane.
   A) 60%  
   B) 50%  
   C) 40%
11) On a dry runway, if an engine fails approximately 1 second before $V_1$, the FAR criteria requires the airplane to reach a minimum height of _________ by the end of the runway.

   A) 15 feet  
   B) 35 feet  
   C) 50 feet  

12) $V_1$ is ____________

   A) the latest point during a takeoff in which the gross weight is limited by the field length, where a stop can be initiated and the airplane stopped by the end of the runway  
   B) the earliest point during takeoff in which the gross weight is limited by the field length, at which an engine out takeoff can be continued and the airplane reach a height of 35 feet at the end of the runway  
   C) an action speed  
   D) all of the above

13) In a situation in which the gross weight is limited by field length, the Go/No Go decision must be made ____________.

   A) before reaching $V_1$  
   B) after reaching $V_1$

14) During a takeoff in which the gross weight is limited by field length, if an engine fails approximately 1 second prior to $V_1$ and the decision is made to reject the takeoff, according to the AFM the airplane will come to a stop ____________.

   A) at the very end of the runway  
   B) well before the end of the runway  
   C) beyond the end of the runway  
   D) before the end of the runway, only if aerodynamic braking is used

15) In a Balanced Field takeoff, ________________

   A) the runway required to accelerate to $V_1$ exactly equals the runway length required to decelerate from $V_1$ to a stop  
   B) the runway length required to accelerate, lose an engine approximately one second before $V_1$ and either bring the airplane to a stop, or continue the takeoff and reach 35 feet above the runway at $V_2$ is exactly the same  
   C) takeoff roll exactly equals landing roll if an emergency return is required  
   D) the cost of the passengers tickets exactly equals the salaries of the crew
16) Actual flight test accelerate-stop distances are increased by several hundred feet in the AFM_______________________________.

A) to allow the crew more time to make the decision to stop or not to stop  
B) because reverse thrust was not used in the flight tests  
C) to allow for unknown variables such as runway condition or contamination and pilot technique  
D) to allow the line crew more time to execute the stopping action

17) In a situation in which the gross weight is limited by field length, if an engine fails 2 seconds before \( V_1 \), the airplane will be able to cross the end of the runway at a height of _____________.

A) 2 - 10 feet  
B) 15 - 30 feet  
C) 35 feet or more

18) During a takeoff in which the gross weight is limited by field length, if an engine fails two seconds before \( V_1 \) and the decision is made to continue the takeoff, the airplane will _____________.

A) not reach rotate speed before the end of the runway  
B) reach \( V_2 \) at less than 35 feet above the end of the runway  
C) reach takeoff speed at the end of the runway

19) When an RTO is necessary on a wet or slippery runway, the pilot should _____________.

A) pump the brakes to minimize excessive anti skid cycling  
B) avoid large puddles  
C) wait until near the end of the runway to apply full braking  
D) bring the airplane to a complete stop once an RTO has been initiated

20) Selecting a larger flap setting for takeoff will result in _______________.

A) a longer takeoff roll  
B) a lower \( V_1 \) speed  
C) improved climb performance  
D) decreased airplane drag
21) The use of engine bleed air for air conditioning/pressurization ________.
   A) has no effect on takeoff performance
   B) reduces takeoff performance
   C) increases the thrust the engine provides

22) The pilot can minimize the probability of a tire failure during takeoff by ________.
   A) taxing quickly to avoid excessive delays getting to the runway
   B) using low taxi speeds and minimum braking whenever possible
   C) ignoring the time and weight limits of the Max Quick Turnaround Weight Charts
   D) maintain steady pressure on the brakes throughout the taxi to avoid excessive speed

23) In the event of a tire failure during takeoff, ________.
   A) the crew should always reject the takeoff because of the possibility of other associated problems, such as hydraulic system failures or tire pieces ingested into the engines
   B) the crew should always continue the takeoff so that the entire runway can be used for stopping on the subsequent landing
   C) the crew's indication is always a loud bang and a significant pulling to one side
   D) the stopping capability of the airplane may be significantly degraded

24) Delaying or not raising the speedbrake during an RTO ________.
   A) will have no effect on stopping distance
   B) can be compensated for by proper aerodynamic braking technique
   C) can be compensated for by using reverse thrust
   D) will result in a longer stopping distance

25) On today's high bypass ratio engines, reverse thrust ________.
   A) greater than idle reverse should not be used in order to minimize stopping distance required
   B) is less effective at higher speeds
   C) generates a larger percentage of the total airplane deceleration on wet or slippery runways
   D) is extremely effective, particularly on dry runways
26) Use of a clearway for takeoff results in ____________________________.
   A) a lower $V_1$ speed and increased maximum weight
   B) a lower $V_1$ speed and decreased maximum weight
   C) a higher $V_1$ speed and increased maximum weight
   D) a higher $V_1$ speed and decreased maximum weight

27) When using the Assumed Temperature Method for reducing takeoff thrust, ________.
   A) $V_{mcg}$ and $V_{mca}$ are reduced to correspond to the takeoff thrust being used
   B) with an engine failure at the associated $V_1$ speed, a 35 foot height above the end of the runway may not be attainable without increasing thrust to the actual maximum rated thrust
   C) the actual true air speed is lower than it would be if the actual temperature were equal to the assumed temperature
   D) the actual true airspeed is higher than it would be if the actual temperature were equal to the assumed temperature

28) Which of the following is not a correct guideline for crews related to eliminating RTO overrun incidents?
   A) Do not initiate a stop after $V_1$ unless you suspect that a tire has failed or a catastrophic engine failure has occurred.
   B) Don’t change your mind, if you have begun an RTO, stop. If you have passed $V_1$, go, unless the pilot has reason to conclude that the airplane is unsafe or unable to fly.
   C) Both pilots must be sure to position the seat and rudder pedals so that maximum brake pressure can be applied.
   D) Use maximum effort brake application.

29) Minimum takeoff distance can be achieved by ____________________________.
   A) sacrificing some runway line-up distance, so that thrust can be advanced for takeoff during the turn onto the runway
   B) minimizing runway line-up distance by a sharper turn to line-up and setting takeoff power prior to releasing the brakes
   C) slowly advancing thrust while rolling down the runway before engaging the autothrottle
   D) line-up distance and setting takeoff thrust have minimal impact on takeoff distance
30) If you use manual braking for a rejected takeoff, ________________.
   A) pump the brakes to minimize skidding
   B) maintain full brake pedal force
   C) release braking when reverse thrust is applied

31) During a rejected takeoff from \( V_1 \), a good technique is to use maximum braking
    and full reverse thrust ________________________.
   A) until the airplane comes to a complete stop
   B) until below 60 knots, then decrease reverse thrust to reduce the likelihood of
      compressor stalls
   C) until the crew judges the remaining runway is sufficient for stopping with
      less than maximum effort
   D) at high speeds, reducing braking at lower speeds to prevent fuse plugs from
      melting, since reverse thrust will further decrease stopping distance

32) For an RTO with anti-skid inoperative __________________________.
   A) the RTO procedure is unchanged
   B) brakes should be applied immediately after reducing power to idle
   C) brakes should be applied after the speedbrake is raised
   D) full brake pressure should only be applied at high speeds

33) On the average, RTO's performed with RTO autobrakes armed result in ___________
    runway distance remaining after a stop than do RTO's performed using manual braking
    only.
   A) more
   B) less
   C) the same

34) The Go/No Go decision must be made by ________________.
   A) the chief pilot and training staff
   B) the crew flying
   C) airline policies and guidelines
   D) developing correct regulations
Instructor Examination Guide

Instructions

This guide contains questions based on the material in the Pilot Guide to Takeoff Safety. The answers to each question can be found in that document. The questions are all multiple choice. There is one answer to each question which is most correct.

The correct answer is listed after each question, along with the section in the Pilot Guide to Takeoff Safety where the correct answer may be found.

Questions

1) Statistically, 1 RTO occurs for every ___________ takeoffs.
   A) 1000
   B) 3000
   C) 7000
   D) 10,000

   Answer: B (Section 2.2.1)

2) Most RTO's are initiated at speeds ___________.
   A) of 80 knots or less
   B) between 80 and 120 knots
   C) near V\textsubscript{T} (within 10 knots)
   D) above V\textsubscript{T}

   Answer: A (Section 2.2.1)

3) Every pilot must be prepared to make the correct Go/No Go decision ___________.
   A) in the event of an engine failure or fire
   B) if it is certain the airplane is unsafe or unable to fly
   C) either A or B
   D) on every takeoff

   Answer: D (Section 2.2.1)

4) Most RTO's are ___________.
   A) engine-related events
   B) wheel/tire events
   C) non-engine events

   Answer: C (Section 2.2.4)
5) The majority of past RTO overrun accidents/incidents are initiated at _______.
   A) speeds below $V_1$
   B) speeds above $V_1$
   Answer: B (Section 2.2.4)

6) Of past RTO overrun accidents and serious incidents about ________ of the RTO's were initiated because of engine failures or indication warnings.
   A) one fourth
   B) half
   C) three fourths
   D) all
   Answer: A (Section 2.2.4)

7) Full takeoff power was available during approximately ________ of past RTO accidents.
   A) 25%
   B) 50%
   C) 75%
   D) 100%
   Answer: C (Section 2.2.4, 2.3.3)

8) In a review of past accident records of revenue flights involving Go/No Go decisions, of the cases where a GO decision was made, ________ of the airplanes failed to make a safe landing.
   A) virtually none
   B) 10%
   C) 25%
   D) More than 75%
   Answer: A (Section 2.2.4)

9) In the majority of past RTO overrun accidents and serious incidents, if the takeoff had been continued, ________.
   A) an uneventful landing would probably have resulted
   B) the airplane probably would have crashed
   Answer: A (Section 2.2.5)
10) In a situation where the gross weight is limited by field length, _______ of the runway is typically left from $V_1$ to stop the airplane.

A) 60%
B) 50%
C) 40%

Answer: C (Section 2.3.1.1)

11) On a dry runway, if an engine fails approximately 1 second before $V_1$, the FAR criteria requires the airplane to reach a minimum height of _______ by the end of the runway.

A) 15 feet
B) 35 feet
C) 50 feet

Answer: B (Section 2.3.1.1)

12) $V_1$ is ____________________________.

A) the latest point during a takeoff in which the gross weight is limited by the field length, where a stop can be initiated and the airplane stopped by the end of the runway
B) the earliest point during takeoff in which the gross weight is limited by the field length, at which an engine out takeoff can be continued and the airplane reach a height of 35 feet at the end of the runway
C) an action speed
D) all of the above

Answer: D (Section 2.3.1.2)

13) In a situation in which the gross weight is limited by field length, the Go/No Go decision must be made _________.

A) before reaching $V_1$
B) after reaching $V_1$

Answer: A (Section 2.3.1.2)

14) During a takeoff in which the gross weight is limited by field length, if an engine fails approximately 1 second prior to $V_1$ and the decision is made to reject the takeoff, according to the AFM the airplane will come to a stop ____________________.

A) at the very end of the runway
B) well before the end of the runway
C) beyond the end of the runway
D) before the end of the runway, only if aerodynamic braking is used

Answer: A (Section 2.3.1.2)
15) In a Balanced Field takeoff:

- A) the runway required to accelerate to $V_1$ exactly equals the runway length required to decelerate from $V_1$ to a stop
- B) the runway length required to accelerate, lose an engine approximately one second before $V_1$ and either bring the airplane to a stop, or continue the takeoff and reach 35 feet above the runway at $V_2$ is exactly the same
- C) takeoff roll exactly equals landing roll if an emergency return is required
- D) the cost of the passengers' tickets exactly equals the salaries of the crew

Answer: B (Section 2.3.1.3)

16) Actual flight test accelerate-stop distances are increased by several hundred feet in the AFM:

- A) to allow the crew more time to make the decision to stop or not to stop
- B) because reverse thrust was not used in the flight tests
- C) to allow for unknown variables such as runway condition or contamination and pilot technique
- D) to allow the line crew more time to execute the stopping action

Answer: D (Section 2.3.2.2)

17) In a situation in which the gross weight is limited by field length, if an engine fails 2 seconds before $V_1$, the airplane will be able to cross the end of the runway at a height of:

- A) 2 - 10 feet
- B) 15 - 30 feet
- C) 35 feet or more

Answer: B (Section 2.3.3.2)

18) During a takeoff in which the gross weight is limited by field length, if an engine fails two seconds before $V_1$ and the decision is made to continue the takeoff, the airplane will:

- A) not reach rotate speed before the end of the runway
- B) reach $V_2$ at less than 35 feet above the end of the runway
- C) reach takeoff speed at the end of the runway

Answer: B (Section 2.3.3.2)
19) When an RTO is necessary on a wet or slippery runway, the pilot should ________.

A) pump the brakes to minimize excessive anti skid cycling
B) avoid large puddles
C) wait until near the end of the runway to apply full braking
D) bring the airplane to a complete stop once an RTO has been initiated

Answer: D (Section 2.3.5.1.2)

20) Selecting a larger flap setting for takeoff will result in ________.

A) a longer takeoff roll
B) a lower V1 speed
C) improved climb performance
D) decreased airplane drag

Answer: B (Section 2.3.5.3.1)

21) The use of engine bleed air for air conditioning/pressurization ________.

A) has no effect on takeoff performance
B) reduces takeoff performance
C) increases the thrust the engine provides

Answer: B (Section 2.3.5.3.2)

22) The pilot can minimize the probability of a tire failure during takeoff by ________.

A) taxing quickly to avoid excessive delays getting to the runway
B) using low taxi speeds and minimum braking whenever possible
C) ignoring the time and weight limits of the Max Quick Turnaround Weight Charts
D) maintaining steady pressure on the brakes throughout the taxi to avoid excessive speed

Answer: B (Section 2.3.5.3.4)

23) In the event of a tire failure during takeoff, ________.

A) the crew should always reject the takeoff because of the possibility of other associated problems, such as hydraulic system failures or tire pieces ingested into the engines
B) the crew should always continue the takeoff so that the entire runway can be used for stopping on the subsequent landing
C) the crew’s indication is always a loud bang and a significant pulling to one side
D) the stopping capability of the airplane may be significantly degraded

Answer: D (Section 2.3.5.3.4)
24) Delaying or not raising the speedbrake during an RTO

A) will have no effect on stopping distance
B) can be compensated for by proper aerodynamic braking technique
C) can be compensated for by using reverse thrust
D) will result in a longer stopping distance

Answer: D (Section 2.3.5.3.7)

25) On today's high bypass ratio engines, reverse thrust

A) greater than idle reverse should not be used in order to minimize stopping distance required
B) is less effective at higher speeds
C) generates a larger percentage of the total airplane deceleration on wet or slippery runways
D) is extremely effective, particularly on dry runways

Answer: C (Section 2.3.5.4)

26) Use of a clearway for takeoff results in

A) a lower $V_1$ speed and increased maximum weight
B) a lower $V_1$ speed and decreased maximum weight
C) a higher $V_1$ speed and increased maximum weight
D) a higher $V_1$ speed and decreased maximum weight

Answer: A (Section 2.3.5.5)

27) When using the Assumed Temperature Method for reducing takeoff thrust, 

A) $V_{MCG}$ and $V_{MCA}$ are reduced to correspond to the takeoff thrust being used with an engine failure at the associated $V_1$ speed, a 35 foot height above the end of the runway may not be attainable without increasing thrust to the actual maximum rated thrust
B) the actual true air speed is lower than it would be if the actual temperature were equal to the assumed temperature
C) the actual true airspeed is higher than it would be if the actual temperature were equal to the assumed temperature
D) the actual true airspeed is higher than it would be if the actual temperature were equal to the assumed temperature

Answer: C (Section 2.3.5.7)
28) Which of the following is not a correct guideline for crews related to eliminating RTO overrun incidents?

A) Do not initiate a stop after \( V_1 \) unless you suspect that a tire has failed or a catastrophic engine failure has occurred.
B) Don’t change your mind, if you have begun an RTO, stop. If you have passed \( V_1 \), go, unless the pilot has reason to conclude that the airplane is unsafe or unable to fly.
C) Both pilots must be sure to position the seat and rudder pedals so that maximum brake pressure can be applied.
D) Use maximum effort brake application.

Answer: A (Section 2.3.6.10)

29) Minimum takeoff distance can be achieved by ____________________________ .

A) sacrificing some runway line-up distance, so that thrust can be advanced for takeoff during the turn onto the runway
B) minimizing runway line-up distance by a sharper turn to line-up and setting takeoff power prior to releasing the brakes
C) slowly advancing thrust while rolling down the runway before engaging the autothrottle
D) line-up distance and setting takeoff thrust have minimal impact on takeoff distance

Answer: B (Section 2.3.6.3)

30) If you use manual braking for a rejected takeoff, ____________________________ .

A) pump the brakes to minimize skidding
B) maintain full brake pedal force
C) release braking when reverse thrust is applied

Answer: B (Section 2.3.6.5)

31) During a rejected takeoff from \( V_1 \), a good technique is to use maximum braking and full reverse thrust ____________________________ .

A) until the airplane comes to a complete stop
B) until below 60 knots, then decrease reverse thrust to reduce the likelihood of compressor stalls
C) until the crew judges the remaining runway is sufficient for stopping with less than maximum effort
D) at high speeds, reducing braking at lower speeds to prevent fuse plugs from melting, since reverse thrust will further decrease stopping distance

Answer: A (Section 2.3.6.5)
32) For an RTO with anti-skid inoperative

A) the RTO procedure is unchanged
B) brakes should be applied immediately after reducing power to idle
C) brakes should be applied after the speedbrake is raised
D) full brake pressure should only be applied at high speeds

Answer: C (Section 2.3.6.6)

33) On the average, RTO's performed with RTO autobrakes armed result in __________ runway distance remaining after a stop than do RTO's performed using manual braking only.

A) more
B) less
C) the same

Answer: A (Section 2.3.6.7)

34) The Go/No Go decision must be made by __________

A) the chief pilot and training staff
B) the crew flying
C) airline policies and guidelines
D) developing correct regulations

Answer: B (Section 2.3.6.10)
Summary of Answers

1. B
2. A
3. D
4. C
5. B
6. A
7. C
8. A
9. A
10. C
11. B
12. D
13. A
14. A
15. B
16. D
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23. D
24. D
25. C
26. A
27. C
28. A
29. B
30. B
31. A
32. C
33. A
34. B
Takeoff Safety Briefing - A paper copy of view foils with descriptive words for each one that can be used for a classroom presentation is contained in this Appendix. The briefing supports a classroom discussion of the Pilot Guide and/or the optional video.
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Takeoff Safety
Rejected Takeoff accidents have been and continue to be a significant contributor to worldwide commercial aviation statistics. We see these accidents and incidents on the evening TV news and read about them in the newspapers. The media’s explanations of the causes of the accidents are seldom correct. The real cause is often a complex series of events.
The National Transportation Safety Board (NTSB) has highlighted two basic reasons for RTO accidents and incidents. In a report on RTO overruns, they stated that historical evidence from two decades of RTO-related accidents "suggests that pilots faced with unusual or unique situations may perform high-speed RTO's unnecessarily or may perform them improperly."
NTSB:

".....Pilots faced with unusual or unique situations may perform high-speed RTO's unnecessarily or may perform them improperly"
From 1959 to 1990, there have been 74 RTO overrun accidents or incidents recorded for the western built jet transport fleet. The rate of the events continues unabated.
Since no comprehensive fleet-wide records are available, it is difficult to identify the total number of rejected takeoffs that have occurred throughout the jet era. However, based on those events that have been documented, the best estimate is that one in 3000 takeoff attempts ends with an RTO. At this rate, there will be nearly 6000 rejected takeoffs during the year 1995. That means that every day in 1995, 16 flight crews will perform an RTO. Statistically, at the rate of one RTO per 3000 takeoffs, a pilot who flies short-haul routes and makes 80 departures per month, might experience one RTO every three years. At the opposite extreme, the long-haul pilot making only eight departures per month may be faced with as few as one RTO every 30 years.
## Takeoffs, RTOs, and Overruns

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<th>Through 1990</th>
<th>Projected 1995</th>
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<td>Takeoffs</td>
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<td>18,000,000</td>
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<td>RTOs (est.)</td>
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<td>RTO Overrun</td>
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<td>Accidents/Incidents</td>
<td></td>
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</table>

- 1 RTO per 3,000 takeoffs
- 1 RTO overrun accident/incident per 3,000,000 takeoffs

Figure 4
The probability that a pilot will ever be required to perform an RTO from high speed is even less. Available data indicates that over 75% of all RTO's are initiated at speeds of 80 knots or less. These RTO's almost never result in an accident. Obviously, low speed RTO's are safer and less demanding than those at high speed. The overrun accidents and incidents that do occur principally stem from the approximately 2% of the RTO's that occur at high speed.
RTO overrun accidents principally come from the 2% of the RTO's that are high speed.
Studies of the previously mentioned 74 accidents/incidents have revealed some interesting statistics:

Fifty-eight percent were initiated at speeds in excess of V1.

Approximately one-third were reported as having occurred on runways that were wet or contaminated with snow or ice.
RTO Initiation Speed

- Greater than $V_1$: 58%
- Not reported: 19%
- Less than/equal to $V_1$: 23%

Runway Condition

- Wet: 24.3%
- Dry: 37.8%
- Ice/snow: 9.5%
- Not reported: 28.4%

Figure 6
Reasons why these unsuccessful RTO's were initiated vary, but approximately one fourth were prompted by engine failures or engine indication warnings.

Although historically training has centered on engine failure as the primary reason to reject, the statistics show that wheel or tire problems have caused just about as many accidents and incidents as have engine events.

Other reasons that rejects occurred were for unsafe configuration, indication or light, crew coordination problems, bird strikes or ATC. Undetermined causes make up the rest. What's important to note here is that the majority of past RTO accidents were not engine failure events. Full takeoff power from all engines was available.
Reasons For Initiating the RTO
(74 Accident/Incident Events)

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<td>Wheel/tire</td>
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<td>Configuration</td>
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<td>Crew coordination</td>
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<td>Bird strike</td>
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<td>ATC</td>
<td>2.4%</td>
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<tr>
<td>Other and Not reported</td>
<td>3.5%</td>
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</tbody>
</table>

Percent of total (74 events)

Engine 24%
Non-Engine* 76%

* Including events "Not reported"
Analysis of the available data suggests that of these RTO accidents and incidents, approximately 80% were avoidable. These potentially avoidable accidents can be divided into three categories. Roughly 9% of the RTO accidents of the past were the result of improper preflight planning. Some of these instances were caused by loading errors and others by incorrect preflight procedures. About 16% of the accidents and incidents could be correlated with incorrect pilot technique or procedures in the stopping effort. Delayed application of the brakes, failure to deploy the speedbrakes, and the failure to make a maximum effort stop until late in the RTO were the chief characteristics of this category. Finally, in approximately 55% of these events, the airplane was capable of continuing the takeoff and landing safely.
80% Were Avoidable

- 55% By continuing the takeoff
- 20% Unavoidable
- 16% By correct stop techniques
- 9% By better preflight planning

Figure 8
What should all these statistics tell a pilot? First, RTO's are not a very common event. This speaks well of equipment reliability and the preparation that goes into operating commercial jet airplanes. Both are no doubt due in large part to the certification and operational standards developed by the aviation community over the thirty plus years of operation. Second, and more important, the infrequency of RTO occurrence may lead to complacency. Every pilot must be prepared to make the correct "Go/No Go" decision on every takeoff.
• RTO's not common
• Infrequency leads to complacency
• Pilot must be prepared

Figure 9
In this presentation we are going to look at what every pilot should know to make better Go/No Go decisions.

We'll look at:

- V1 and the associated takeoff rules
- Transition to the stop configuration
- Takeoff calculations
- Performance factors affecting takeoffs and RTO's such as atmospheric conditions
- Airplane configuration
- and ways to increase RTO safety margins including runway lineup, braking techniques, and crew resource management.
What Every Pilot Should Know:

- $V_1$/Takeoff Rules
- Transitions
- Takeoff Calculations
- Performance Factors
- Configuration
- Increase Safety Margins

Figure 10
The term V1 was used several times in the preceding definitions and discussion. However, studies have shown that many pilots may not clearly understand the definition of V1 or how the choice of V1 can affect their takeoff performance.
Paragraph 25.107 of the FAA Regulations defines the relationship of the takeoff speeds \( V_{EF} \), \( V_1 \), \( V_R \), and \( V_2 \), as published in the Airplane Flight Manual (AFM), to various speeds determined in the certification testing of the airplane. The most important statement within this "official" definition is that \( V_1 \) is determined from..."the pilot's application of the first retarding means during the accelerate-stop tests."
"official definition"

\[ V_1: \text{ application of first retarding means during accelerate \ - \ stop tests.} \]
In the context of a Field Length Limit Weight takeoff, the correct definition of \( V_1 \) consists of two separate concepts:

First, with respect to the "NO-GO" criteria, "\( V_1 \) is the maximum speed at which the rejected takeoff maneuver can be initiated and the airplane stopped within the remaining field length under the conditions and procedures defined in the FAR's."

Second, with respect to Field Length Limit Weight "GO" criteria, \( V_1 \) is also the earliest point from which an engine out takeoff can be continued and the airplane attain a height of 35 feet at the end of the runway.
$V_1$ is Two Concepts

$V_1$-Stop
Max Stop Speed

$V_1$-Go
Min Go Speed

Figure 13
It is important that all pilots understand the takeoff field length/weight limit rules and the margins these rules provide. Misunderstanding the rules and their application to an operational takeoff situation could contribute to an incorrect Go/No Go decision.

First, we need to establish the basic definitions of the takeoff from the viewpoint of the "rules". The "FAR" Takeoff Field Length determined from the Airplane Flight Manual considers the most limiting of each of the following three criteria:

1. The "All Engine Go Distance"

   This is 115% of the actual distance required to accelerate, liftoff and reach a point 35 feet above the runway with all engines operating.
Takeoff Rules

FAR TAKEOFF FIELD LENGTH

All engine
Go Distance (115% actual)

- 35 feet
- $V_2 + 10$ to 25 knots*
  *(Varies with airplane type)

1.15 times the actual distance
2. "Engine-Out Accelerate-Go Distance"

This is the distance required to accelerate with all engines operating to the engine failure speed $V_{EF}$, have one engine fail at least one second before $V_1$, continue the takeoff, liftoff and reach a point 35 feet above the runway surface at $V_2$ speed.
Takeoff Rules

FAR TAKEOFF FIELD LENGTH

One engine inoperative Accelerate-Go Distance

• $V_1$
• $V_R$
• $V_{EF}$
• $V_{LOF}$

1 sec

35 feet

Figure 15
3. "Engine-Out Accelerate-Stop Distance"

This is the distance required to accelerate with all engines operating to the engine failure speed $V_{EF}$ have an engine fail at least one second before $V_1$, recognize the failure, reconfigure for stopping and bring the airplane to a stop using maximum wheel braking with the speedbrakes extended. Reverse thrust is not used in the FAR distance calculation.
Takeoff Rules

FAR TAKEOFF FIELD LENGTH

One engine inoperative
Accelerate-Stop Distance

$V_{EF}$ $V_1$

RTO transition complete

1 sec

Transition

Stop

Figure 16
These three criteria determine the length of runway required to perform a legal takeoff when the weight of the airplane is specified. For a given length runway, if the actual weight of the airplane is equal to the limiting weight, as determined by any of these three criteria, the takeoff is described as being at a Field Length Limit Weight. (It is estimated that on the average, few of the world’s takeoffs are performed at Field Length Limit Weights, but, for some operators, a Field Length Limit Weight takeoff may be the normal situation.)
All-Engine Go

- 35 feet
- \( V_2 + 10 \) to 25 knots

115\% of the actual distance

Engine-out Go

- 35 feet
- \( V_2 \)

\( V_{EF} \), \( V_R \), \( V_{LOF} \)

1 sec

Engine-out Stop

RTO transition complete

\( V_{EF} \)

1 sec

Transition

Figure 17
If a takeoff is rejected, it will take time and distance for the airplane to come to a full stop. First, let’s look at how this time and distance are calculated. Then we will examine how the calculated numbers relate to what the line pilot does during an operational RTO.

From the certification flight testing, the average demonstrated time for the test pilot to apply maximum braking, bring the thrust levers to idle and raise the speedbrakes is about one second.

The regulations acknowledge that the line pilot does not know when or if a reject will occur, so an additional two second distance allowance is added.

This additional distance allowance is provided to give the line pilot adequate distance to get the airplane into the full stopping configuration. It is not there to give additional time for the Go/No Go decision.

"Prompt" accomplishment of the RTO procedure is therefore essential to a successful stop maneuver. Rapid completion of the RTO procedure can represent a stopping distance advantage over the calculated distance of up to 600 feet.
Transition to Stopping Configuration

Decision

Distance Allowance

Speedbrakes Raised

Brakes Applied

Thrust Levers Idle

V1
The objective of the rejected takeoff procedure is to quickly reconfigure the airplane to produce the maximum retarding forces possible under the prevailing conditions. The “correct” procedure for accomplishing a rejected takeoff is contained in company approved training manuals and pilot handbooks. It is important that these procedures be followed in order to achieve the maximum stopping performance.

Basically, full brakes must be applied, the thrust must come to idle, the speedbrakes/spoilers must be raised and maximum reverse thrust consistent with airplane controllability must be applied until the crew is assured that the airplane will stop within the remaining runway.
Under FAA rules, reverse thrust is not used in the flight test demonstration, nor is credit for reverse thrust allowed when calculating takeoff performance. Since reverse thrust is typically available to the line pilot, this can provide an additional stopping margin.

However, the potential margin associated with reverse thrust will not adequately compensate for incomplete or slow procedures.
Reverse Thrust

Figure 20
Another concept that is essential in discussing rejected takeoffs is that of the Balanced Field.

From the standpoint of the "STOP" criteria, the V1 speed establishes the point at which the stop is initiated. Therefore, if a high speed is chosen for V1, the weight of the airplane must be restricted to enable the stop to be completed within the available runway. Conversely, if the V1 speed is low, the airplane can weigh more and still stop on the runway. This result is shown by the line labeled "REJEC TED TAKEOFF".

The trade between V1 and allowable takeoff weight is exactly the opposite for the "GO" case. If a low value of V1 is chosen, the airplane will need to be at a lower weight in order to accelerate to flying speed with one engine failed. If a higher value of V1 is chosen, the airplane weight can be increased because all engines are operating for more of the takeoff run. This result is shown by the line labeled "CONTINUED TAKEOFF" in the slide.
Effect of $V_1$ Speed on Takeoff Weight
(for a fixed runway length)

Figure 21
The intersection of the “REJECTED TAKEOFF” and the “CONTINUED TAKEOFF” lines defines the maximum airplane weight that will satisfy both of the engine-out criteria. If this weight is less than the all-engine Field Length Limit Weight, it then becomes the limiting weight for the takeoff. The takeoff is then described as being at a “Balanced Field Limit Weight” because the “GO” and “STOP” distances are equal. It is characterized by the fact that the airplane will require the entire runway length to reach 35 ft or to stop if an engine fails at VEF and the RTO is initiated at V1.
Figure 22

Balanced V1 Speed

Airplane weight

Increasing

Continued takeoff

Rejected takeoff

Field limit weight

Balanced field

V1 speed

Increasing

Limit V1 speed
Simply put, a "Balanced Field" condition means the engine-out-go distance equals the engine-out-stop distance.

If an engine failure should occur in a typical operational situation where the actual airplane weight is less than the Field Length Limit Weight, the pilot can either continue or reject the takeoff, (depending on when the engine failure occurred relative to \( V_1 \)), and achieve 35 ft or stop before reaching the end of the runway. Although the takeoff was planned using the "balanced \( V_1 \)" there was excess runway available for both the GO and STOP cases.

In either case, the associated \( V_1 \) speed is correctly referred to as a "Balanced \( V_1 \) Speed." However, many pilots assume that they are field length limited because they are using a balanced \( V_1 \) speed, which is obviously not the case.
Balanced Field

Engine-out-go distance = Engine-out-stop distance

But the actual runway available is usually longer than the minimum Balanced Field Length Required
It is important to note that at a Field Length Limit Weight, it typically requires approximately 60% of the runway to accelerate to V1. This means that there may be as little as 40% of the runway available to either STOP or GO from V1.

That means for an 820,000 lb. large jet transport, with V1 equal to 163 knots, on a 12,000 ft. runway, you might have only 4,800 ft. to transition to the stopping configuration and come to a stop,

or, for a typical small jet transport weighing 110,000 lbs, with V1 at 129 knots on a 6,000 ft. runway, you could have only 2,400 ft. to transition and stop.

Prompt accomplishment of the correct procedure is required to successfully accomplish this maneuver. It is within the capabilities of the every line pilot to accomplish this successfully. However, misunderstanding what is meant by "prompt and correct" can have a very detrimental effect on the outcome of any RTO.
Figure 24
Let's now turn our attention to the Go decision. With all engine takeoff power, the airplane will reach a height of approximately 150 ft. over the end of a minimum length runway.
Even if an engine fails one second or less before V1, in a runway limited situation, the FAR "Go" criteria require that the airplane be able to continue to accelerate, rotate, liftoff and reach V2 speed at a point 35 ft. above the end of the runway. The airplane must remain controllable throughout this maneuver and must meet certain minimum climb requirements. These handling characteristics and climb requirements are demonstrated many times throughout the certification flight test program. While a great deal of attention is focused on the engine failure case, it is important to keep in mind that the majority of past "Go/No Go" decisions were made when full takeoff power was available. As you recall, in fully 75% of all RTO accident cases full takeoff power was available.
Consider a one-engine-inoperative case where the engine failure occurs more than the prescribed one second before V1. In this situation, additional distance is needed to accelerate to VR and, as a consequence, the liftoff point will be moved further down the runway. The altitude (or "screen height") achieved at the end of a limit runway length is somewhat reduced depending on how much more than one second before V1 the engine failure occurs.

A typical range of accelerations for jet transports is 3 to 6 knots per second when near V1, so the shaded area shows the range in screen height that might occur if the engine failed "one second early", or two seconds prior to V1. In other words, a "Go" decision made with the engine failure occurring two seconds prior to V1 will result in a screen height of 15 to 30 ft. for a Field Length Limit Weight takeoff.
By far, the most likely takeoff scenario for the line pilot is the case where the actual airplane weight is less than any limit weight. It also is possibly the most easily misunderstood area of takeoff performance since the fact that the airplane is not at a limit weight is about all the flight crew can determine from the data usually available on the flight deck. They know there is more runway in front of them at brake release than the rules require, however, few operators provide any information that will let the crew determine how much excess runway is available, what it means in terms of the V1 speed they are using, or how to best maximize the potential safety margins represented by the excess runway.
There is another case for the one-engine "GO" situation that may occur more often in service. This is the takeoff scheduled at or near the takeoff climb limit weight. The rate of climb and the acceleration capability may appear to be substantially less than the crew anticipates or is familiar with.

The FAR's require that the takeoff climb gradient for the second segment portion of the takeoff (V2 speed, landing gear retracted, takeoff flaps, one-engine inoperative) be at least 2.4%. If V2 is 150 knots, this converts to a rate of climb of 364 ft. per minute. If maneuvering is required, a 15 degree bank will reduce the climb rate by approximately 100 ft. per minute. Crews should be aware of this low rate of climb capability and not be unduly alarmed if they experience it.
Minimum Gradient Required  | Typical rate of climb
---------------------------|------------------------
4 engine 3%                | 520 FPM at $V_2 \sim 170$ knots
3 engine 2.7%              | 440 FPM at $V_2 \sim 160$ knots
2 engine 2.4%              | 360 FPM at $V_2 \sim 150$ knots

15 degree bank turn will reduce these climb rates by approximately 100 FPM

Figure 29
Now let's look at some of the Factors affecting takeoff and RTO performance.

Both the continued and the rejected takeoff performance are directly affected by atmospheric conditions, airplane configuration, runway characteristics, engine thrust available, and by human performance factors.

Changes in these variables can have a significant impact on a successful "Go/No Go" decision, and in many instances, the flight crew has a degree of direct control over these changes.
Factors Affecting Takeoff and RTO Performance

- Atmospheric Conditions
- Airplane Configuration
- Runway Characteristics
- Engine Thrust
- Human Performance
Atmospheric Conditions

The effect of the wind speed and direction on takeoff distance is very straightforward. At any given airspeed, a 10 knot headwind component lowers the ground speed by 10 knots. Since V1, rotation, and liftoff speeds are at lower ground speeds, the required takeoff distance is reduced. The opposite occurs if the wind has a 10 knot tailwind component, producing a 10 knot increase in the ground speed. The required runway length is increased. Typical takeoff data supplied to the flight crew by their operations department will either provide takeoff weight adjustments to be applied to a zero wind limit weight or separate columns of limit weights for specific values of wind component. In either case, it is the responsibility of the flight crew to verify that last minute changes in the tower reported winds are included in their takeoff planning.
Atmospheric Conditions

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<td>104500F</td>
</tr>
<tr>
<td>20</td>
<td>95800F</td>
<td>104700F</td>
</tr>
<tr>
<td>18</td>
<td>96000F</td>
<td>111800F</td>
</tr>
<tr>
<td>16</td>
<td>114200F</td>
<td>115000F</td>
</tr>
</tbody>
</table>

Figure 31
Flaps

The airplane's takeoff field length performance is affected by flap setting in a fairly obvious way. For a given runway length and airplane weight, the takeoff speeds are reduced by selecting a larger flap setting. This is because the lift required for flight is produced at a lower speed with the larger flap deflection. Since the airplane will reach the associated lower V1 speed earlier in the takeoff roll, there will be more runway remaining for a possible stop maneuver. On the "GO" side of the decision, increasing the takeoff flap deflection will increase the airplane drag and the resulting lower climb performance may limit the allowable takeoff weight. However, the takeoff analysis used by the flight crew will advise them if climb or obstacle clearance is a limiting factor with a larger flap setting.

Flap Selection: Most airplanes have two or more takeoff flap settings in order to provide optimal takeoff weight capability for the variety of runway conditions found around the world. Most takeoffs are not at the runway limit weight and crews frequently select a low flap setting for a variety of reasons. Some airlines have elected to use only one setting for simplicity. Regarding RTO safety, the higher the flap setting used, the lower the V1 speed and consequently, the larger the stopping margin for a given runway length should an RTO be attempted. If an airline wishes to increase the number of takeoff flap options provided the crew, they must insure the crews are familiar with the advantages and limitations of one setting versus another.
Flap Selection

Typical large two-engine airplane takeoff performance

<table>
<thead>
<tr>
<th>8,700 FT RUNWAY SEALEVEL 37°C</th>
<th>FLAP SETTING</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
</tr>
<tr>
<td>Runway limit weight, lb (kg)</td>
<td>358,300 (162,494)</td>
</tr>
<tr>
<td>Climb/Obstacle limit weight, lb (kg)</td>
<td>414,100 (187,800)</td>
</tr>
</tbody>
</table>

Figure 32
Engine Bleed Air

Whenever bleed air is extracted from an engine, the amount of thrust the engine generates is reduced. Therefore, the use of engine bleed air for air conditioning and pressurization reduces the airplane's potential takeoff performance for a given set of runway length, temperature and altitude conditions.

When required, using engine and/or wing anti-ice further decreases the performance on some airplane models. This "lost" thrust may be recoverable through increased takeoff EPR or N1 limits as indicated in the operations manual. It depends on engine type and the specific atmospheric conditions.
Engine Bleed Air

- Bleed Air Reduces Thrust
- Air conditioning
- Anti-ice
Missing or Inoperative Equipment

Inoperative or missing equipment can sometimes affect the airplane's acceleration or deceleration capability.

For instance, MEL items such as a deactivated brake may impact both the continued takeoff and RTO performance through degraded braking capability and loss of in-flight braking of the spinning tire.

The flight crew should bear in mind that the performance of the airplane with these types of Configuration Deviation List (CDL) or MEL items in the airplane's maintenance log at dispatch will be within the certified limits. However, it would be prudent for the flight crew to accept final responsibility to assure that the items are accounted for in the dispatch process and to insure that they, as a crew, are prepared to properly execute any revised procedures.
# Configuration Deviation List

## Minimum Equipment List

<table>
<thead>
<tr>
<th>Model Number</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### APPENDIX D

1. Ensure ground is properly grounded and disconnected prior to testing.
2. Disconnect the power by one of the following methods:

### POWER SYSTEM TEST CERTIFIED

- Install proper ground (disconnect equipment to be tested before applying test voltage).
- Ensure all test voltages exceed 0.15V above normal operational levels.
- Disconnect the power system at the point where it is to be tested.
- Ensure all test voltages exceed 0.15V above normal operational levels.
- Disconnect the power system at the point where it is to be tested.
- Ensure all test voltages exceed 0.15V above normal operational levels.

### CHECK REVISED PROCEDURES

Figure 34
Tires and Brakes

Heat buildup can cause a breakdown of the rubber compound, ply separation, and/or rupture of the plies. This damage might not cause immediate tire failure and because it is internal, it may not be obvious by visual inspection. However, the weakened tire is more prone to failure on a subsequent flight. Long taxi distances especially at high speeds and heavy takeoff weights can aggravate this problem and result in a blown tire. While underinflation that causes a rapid heat buildup, is a maintenance issue, flight crews can minimize tire failures due to overheating by using low taxi speeds and minimizing braking whenever possible.

Foreign objects in parking areas, taxiways and runways can cause severe cuts in tires. The abrasion associated with sustained locked or skidding wheels that can be caused by various antiskid or brake problems can grind through the tire cords until the tire is severely weakened or a blow-out occurs. Occasionally, wheel cracks develop which deflate a tire and generate an overloaded condition in the adjacent tire on the same axle. Some of these problems are inevitable, however it cannot be overstressed that proper maintenance and thorough walk around inspections are key factors in eliminating tire failures during the takeoff roll.
Tires and Brakes

If you hear a bang or feel a vibration, how do you know it's a tire failure?

You may only have a second or two to analyze the problem and decide.

The British government Air Accident Investigation Branch (AAIB) has also been investigating tire failure and reject decisions. They reported that pilots often incorrectly interpret a tire failure as an event that threatens the safety of flight. As a result the pilots do an unnecessary reject.

When a tire fails at high speed it's possible that pieces of it can be thrown against the aft body or the flaps, but it's visually not going to affect the ability of the airplane to fly.

Unless a tire failure in the high speed regime has produced damage that puts the ability of the airplane to fly in serious doubt, it is recommended that the takeoff be continued.

Also, there will be more distance available for the stop with a blown tire if the takeoff is continued and the airplane returns to land.
Available Runway

- Takeoff flaps
- Certified performance
- Dry runway
- Field length limit weight

Go

Engine fail

Transition complete

Full stopping

no reverse

Reject

35 ft

Approx 150 ft

Tire fails

Same initial conditions

Go

Transition complete

Reduced braking capability plus all engine reverse

40 to 60 kts

300 to 500 ft overrun

50 ft

- Landing flaps
- Certified performance less blown tire effects
- Takeoff weight minus burnoff and fuel dump (opt)

Stop

Zone

Margin

40 to 60%

60 to 40%

Figure 36
Residual Brake Energy

After a brake application, the energy which the brake has absorbed is released as heat and until this heat is dissipated, the amount of additional energy which the brake can absorb without failure is reduced. Therefore, takeoff planning must consider the effects of residual brake energy (or brake temperature) if the previous landing involved significant braking and/or the airplane turnaround is relatively short. There are two primary sources of information on this subject. The brake temperature limitations and/or cooling charts in the airplane operating manual provide recommended information on temperature limitations and/or cooling times and the procedures necessary to dissipate various amounts of brake energy. In addition, the Maximum Quick Turnaround Weight (MQTW) chart in the AFM is a regulatory requirement that must be followed. This chart shows the gross weight at landing where the energy absorbed by the brakes during the landing could be high enough to cause the wheel fuse plugs to melt and establishes a minimum waiting/cooling time for these cases. The MQTW chart assumes that the previous landing was conducted with maximum braking for the entire stop and did not use reverse thrust, so for many landings where only light braking was used there is substantial conservatism built into the wait requirement.
Residual Brake Energy

Observe Temperature Limitations and/or Minimum Cooling Times

Figure 37
Speedbrake Effect on Wheel Braking Performance

While jet transport pilots generally understand the aerodynamic drag benefit of speedbrakes and the capability of wheel brakes to stop an airplane, the effect of speedbrakes on wheel brake effectiveness during an RTO is not always appreciated. The reason speedbrakes are so critical is their pronounced effect on wing lift. Depending on flap setting, the net wing lift can be reduced, eliminated or reversed to a download by raising the speedbrakes, thereby increasing the vertical load on the wheels which in turn can greatly increase braking capability.

The speedbrakes increase the total drag by 70% to 100%. With the speedbrakes up, the total high speed stopping force that can be generated is 30%-50% more than the stopping capability with the speedbrakes left down (for takeoff flap settings). At low speeds the speedbrakes are less effective and thus have a lesser impact on the stopping performance.
Speedbrake Effects

(Braking force = braking friction x load on tire)*

* Brake torque not limiting

<table>
<thead>
<tr>
<th></th>
<th>Speedbrake position</th>
<th>Difference speedbrake up</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Down</td>
<td>Up</td>
</tr>
<tr>
<td>Drag</td>
<td>8,500 lbs</td>
<td>14,700 lbs</td>
</tr>
<tr>
<td>Lift</td>
<td>52,000 lbs</td>
<td>-1,200</td>
</tr>
<tr>
<td>Net load on wheels</td>
<td>141,600</td>
<td>194,800</td>
</tr>
<tr>
<td>Max. braking force</td>
<td>75,900</td>
<td>98,000</td>
</tr>
<tr>
<td>Max. stopping force (brakes &amp; drag)</td>
<td>84,400</td>
<td>112,700</td>
</tr>
</tbody>
</table>

Figure 38
Speedbrakes

During the RTO certification flight tests, the stopping performance was obtained with prompt deployment of the speedbrakes. Failure to deploy the speedbrakes during an RTO or deploying them late will significantly increase the stopping distance.

On a dry runway, raising the speedbrakes 5 seconds late during the RTO will increase the stopping distance of a typical jet transport by nearly 300 ft. Not raising the speedbrakes will extend the stopping distance by up to 600 feet, or result in an overrun speed of up to 70 knots.
Stopping with brakes
but no speedbrakes

60-70 kts

400 to 600 feet overrun

Figure 39
Speedbrakes vs. Reverse Thrust

Most of the takeoffs performed in the world do not include reverse thrust credit. This is because the rejected takeoff certification testing under FAA rules does not include the use of reverse thrust. As a result, an additional stopping margin is produced by using maximum reverse thrust.

One common misconception among pilots is that the quick use of thrust reversers will offset any delay or even the complete lack of speedbrake deployment during an RTO. This is simply not true. On a dry runway, failure to raise the speedbrakes will result in a substantial overrun, even if maximum engine-out reverse thrust is used.
Speedbrakes vs. Reverse Thrust

Field Length Limit Dry Runway

One Engine-out RTO
Brakes + Speedbrakes + Reverse Thrust

100 to 300 FT Margin

One Engine-out RTO
Brakes + Reverse Thrust

300 to 600 FT Overrun

Figure 40
Runway Surface Condition

The term “runway surface condition” can cover everything from a heavy rain, snow, or slush covered runway with poor stopping potential to a specially constructed runway with a grooved or Porous Friction Coat (PFC) surface which can offer improved braking under adverse conditions. The certification testing is performed on a dry clean runway, therefore, any contamination which reduces the available friction between the tire and the runway surface will increase the required stopping distance for an RTO.
Hydroplaning is a particularly interesting subject since most pilots have either heard of or experienced instances of extremely poor braking action on wet runways during landing. The phenomenon is highly sensitive to speed which makes it an especially important consideration for RTO situations. Since the conditions required to initiate and sustain total dynamic hydroplaning are unusual, it is rarely encountered. When it does occur, however, it virtually eliminates any tire braking or cornering capability. The pilot remedies are fairly simple: apply steady brake pressure and depend on the antiskid system to provide the best possible braking capability and confirm that the speedbrake handle is raised and apply maximum reverse thrust.
There are several areas in which a crew can improve their performance:

Good preflight preparation to include the briefing.

Use of standard callouts during the takeoff.

Take positive preconsidered action if a malfunction occurs.
The Crew

- Briefing
- Callouts
- Positive action
The pretakeoff briefing should be clear and concise including a description of the departure path with emphasis on the anticipated track and altitude restrictions.

Additional briefing items may be required when any elements of the takeoff and departure are different from those routinely used. These may include inclement weather, adverse runway conditions, unique noise abatement requirements, dispatch using minimum equipment list or any other situation where it is necessary to review or define crew responsibilities.

There should be no doubt in any crew member's mind what his or her role will be during the takeoff.
The Briefing

Clear Agreement on Responsibilities

Concise Roles Understood

Figure 44
During takeoff, callouts fall into three general categories:

- Those normally made prior to V1, malfunctions, the V1 callout itself.
Callouts

- Standard
- Malfunctions
- V₁
As was recommended by the NTSB, it is important to clearly announce when entering the company-defined "high speed" regime.

In the low speed regime it's reasonable to reject for:

- System Failures
- Unusual Noise or Vibration
- Tire Failures
- Abnormally Slow Acceleration
- Unsafe Takeoff Configuration Warning
- Engine Failure or Fire
- The Airplane is Unsafe or Unable to Fly

However in the high speed regime, it's only recommended to reject for the most critical items: Engine Failure or Fire, or the Airplane is Unsafe or Unable to Fly.
Items to Reject For

Low Speed:
System Failures
Unusual Noise or Vibration
Tire Failures
Abnormal Acceleration
Configuration
Engine Failure/Fire
Unsafe/Unable to Fly

High Speed:
Engine Failure/Fire
Unsafe/Unable to Fly

Figure 46
The few seconds of communication regarding a non-normal situation during takeoff can mean the difference between success and disaster. For this reason, communications must be precise, effective and efficient. Standard callouts contribute to situation awareness. The callouts, coupled with both/all crew members monitoring airspeed, leave the crew with a common perception of what actions are proper in the event of a non-normal indication. The crew member noting a problem should communicate this clearly and precisely without inferring things that may not be true. The pilot tasked to make the RTO decision should clearly announce the decision to continue or reject the takeoff using the standard airline words.
Communication

Clear

Precise

Standard Terminology

Figure 47
Basic operating procedures call for the pilot flying the airplane to include airspeed in his instrument scan during the takeoff ground roll. Hence he is always aware of the approximate speed. The pilot not flying monitors airspeed in more detail and calls "Vee-One" as a confirmation of reaching this critical point in the acceleration.

The pilot flying cannot react properly to V1 unless the V1 call is made in a timely, crisp, and audible manner. One method used by a major U.S. carrier is their adoption of a policy of "completing the V1 callout by the time the airplane reaches V1." This is an excellent example of the way airlines are implementing procedures to improve RTO safety. It is a good procedure and it should preclude a situation where the "No Go" decision is inadvertently made after V1.
The crew must be prepared to make the Go/No Go decision on every takeoff. If a "No Go" decision is made, the crew must quickly use all of the stopping capability available. Too often, the records show uncertainty in the decision process and a lack of completeness in the procedures. Be ready to decide and be ready to act.
Be Ready to Decide

Be Ready to Act

Figure 49