

A SYNTHESIS OF AN AIRCRAFT APPROACH, LANDING & OVERRUN

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ABSTRACT

All conventional aircraft flights start at a point of departure with a take-off and end at the destination with a landing. During this phase, the aircraft is transferred from the airborne state to the ground-borne state and brought to a halt. Although landing an aircraft looks simple but in reality it is difficult to predict the performance during this phase due to its very dynamic nature, a high sensitivity to piloting technique and uncertainties in aerodynamics. As this critical manoeuvre (beside takeoff) takes place in close proximity to the ground, and at a low airspeed ('dirty'), there is a relatively a high risk to the safety of the aircraft and its occupants. A significant number of incidents and accidents occur during this crucial phase in which the aircraft could not be stopped on the runway during landing-known as overruns. Although it has been a problem for quite a long time, unfortunately, not much has been learned. This paper presents some important and interesting facts regarding runway overruns and the crucial aspects during the penultimate stages of the landing process together with the airworthiness and regulatory requirements.

Keywords: *Approach & landing, landing profile, runway, overrun*

1.0 INTRODUCTION

Each day thousands of safe landings are made worldwide, mostly on runways that are longer than the minimum required length. However, recently some of the fatal accidents that usually falls within the 'standard' accident categories, such as Controlled Flight into Terrain (CFIT) or 'loss of control'; appears to be in the Approach and Landing category. Statistics shown in Figure 1 indicates that although the Approach and Landing phase only consists about 4% of the total flight time of an aircraft operations, Approach and Landing Accidents (ALAs) represents about 52% of all fatal accidents involving all jet and turboprop aircraft over 5700kg maximum take off weight more than in any other flight phase. 15% of the accidents occur in the airport approach areas, usually 15 miles of the airport

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with almost 80 % occurring on the active runway, or its overrun areas. Of this 12% are due to runway overruns [1, 2, and 3].

Overrun is accident in which the pilot was not able to stop the aircraft before the end of the runway. Overruns can occur during both takeoffs and landings [4]. However the vast majority took place during landings. This type of landing accident has been responsible for the majority of airliner hull losses for years and is one area in aviation safety that has shown little or no improvement in the past dozen years. Unfortunately we are not learning from the harsh lessons visited upon our colleagues who have actually been involved in overrun accidents. Some of recent such a high-profile cases the were close to being catastrophic were the A340 Air France overrun at Toronto Pearson Airport and the Southwest Airlines B737 overrun at Chicago Midway and the B747 Qantas overrun at Bangkok [4]. In this paper a synthesis of the aircraft approach, landing and overrun are addressed together with the airworthiness and regulations requirement and related issues.

Accidents and Onboard Fatalities by Phase of Flight
Hull Loss and/or Fatal Accidents – Worldwide Commercial Jet Fleet – 1996 through 2005

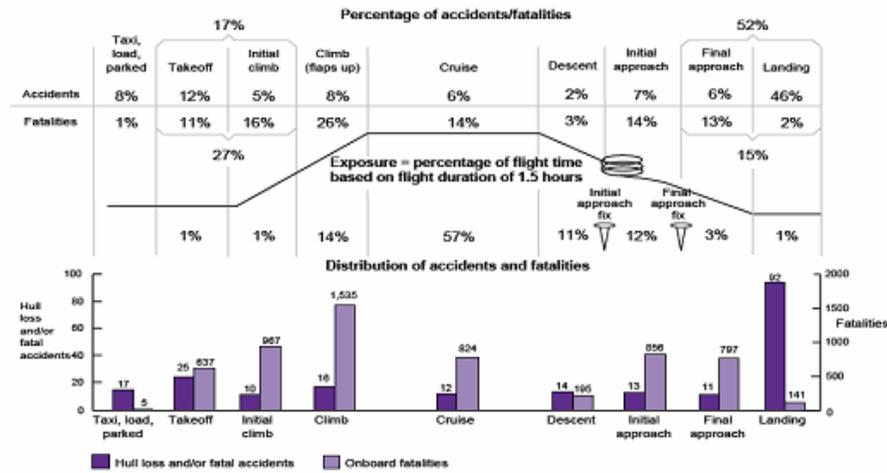


Figure 1: Accident and onboard fatalities by phase of flight [2]

2.0 THE LANDING PROFILE

The actual descent commences from the cruise altitude and ends at an altitude of 1500 ft above the airport of destination as illustrated in Figure 2. Well before initiating the descent, landing performance will be carefully assessed through onboard computers, charts or tables to establish whether a safe landing is viable. The required landing field length and speed which corresponds to the landing weight will be calculated. This is also to ensure that the aircraft can carry out a missed approach if required and satisfying the legal climb gradient requirement.

From this initial approach fix (IAF) of the landing approach position the pilot will start to configure the aircraft to reduce the speed by extending the flaps.

Before reaching 1000 above the threshold of the landing runway, the undercarriage is lowered and full flaps are set to the landing configuration to satisfy the stabilized approach criteria. The aircraft is now been flown at the lowest airspeed, V_{ref} . It is a requirement by FAR 25.125(a) that the approach airspeed must not be less than $1.3 V_s$ to provide a safe margin over the stalling speed in the landing configuration down to the 50ft point [5] and [6]. Changes may be made to power and the landing must be made without the need for exceptional skill. The handling qualities must be such that that the aircraft can be flown with accurate flight path control by the pilot. The aircraft is now at high drag. This implies that the airspeed should not be less than the minimum drag speed, V_{md} to maintain the flight path stability. A further benefit is that the increased drag will require the engines to be operated at a fairly high thrust setting. In this state, should the aircraft have to abandon the approach and go around, the engines will respond quickly to the demand for maximum thrust. At the same time, the high speed devices can be retracted and an excess thrust over drag for the climb can be achieved in the minimum time [7]. FAR 25.119–requires that aircraft must be able to achieve a 3.2% steady climb gradient in the landing configuration with power available within 8 seconds with not more than $1.3V_s$ [6].

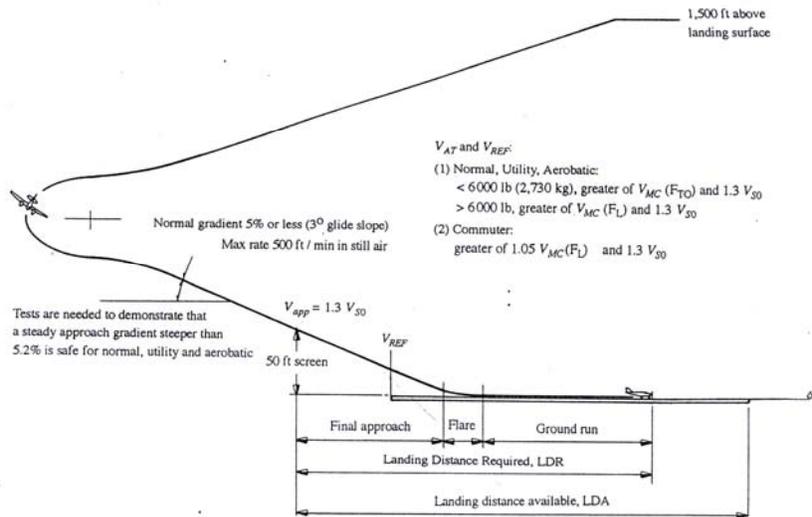


Figure 2: A typical CTOL aircraft approach and landing profile

During the final approach, speed, pitch attitude and the gradient of the flight path are the main criterion. The low speed is to minimize the stopping distance on the runway. The aircraft attitude will be approximately 5 degrees nose pitch on a typical 3 degree approach path, which would give the pilot a good view of the runway ahead. The gradient of the approach path must be steeper than the minimum approach sector gradient of 2% and will usually be about 3% for Conventional Takeoff and Landing (CTOL) aircraft but not too steep that the flare to touchdown requires an excessive pitch attitude change. Typically the descent

gradient by large transport aircraft will be about 3 degree, which is equivalent to a 5.2% gradient [7] and [8].

As the aircraft passes the runway threshold at a standard screen height of 50 feet, a 'flare' manoeuvre is introduced. In the flare, the pilot aims to reduce the vertical component of the velocity by progressively increasing the angle of attack to a pitch attitude of about 5 degree nose up and at the same time reducing the thrust to flight idle so that it is no more than about 0.5 m/s when the main wheels touch the runway [5]. Touchdown speed is usually about $1.25 V_s$. About 2-3 seconds later, as the airspeed decreases, there will be insufficient pitching moment produced by the elevator control to hold the nose up attitude. The nose is lowered onto the runway and the aircraft is brought to a halt by the use of wheel brakes, sometimes assisted by lift dumpers or spoilers to reduce the wing lift and thus increase the ground reaction, and indirectly assisting the wheel braking by increasing the load on the brakes (also reducing brake wear) while also increasing the drag. Modern jet transports are also equipped with an automatic braking system that automatically controls the braking of the aircraft after touchdown with several deceleration levels. Reverse thrust from the engines or propeller or parachutes on some military aircrafts are also used to increase the drag. As much as 40% of the forward thrust can be achieved during reversal [9]. FAR regulations dictate, however, that a plane must be able to land on a runway without the use of thrust reversers JAR regulations however allows for reverse thrust credit [6]. On some fighter jets the pilots tend to keep the nose up as long as possible in order to increase drag and shorten the needed runway length. This technique is called 'aerodynamic braking' and is an acceptable technique on some fighter jets. However for commercial transport aircraft it is not a recommended technique. The 'aerodynamic braking' technique has resulted in landing overruns with commercial transport jets in the past [8]. The landing is complete when the aircraft has been brought to a halt on the runway.

3.0 LANDING OVERRUN FACTORS

Landing an aircraft involves four phases: descent, approach, flare, and stopping. Any single or combination of factors affecting one or more of these phases can create a condition ripe for a landing overrun. Many factors have been identified as potential influences in overruns.

3.1 Difference in Flight Test & Practicality

The landing distances determined under FAA 14 CFR Part 25, section 25.125 and published in approved Airplane Flight Manual (AFM) are considerably shorter than the landing distances achieved in normal operations since the former are determined using flight test methods and analysis criteria not representative of everyday practices. For example, test pilots often use high touchdown sink rates (as high as eight feet per second) and approach angles of -3.5 degrees to minimize the airborne portion of the landing distance. There is only enough flare to keep the touchdown sink rate structurally tolerable. The time taken to activate deceleration devices is markedly different between the flight test setting and out in the operational world. Test pilots initiate maximum braking as soon as possible after

landing. In daily operation pilots try to be smoother and easier on the hardware [6].

In practicality it is found that, the runway length required for landing can be much greater than the length given by simple calculations because of the problem of controlling the flare trajectory (misjudged or started at a too great a height) resulting in extended flare and float before touchdown. It is also not possible to position the aircraft with absolute accuracy at the screen height above the runway threshold on the approach. Neither, it is possible to guarantee that the aircraft is flying at the exactly the correct approach speed, V_{ref} , as it passes the screen height. Consequently, this leads to considerable variation in the touchdown point and hence increase the length of the runway required for an aircraft to come to a stop. A report by Pinsker cited in [5], of computer studies by Lockheed on the spread of touchdown positions in landing of the L1011 (Tristar) shows that touchdown point occurs within the required point and that actual landing distance is about 700 m greater than the length given by simple calculation, because of the uncertainties of the touchdown positions.

Further, flight tests are typically conducted in ideal atmospheric conditions, allowing the test pilot to easily establish a stabilized approach without having to compensate for the turbulence or gusty winds, so common in line flying. Out in the real world, flight path deviations do occur, and professional pilots try to smoothly correct back to the flight path without giving passengers a roller coaster ride. If a sudden wind gust or thermal balloons the aircraft 100 feet over the threshold instead of the usual 50, landing distance will be increased almost 1,000-ft [6].

3.2 Environmental, Runway & Weight

The atmosphere plays an important part in the runway length required. At higher altitudes, true landing speeds are greater, and less dense air reduces the drag available to assist in decelerating during the landing roll. The higher the temperature, the longer the runway required because higher temperature creates lower air densities resulting in lower output of thrust and reduced lift. All other factors being equal, the higher the elevation of the aerodrome with corresponding lower barometric pressure, the longer the runway required. Finally higher weight means higher approach speeds. The greater the tailwind down a runway, the longer the runway length required for landing. The effect of runway slope is that an aircraft landing uphill gradient requires less runway length than it would on a level or downhill gradient; the specific amount depends on the elevation of the aerodrome and the temperature. A weight increase of 10% would be expected to increase the distance in the flare by about 7% and the ground run distance increases by about 20 % for a weight increase about 10% [5], [7] and [10].

3.3 Human Factors

Visual illusions can also result in overruns [11]. It happens when conditions modify the pilot's perception of the environment relative to his/her expectations relative to the runway threshold. Visual illusions affect perception of heights, distances and/or intercept angles. It is most critical when transitioning from

Instrument Meteorological Condition (IMC) and instrument references to Visual Meteorological Condition (VMC) and visual references. Visual illusions usually induce crew inputs (corrections) that cause the aircraft to deviate from the original and intended vertical or lateral flight path. 30% of approach-and-landing accidents occur during the conduct of visual approaches or during the visual segment of an instrument approach. Katwa & Helmreich cited in IDR [8] indicate that about 20-25% landings occur at night. Visual approaches at night present a greater exposure because of reduced visual cues, increased likelihood of visual illusions and risk of spatial disorientation. It is found from experience that a minimum period of about 3 seconds is required by the pilots to react and adjust the aircraft after seeing a visual aid. Then, for an aircraft moving at a speed of about 130 knots, the minimum horizontal segment on the ground should be not less than 200 m. The best source of getting height information will be the instrument in the aircraft such as the Instrument Landing System (ILS) or the radio altimeter. Other method is using the airport glide path guidance such as the Visual Approach Slope Indicator (VASI) or Precision Approach Path Indicator (PAPI) [10].

The Flight Safety Foundation's Approach and Landing Accident Reduction (ALAR) study noted that 68% of the overruns were crew-related [2]. Crew poor decision making and lack of co-ordination also contributes to some landing overruns. This maybe due to stress, possibly due to the self-imposed commitment to get the passengers to their destination, fatigue after long duty day or during heavy weather conditions. Press-on-itis was very prevalent in this accident with even reports of deteriorating weather conditions. In times of stress, one can become task saturated (the point at which situational awareness is superseded by adrenaline). A pilot is really only in control of his approach's "setup." [3]. Once he has crossed the threshold, he is wholly unaware of runway behind him and is only concentrates close in for his landing flare cues and upon a smooth touchdown to the extent that he is blissfully ignorant of the rate at which he is running out runway and unaware of any impending peril [5]. In fact, once past the threshold, he just does not know accurately what roll-out distance remains. Other example is unable to identify and react to system failures such as auto-spoilers failure to deploy automatically. Even a 2 second at a speed of 120 knots can increase the stopping distance by almost 400 ft. Aircraft with simple brakes and without spoilers will have considerably longer distances [5].

Finally, high and fast approaches are without doubt are the frequent feature of landing overruns. It normally happens during non-precision visual approaches with significant tailwind present. The excess speed and height leads to the aircraft touching down far beyond the threshold with insufficient runway to stop. Although not all unstabilised approached leads to overrun, but most overruns are due to unstabilised approaches [2] and [4].

4.0 INITIATIVES TO REDUCE

During the late nineties studies were conducted by the Flight Safety Foundation (FSF) task force on Approach & Landing accidents [2], with special attention to landing overruns.

4.1 Safety Factor

Landing performance calculations for air carrier operations typically are conducted before flight by dispatchers before flight and before arrival by pilots. The pre-flight calculations are based, in part, on landing performance demonstrated by the manufacturer during certification flight tests. Dispatch calculations are intended to ensure that dispatched flights will be able to land safely at the intended destination airport or at planned alternate by factors 1.67 and 1.92 respectively and are based on estimated landing weights and forecast conditions [6]. Arrival calculations are based on updated information on aircraft landing weight, weather, runway conditions and other factors. No “safety margin” is padded to the arrival landing-distance calculations. The very crude landing rules have been a factor in several overrun incidents and accidents. During certification flight testing where manufactures used extreme landing techniques in the attempt to certify short landing distances [5]. This is also the main point on criticism on the landing rule, which allows for techniques that have no relation whatsoever to normal airline landings. Over the years there have been many discussions with a view to introducing a more rational landing distance certification rules. After numerous runway overruns, the Federal Aviation Authority (FAA) issued an operating rule to add 15 percent margin on the calculated landing distance. The flight crew must establish the margin of error between the landing distance available and landing distance required before conducting an approach. However, it is till partly be up to operators to determine when an additional landing safety assessment is needed [14].

Despite these regulations, aircraft still do occasionally overrun the end of runways. The International Civil Aviation Organization (ICAO) therefore recommends that a Runway End Safety Area (RESA) be provided; so that the majority of overruns have a benign outcome [15] has recently strengthened its Standards and Recommendations for the provision of RESA from previous recommendation for a 90 m RESA to 240 m [10]. At some airports with insufficient space for the full RESA, an Engineered Materials Arresting System (EMAS), which is a mixture of water, foam and cement are installed as an acceptable alternative. Tests showed that just 400 feet of EMAS can stop a passenger jet travelling 60 knots an hour without causing substantial damage to the airplane [15] and [4].

4.2 Runway Markings

In the view of the vital function of the runway in providing for safe and efficient aircraft landings, it is very imperative that their design take into account the operational and physical characteristics of the aircraft expected to use the runway beside the engineering and economic considerations. Uniformity in airport markings and signs from one airport to another will enhance safety efficiency while ineffective, incorrect, or confusing markings or signs on an airport could endanger the approach [10].

There are few runway markings that can use by the pilots to provide them with the runway length information to assist them in carrying out the landing operations. The distance markers indicated by large numerals indicating hundreds or thousands of feet remaining to the end of the runway informs the pilot of a

landing aircraft. It is usually installed at military facilities, but becoming increasingly popular at civilian airports too. Beside that runway lightings also provide some distance information [15]. For example red runway lights are installed on the centreline from the last 1,000 feet to the runway end. However, this type of information it is not practical because that the attention of the pilot might be diverted from the primary task (activating reverse thrust), with the potential increase of running sideways. Figure 3 shows the ICAO Standard Runway Markings.

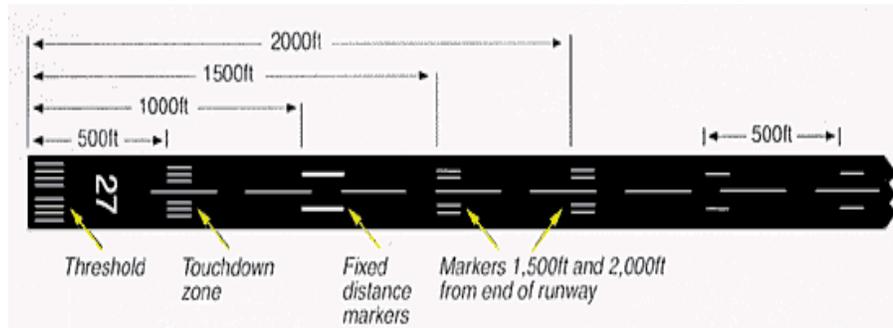


Figure 3: ICAO standard runway markings

4.3 Technology & Education

In the most phases of the flight a pilot has sufficient information available to monitor the progress of his operation except during the landing run. Although the landing distance required is calculated prior to landing, however during the manoeuvre itself he/she does not have accurate information in real time of the exact point at which the aircraft will/has touched down and stop. Thus it may be useful for aircraft to have a landing system which is analogous to the system used on takeoff - one that advises when things are going badly and the landing should be abandoned. Thus suitably designed landing performance monitor (LPM) could fill this gap. At present there is yet no such a system in use.

In addition to technological solutions, pilot training on the subject must be improved. The Flight Safety Foundation (FSF) formulated an Approach and landing Reduction (ALAR) "tool kit" to assist pilots in analyzing hazardous situations and applying appropriate measures to manage the associated risks. The overall intent is to develop a systematic methodology which will enable pilots to more easily identify all the variables of hazardous landing situations.

The new training course on overruns should be designed to improve rule-based and natural decision making by teaching the reasons for adherence to SOPs and by seeing the consequences for failure to abide by them we need to improve cockpit discipline [3]. At the heart of the matter is the importance of the stabilized approach. A go-around is required if the aircraft becomes unstable below those levels. Moreover, every flight operation must employ and emphasize a "no fault go-around policy" to help change pilot attitudes. Too many pilots regard a go-around as an indication of failure, whereas a go-around is actually the carefully scripted continuation of every approach [13] and [4].

5.0 CONCLUSION

Landing is the concluding phase of a flight. Lately there have been many runway overruns cases after landing. In this paper, statistics, the landing profile with its regulatory requirements, factors that contribute to the landing overruns and the initiatives that has been considered. It is clear that we have now reached a point where there is a need for a greater awareness in this area. Mastering landings requires attention to details and a healthy respect for the limitations and fundamental knowledge and understanding of aircraft, environment and pilot themselves. Runway overruns can be reduced by raising awareness of the problems contributing to these accidents and by the proper application of technology [16], training and discipline.

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NOMENCLATURES

N	Normal force
L_g	Lift
W	Weight
T	Thrust
D	Drag
μ	Coefficient of Friction
g	Gravity
V	Forward velocity
t	Time
m	Mass

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