HYPOTHETICAL COLLISION OF TU-154M WITH BIRCH TREE VERSUS FULL-SCALE CRASH DYNAMIC TESTS OF DC-7 AND LC-1649

Jacek F. Gieras

Abstract

A comparative analysis of hypothetical collision of Tu-154M with birch tree, full-scale dynamic crash test of Douglas DC-7 and full-scale dynamic crash test of Lockheed Constellation 1649 has been presented. The analysis pertains to the technical data of the Tu-154M, DC-7 and LC-1649 airliners, differences in their construction and conditions of collision /impact.

Keywords – *collision, comparative analysis, crash, DC-7, full-scale test, LC-1649, Tu-154M.*

Streszczenie

Przedstawiono analize porownawcza hipotetycznej kolizji Tu-154M z brzoza oraz testami dynamicznymi zderzen z przeszkodami wykonanymi w pelnej skali przy uzyciu samolotow DC-7 oraz LC-1649. ***Analiza porownawacza dotyczy danych technicznych samolotow, roznic w ich konstrukcji oraz warunkow zderzen.***

Słowa kluczowe *– analiza porownawcza, katastrofa, kolizja, DC-7, LC-1649, test w pelnej skali, Tu-154M.*

1. INTRODUCTION

In 1965 full-scale dynamic crash tests on DC-7 and Lockheed 1649 Constellation have been performed by the Federal Aviation Agency, USA, Aviation Safety Engineering and Research, USA, and number of other agencies and organizations [5,6]. The objective of these experiments was *exploration of the manner in which large aircraft are damaged in survivable accidents and accurate measurement of the crash loads* [4,5]. In the case of the DC-7, after collision with telephone poles, the tip of right wing finally fell off [2,5]. This fact is frequently cited by supporters of the official crash report [3] as a proof that the collision of the Tu-154M No 101 with the trunk of a birch tree on April 10, 2010 near Smolensk North Military Air Base severed the tip of the left wing and finally caused fatal collision of theTu-154M Nr 101 with the ground.

It is necessary to point out the following differences in:

- weight and volume envelope of the Tu-154M, DC-7 and LC-1649 aircraft;
- kinetic energy prior to impact;
- construction of aircraft and their wings;
- height at which the wing hit the pole or tree;
- properties of timber/wood;
- how the telephone poles and birch tree have been anchored.

Professor Jacek F. Gieras, PhD, DSc, FIEEE, University of Technology and Life Sciences, Department of Electrical Engineering, Bydgoszcz, Poland (e-mail: jacek.gieras@utp.edu.pl).

2. TEST SITE

The test site has been designed in such a way as to obtain the desired impact conditions for accelerating the tested aircraft to approximately the climbout velocity, controlled guidance of the aircraft to the initial impact point, and appropriate location of earthen barriers and telephone poles (Fig. 1).

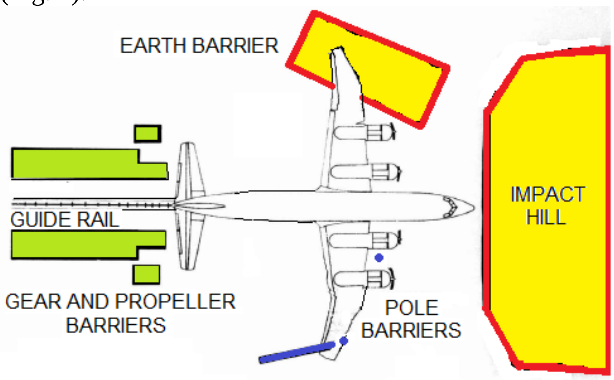

Fig. 1. DC-7 test site and wing impact sequence. Telephone poles have been marked with blue color [5].

Fig. 2. LC-1649 full-scale dynamic crash test. Outboard pole impact [6].

Fig. 3. LC-1649 full-scale dynamic crash test. Inboard pole impact [6].

The runway consisted of two soil-cement strips 4.57-m wide and 5.49-m apart laid over the desert soil to support the main landing gear wheels [5,6]. The length of strips from release point to the impact barriers was 1219 m [5,6]. The aircraft was guided along a single track made of standard 41-kg railroad rails laid on a continuous reinforced concrete base [5,6].

The rock, earthen and pole barriers were erected to break the nose landing gear, propellers of engines and wings, respectively [5,6]. The left wing earthen barrier was a 4.57-m high inclined earthen mound with the face sloped 35^o (Fig. 1). The right wing pole barriers (Figs 2 and 3) were made of standard 0.305-m diameter telephone poles (southern yellow pine) buried approximately 1.22 in the ground [4,5]. The earthen impact hill located behind the wing barriers (Fig. 1) was an 8^o slope extending for approximately 38 m along the main axis of the test site [5,6].

Table 1. Conditions prior to crash or full-scale tests

Parameter	Tu-154M 101	DC-7	LC-1649
Gross weight of airliner at the time of crash/test. kg	78,600 (estimated [3])	49,010 [5]	72,245 [6]
Velocity prior to contact with barrier, km/h	approx. 270.0 (birch tree)	257.4 (gear barrier)	207.6 (gear barrier)
Linear momentum, MNs	5.896	3.504	4.166
Kinetic energy, MJ	221.1	125.3	120.1
Leading edge sweep of wings, degree	approx. 37	approx. 5	approx. 6
Material of wooden barriers	birch tree	processed pine	processed pine
Height of impact point measured from the ground level, m	approx. 5.1	approx. 3.2	approx. 2.0
Diameter of pole/tree	0.3 to 0.4	0.305	0.305
Distance of impact point measured from the center axis of the fuselage	12.675	13.83	unknown
Length of the tip wing being cut off, m	6.1	3.66	unknown

In the presented comparative analysis of the Tu-154M, DC-7 and LC-1649 only the wing pole barriers have been discussed (Figs 2 and 3). Conditions prior to crash or full-scale dynamic tests are summarized in Table 1.

3. Construction of Aircraft

The first version of the Tu-154M project appeared in 1964 [4]. A pair of Tu-154M "Salons" (VIP version "Lux") was delivered to Polish Air Force in June 1990, reserialled "01" and "02" in 1995 [4].

The Douglas DC-7 military transport and civilian aircraft were built by the Douglas Aircraft Company, Santa Monica, CA from 1953 to 1958.

The Lockheed Constellation model 1649 aircraft was built by Lockheed, Burbank, CA between 1943 and 1958. A total of 856 aircraft were produced in various models. The Constellation was used as a civilian airliner and as the US military transport plane, servicing amongst other the *Berlin Airlift*. It was the presidential aircraft for the US President D. D. Eisenhower.

The Tu-154M is propelled by three D30-KU turbofan engines, while the DC-7 and LC-1649 are propelled by four R3350 piston engines. The Tu-154 has rear-engine layout with its wings "aerodynamically clean". The DC-7 and LC-1649 have engines buried in the wings.

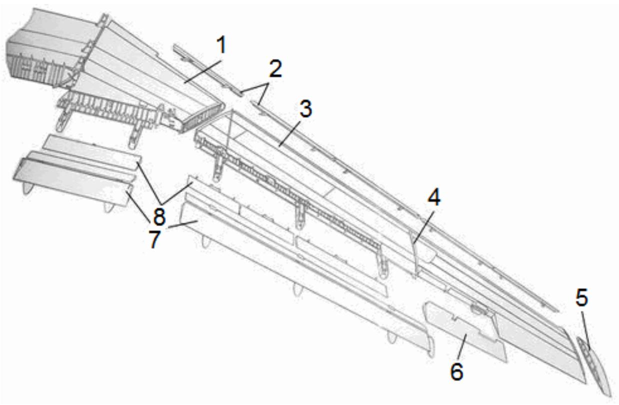

Fig. 4. Construction of wing of Tu-154. 1 - center section, 2 - slats, 3 - detachable portion of the wing, 4 - wind baffle, 5 - limit fairing, 6 - aileron, 7 - flaps, 8 - spoilers [9,10].

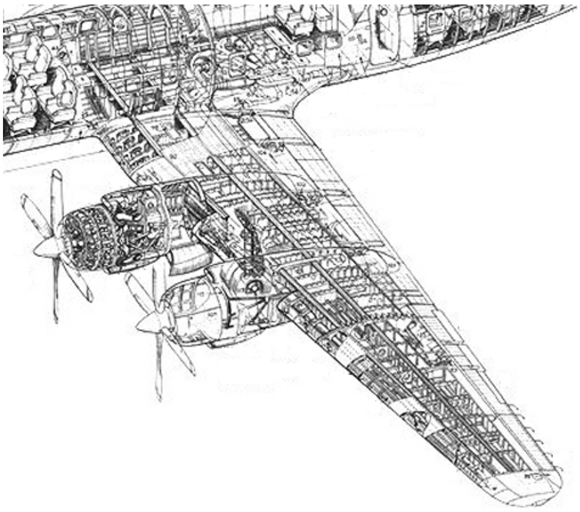

Fig. 5. DC-7 wing cutaway. Source: www.flightglobal.com

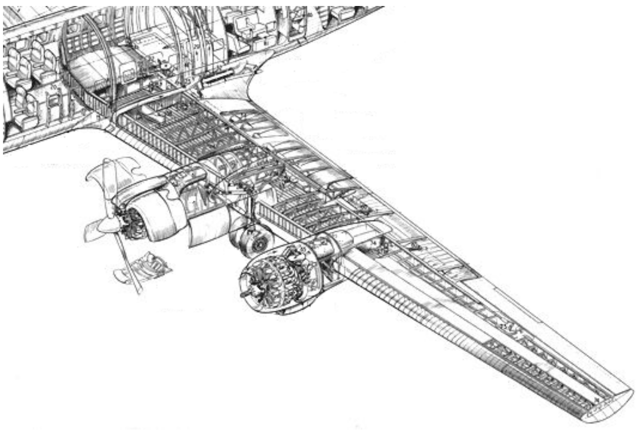

Fig. 6. LC-1649 wing cutaway. Source: www.flightglobal.com

The construction of wing of Tu-154 is shown in Fig. 4. The 3D cutaways of DC-7 and LC-1649 wings with engines are shown in Figs. 5 and 6.

Specifications of the Tu-154M, Douglas DC-7 and Lockheed Constellation LC- 1649 are listed in Table 2. Dimensions of all three aircraft are sketched in Figs 7 and 8. The Tu-154M is much longer (47.9 m versus 29.53 m and 35.41 m) and heavier (empty weight 55.3 t versus 37.785 t and 41.969 t) aircraft than the DC-7 and LC-1649.

Table 2. Specifications of Tu-154M, Douglas DC-7 and Lockheed Constellation 1649 aircraft

Specifications	Aircraft		
	Tu154M	DC-7	Lockheed Constellation Model 1649
	Dimensions:		
Wing span , m	37.55	34.98	45.72
Length, m	47.90	29.53	35.41
Height, m	11.40	8.75	7.54
Wing area, m^2	201.5	188.3	171.87
	Weights		
Empty weight, kg	55,300	37,785	41,969
Loaded weight, kg	max 100,000	57,200	72,575
	Performance		
Max. speed, km/h	950	650	606 at 5669 m
Cruising speed, km/h		560	466
Service ceiling, m	11,100	6850	7223
Max range, km	5200	9000	9945 with 3628 kg payload
Range with max payload, km	3900	7400	7950 with 8845 kg payload
Power plant	Three Aviadvigatel (Soloviev) turbofan D-30KU rated at 108 kN (24,270 lb) each	Four Wright R-3350 988TC-DA turbo compound radial rated at 2420 kW (3250 hp)	Four Wright Cyclone R-3350-988TC-18EA-2 turbo-compound rated at 2535 kW (3400 hp) each

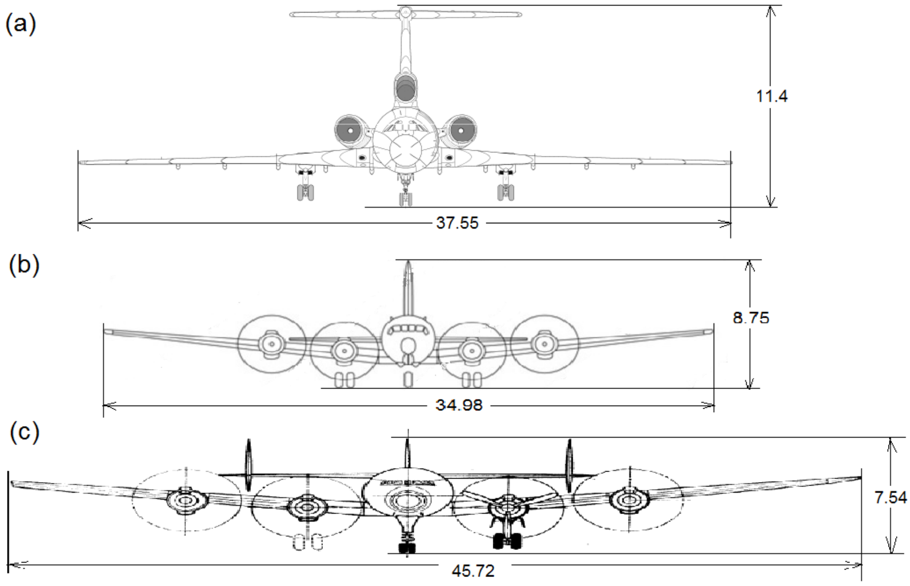

Fig. 7. Comparison of wing span: (a) Tu-154M; (b) DC-7; LC-1649.

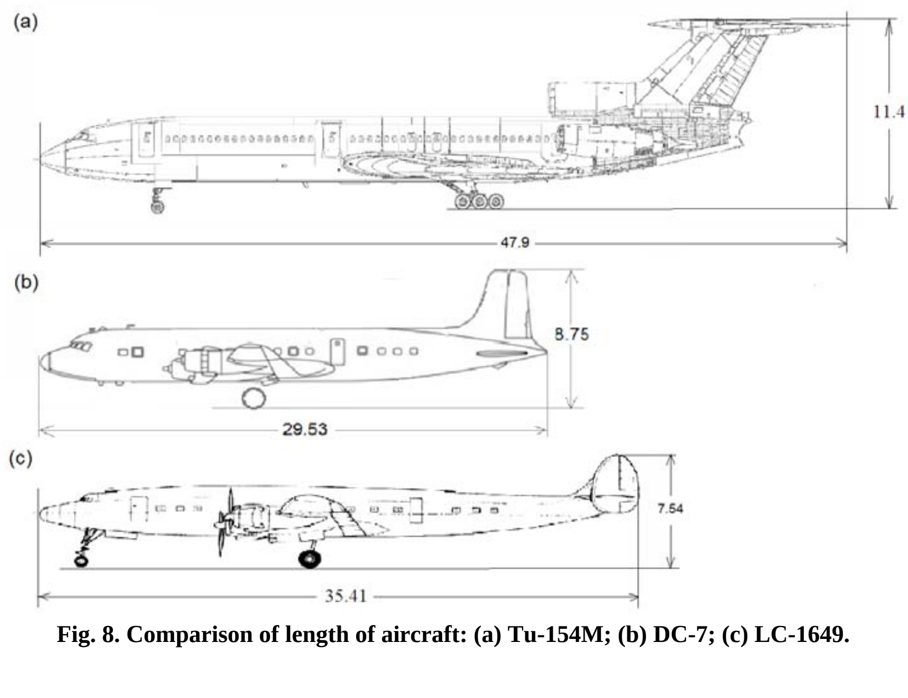

Fig. 8. Comparison of length of aircraft: (a) Tu-154M; (b) DC-7; (c) LC-1649.

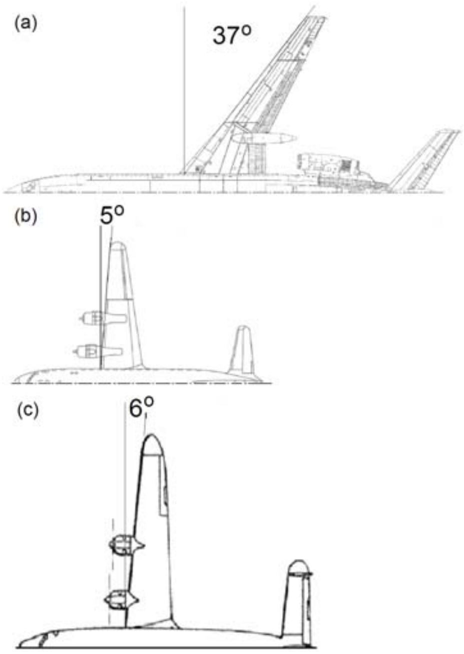

Fig. 9. Leading edge sweep of wings of (a) Tu-154M, (b) DC-7 and (c) LC-1649 aircraft.

The *leading edge sweep*[1] of the wing (Fig. 9) is about 37° for the Tu-154M, about 5° for the DC-7 and about 6° for the LC-1649 aircraft (Table 1). It is easier to cut a pole/tree barrier by a wing with large leading edge sweep angle (Tu-154M) than by a wing almost perpendicular to the center line of the fuselage (DC-7, LC-1649). For example, to decrease the amount of force required in a guillotine cutter and to cut the material more swiftly, the blade is angled. This angle is referred to as the *shear angle*. A 5° degree shear angle decreases the force by about 20%, but increases the stroke.

4. Dynamic test results

In the case of dynamic tests of the DC-7 (Appendix A), the impact of the right wing with the outboard pole cut off the wing approximately 3.66 m from the tip [5]. Roughly 0.15 s after the first pole impact, the aircraft contacted the second pole barrier, which crushed the wing leading edge structure back to the forward spar [5]. Then, the second pole broke [5]. The left wing tip after touching the earthen wing barrier suffered only slight flattening [5].

The left wing of the LC-1649 (Appendix B) after striking the earthen barrier separated from the fuselage at the wing root [6]. The right wing hit the pole barriers, which opened up the wing about 7.6 m from the tip and between engines [6]. At approximately the same time, the fuselage touched the ground and finally became separated from this right wing section [1,6].

According to [2], in both cases the poles were first cut by the wing, and the wing tip detachment process in the case of the DC-7 was due to air resistance at a distance of about 20 m behind the point of impact (pole). The wing tip of the DC-7 was torn off in a more distant place from the fuselage than the point of impact with the pole. The wing tip of the LC-1649 fell off only when the aircraft hit the 6° hill [1,2].

[1] The leading edge sweep is the angle between a constant percentage chord line along the semispan of the wing and the lateral axis perpendicular to the aircraft center line.

5. Collision of Tu-154M with birch tree

There is no clear evidence that the Tu-154M Nr 101 on April 10, 2010 hit the trunk of a *birch tree* situated 63 m to the left of the glide path and 855 m from the RWY26 runway threshold. According to K. Nowaczyk [8], the data retrieved in the US by Universal Avionics Systems Corporation [7] show that the Tu-154M has been destroyed at an altitude of over 30 m above the crash site level. These records have been known to the Committee for Investigation of National Aviation Accidents (in Polish KBWL) [3], but have been hidden [8].

Fig. 10. Fracture of famous birch tree trunk. No piece of metal is visible. Photograph taken immediately after crash.

The famous birch tree has appeared two weeks after the crash. Before that, it was officially claimed that the wing of the plane hit the mast of the inner non-directional radio beacon (NDB) located 1100 m from the runway threshold. There is no clear evidence of detailed investigation of the famous birch tree and separated tip of the left wing. The photograph taken immediately after the crash (Fig. 10) does not show any pieces of metal embedded in the wood. The photographs taken by S. Amelin and J. Gruszynski also do not show chunks of metal.

Fig. 11. Tip of the left wing. The wing has been cut off while the slat is intact. http://vfl.ru/fotos/aa582e8c473661.html

The tip of the severed wing looks peculiar (Fig. 11). The slat has not been damaged and protrudes several inches beyond the cut-off line of the wing. Slats of the left wing have been almost intact along the entire length, only with three small cavities. The report [3] does not explain why the adjacent slat, extending in the direction of the fuselage had not been destroyed by the hypothetical collision with the trunk of a birch tree, and how did it happen that the zone of destruction begins behind the slat (Fig. 11).

6. CONCLUSIONS

From the presented comparative analysis the following conclusions can be drawn:
(a) The Tu-154M is much longer (47.9 m versus 29.53 m and 35.41 m) and heavier (empty weight 55.3 t versus 37.785 t and 41.969 t) aircraft than the DC-7 and LC-1649.
(b) The construction of the Tu-154M, DC-7 and LC-1649 aircraft and their wings is very different, e.g., leading edge sweep. The first version of the Tu-154M was designed in 1964, while the DC-7 was designed before 1953 and LC-1649 before 1943. The turbofan engines of the Tu-154M are mounted in the rear of the fuselage. The piston engines of the DC-7 and LC-1649 are buried in wings.
(c) The kinetic energy prior to impact of the Tu-154M was 221.1 MJ versus 125.3 MJ for DC-7 and 120.1 MJ for LC-1649.
(d) It is easier to cut a pole/tree barrier by a wing with large sweep angle (Tu-154M) than by a wing perpendicular to the center line of the fuselage (DC-7, LC-1649).
(e) The physical parameters of the "live" birch tree are different than those of telephone poles made of processed timber (processed southern yellow pine).
(f) The height of impact point measured from the ground level is different for each case, i.e., approximately 5.1 m for the Tu-154M, approximately 3.2 m for the DC-7 and approximately 2 m for the LC-1649.
(g) The birch tree grew probably in a meadow or swampy ground, while the telephone poles were buried approximately 1.22 in the ground. It is unknown if a layer of concrete has been applied.
(h) Research performed by K. Nowaczyk [8], photographs of the birch taken immediately after the crash (Fig. 10), appearance of trees broken by wind gusts, lack of damage to the slat (Fig. 11) and lack of detailed investigation of the birch tree and wing testify that there was rather no collision of the Tu-154M Nr 101 with the trunk of a birch tree.

Therefore, the separation of the tip of wings in full-scale dynamic tests [5,6] using the DC-7 and LC-1649 aircraft can not be a proof of cutting off the tip of the wing of the Tu-154M as a result of a collision with a birch tree trunk.

APPENDIX A. DC-7 RELEASE AND CRASH SEQUENCE

The DC-7 aircraft was released for full-scale dynamic test under the following arrangements [5]:

- Normal take-off configuration;
- Flaps positioned full-up to reduce lift and drag;
- Upon release, the throttles advanced to pre-determined take-off position, 3050 bhp[2] (2.275 MW) per engine;
- Smooth and continuous acceleration of the aircraft during the 1292 m run until the impact with the propeller and landing gear barriers (Fig. 13);
- Velocity of 257.4 km/h (139 knots).

[2] Brake horsepower (bhp) is measured with a dynamometer (brake), which measures the true power of the engine, without power losses caused by the gearbox, generator, pumps, and other auxiliary equipment.

The step-by-step crash test sequence of the DC-7 is described below [5]:

- The first barrier was the landing gear barrier (Fig. 12a).
- All four propellers were broken as a result of hitting the propeller barriers (Fig. 12b). All four engine mounts failed.
- The gear barrier torn out the right main landing gear, which struck the right horizontal stabilizer (Fig. 12c).
- The impact with the outer pole (Fig. 1) cut off the right wing approximately 3.66 m (12 feet) from the tip. The main tank No 4 (Fig. 13) was ruptured by the pole.
- The aircraft hit the second inner pole approximately 0.15 s after the first pole impact. The inner pole struck the right wing between engines No 3 and No 4 (Fig. 14). The wing leading edge structure back to the forward spar was crushed. Then, the inner pole broke.
- The left wing tip rasped the earthen wing barrier, experiencing only slight flattening underneath its tip.
- The aircraft struck the 8^{o} hill after passing through the poles. While sliding up the hill, both wings failed at the wing roots and the fuselage broke.

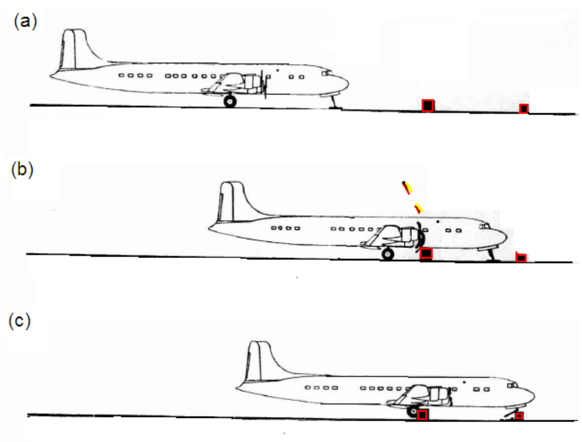

Fig. 12. Gear and propeller impact sequence: (a) aircraft approaching gear and propeller barriers; (b) impact with propeller barrier; (c) impact with main and front landing gear barrier [5].

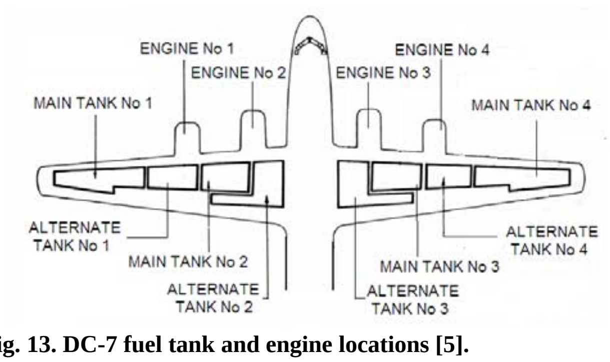

Fig. 13. DC-7 fuel tank and engine locations [5].

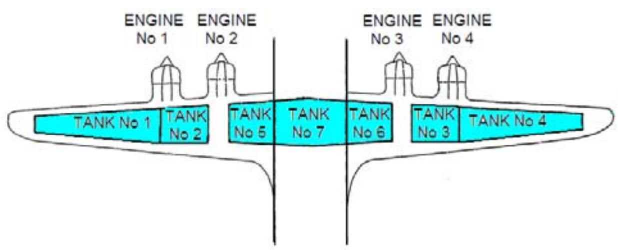

Fig. 14. LC-1649 fuel tank and engine locations [6].

- The aircraft slid along the 8^o slope of the hill and then struck the 20^o slope approximately 3.0 m (10 feet), vertically from the summit.
- The final impact occurred on the back side, at the foot of the hill. The main portion of the aircraft came to rest 262 m (860 feet) from the point of initial collision with the main landing gear barriers.
- During passing over the summit of the hill, the left wing, torn completely free, flew ahead of the fuselage and impacted approximately 15.2 m (50 feet) ahead of the main fuselage.
- The right wing remained fastened to the fuselage by the control wires and came to rest right side up.
- The aft section of the fuselage came to rest at a 45^o angle to the flight path and rolled over on its left side.
- The tail section of the aircraft broke partially free of the main fuselage.

Most of large pieces remained together during the entire sequence of test and came to rest in a small area on the center line of the original path. A lot of smaller parts were scattered over the crash site. Several small fires occurred when the aircraft broke up during the test [5].

Prior to the initial impact with the landing gear barriers, a voltage control regulator failed in the onboard data recording system resulting in the loss of all electronic data in the airborne recording system [5].

APPENDIX B. LC-1649 RELEASE AND CRASH SEQUENCE

The LC-1649 aircraft was prepared for full-scale dynamic test as follows [6]:

- Normal take-off configuration;
- Flaps positioned full up to reduce lift and drag;
- Upon release, the throttles were moved to the pre-determined power settings;
- Smooth acceleration along the guide rail until the impact with the propeller and landing gear barriers;
- Velocity of 207.4 km/h (112 knots).

The step-by-step crash test sequence of the LC-1649 is outlined below [6]:

- The left landing gear was broken and caused the engine No 2 (Fig. 14) to roll under the left wing.
- The right landing gear was also broken and severed the right vertical fin of the right horizontal stabilizer.
- The propeller of the engine No. 2 (Fig. 14) was sheared off by the landing gear barrier.
- The engines No 1, 3, and 4 (Fig. 14) and their propellers were intact, with the exception of one propeller blade of the engine No 3, which was sheared off by the right main gear barrier.
- The rail guide shoe was broken off on impact with the nose gear barrier. The gear strut was forced into the forward fuselage.
- After passing through the gear barriers and hitting the earth, propellers on engines No 1, 3, and 4 (Fig. 14) lost their blades. A tear in the wing structure adjacent to the engine nacelles became visible.
- The left wing struck the earthen barrier and started to separate from the fuselage at the wing root, while the right wing hit the poles.
- The first pole nearly sheared off the outer panel of the right wing and opened up the fuel tank No 4 (Fig. 14) about 7.6 m (25 feet) from the tip (Fig. 2). The second pole cut into the wing and the No. 3 fuel tank between the engines No 3 and No 4 (Fig. 14). The portion of the right wing inboard of the No 3 engine nacelle remained attached to the fuselage throughout the crash (Fig. 3).
- The fuselage contacted the ground at approximately the same time and as it slid along this partially severed right wing section, finally became separated, and came to rest upside down.
- The nose of the plane contacted the ground at the threshold of the 6^o slope and climbed into the hill. No major breakup of fuselage structure occurred during this impact.
- The impact with the 20^o degree slope broke the aft of the cockpit and aft of the galley.

The main landing gear, right vertical stabilizer and all major parts of the aircraft except for the engines came to rest in a small area with the fuselage nearly aligned with the line of the guide rail. Small fires resulted as the aircraft broke up during the crash [6].

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