SAE Aerospace
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AEROSPACE INFORMATION REPORT

SAE AIR5938

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Information on Hard Landings

RATIONALE

The industry requested that general reference information on hard landings be compiled including detection methods, inspection procedures, and historical incidence data.

TABLE OF CONTENTS

1. SCOPE

This document provides information on the current practices used by commercial and military operators in regards to hard landings (or overload events designated as hard landings). Since detailed information on inspections would be aircraft specific, this AIR provides only a general framework. Detailed information and procedures are available in the maintenance manuals for specific aircraft.

Because hard landings potentially affect the entire aircraft, guidelines are listed here for non-landing gear areas. But, the primary focus of the document is the landing gear and related systems. The document may be considered to be applicable to all types of aircraft.

This document does NOT provide recommended practices for hard landing inspections, nor does it provide recommendations on the disposition of damaged equipment. Refer to ARP 4915 and ARP 5600. Also, this document does not necessarily address overloads from circumstances other than landings, such as from tow vehicles, runway bumps, traversing cables, etc.

2. REFERENCES

2.1 Applicable Documents

The following publications form a part of this document to the extent specified herein. The latest issue of SAE publications shall apply. The applicable issue of the other publications shall be the issue in effect on the date of the purchase order. In the event of conflict between the text of this document and references cited herein, the text of this document takes precedence. Nothing in this document, however, supersedes applicable laws and regulations unless a specific exemption has been obtained.

2.1.1 SAE Publications

Available from SAE International, 400 Commonwealth Drive, Warrendale, PA 15096-0001, Tel: 877-606-7323 (inside USA and Canada) or 724-776-4970 (outside USA), www.sae.org.

AIR 4566 Crashworthy Landing Gear Design

ARP 4915 Disposition of Landing Gear Components Involved in Accidents/Incidents

ARP 5600 Disposition of Damaged Wheels Involved in Accidents/Incidents

ARP 5908 Landing Gear Servicing

2.1.2 AIA Publications

Available from Aerospace Industries Association, 1000 Wilson Boulevard, Suite 1700, Arlington, VA 22209-3928, Tel: 703-358-1000, www.aia-aerospace.org.

AIA Pub 05-01 Best Practices Guide, Inspection Procedures Following High Load Events

2.1.3 FAR Publications

Available from Federal Aviation Administration, 800 Independence Avenue, SW, Washington, DC 20591, Tel: 866-835-5322, www.faa.gov.

FAR 23 Federal Aviation Regulations - Airworthiness Standards: Normal, Utility, Acrobatic, And Commuter Category Airplanes, para. 23.473 “Ground load conditions and assumptions”

FAR 25 Federal Aviation Regulations - Airworthiness Standards: Transport Category Airplanes, para. 25.473 “Landing load conditions and assumptions”

FAR 27 Federal Aviation Regulations - Airworthiness Standards: Normal Category Rotorcraft, para. 27.725 “Limit Drop Test”

FAR 29 Federal Aviation Regulations - Airworthiness Standards: Transport Category Rotorcraft, para. 29.725 “Limit Drop Test”

2.1.4 Other Publications

AS8860	Landing Gear Structural Requirements as Listed in the MIL-886X Series of Specifications
CS 23	Certification Specifications For Normal, Utility, Aerobatic, and Commuter Category Aeroplanes, para. 23.473 “Ground load conditions and assumptions
CS 25	Certification Specifications for Large Aeroplanes, para. 25.473 “Landing load conditions and assumptions”
CS 27	Certification Specifications for Small Rotorcraft, para. 27.725 “Limit Drop Test”
CS 29	Certification Specifications for Large Rotorcraft, para. 29.725 “Limit Drop Test”
SAWE Recommended Practice 7	Mass Properties Management and Control for Military Aircraft
DOT/FAA/AR-97/106	Video Landing Parameter Survey- Washington National Airport
DOT/FAA/AR-00/72	Video Landing Parameter Survey- Honolulu International Airport
DOT/FAA/AR-96/125	Video Landing Parameter Survey - John F. Kennedy International Airport
DOT/FAA/AR-04/47	Commuter Aircraft Video Landing Parameter Surveys, Summary Report - London City Airport, Philadelphia International Airport, and Atlantic City International Airport
DOT/FAA/AR-07/53	Video Landing Parameter Survey- Summary Report, LHR Heathrow International
http://www.ntsb.gov/ntsb/query.asp	NTSB Aviation Accident Database

2.2 Definitions / Abbreviations

Accident: The NTSB defines Accident as an occurrence associated with the operation of an aircraft which takes place between the time any person boards the aircraft with the intention of flight and all such persons have disembarked, and in which any person suffers death or serious injury, or in which the aircraft receives substantial damage.

AIA: Aerospace Industries Association

AMM: Aircraft Maintenance Manual

Autoland: A system that fully automates the landing portion of an aircraft flight for low visibility and bad weather conditions.

CLDGW: Carrier Landing Design Gross Weight – The aircraft maximum gross weight specified for landing / arrestment operations on an aircraft carrier.

CG: center of gravity

DLW: Design Landing Weight – The highest aircraft gross weight corresponding to the maximum required sink rate. This definition is common for both military and commercial land based fixed wing aircraft and rotorcraft.

EASA: European Aviation Safety Agency

FAA: Federal Aviation Administration

FPI: Fluorescent penetrant inspection

Hard Landing: The term 'Hard Landing' can have multiple definitions. It can refer to the report or declaration of a landing event, where it is suspected that the landing gear or airframe structure, were possibly subjected to damage. Also, a 'Hard Landing' declaration is not necessarily limited specifically to the touchdown event. For aircraft which rely on pilot declaration, a hard landing may be declared based on other landing-related events such as flat tires, rolling off the runway, a heavily rolled landing, etc. 'Hard Landing' can also be used to describe those relatively few events where design landing conditions were truly exceeded resulting in damage or injury.

Incident: The NTSB defines Incident as an occurrence other than an accident, associated with the operation of an aircraft, which affects or could affect the safety of operations.

LLDGW: Landplane Landing Design Gross Weight – This term is used in military applications and is equivalent to the DLW. Typically, the following guidelines are used to establish LLDGW. For utility, observation, and trainer aircraft, LLDGW = maximum flight weight minus the following: payload to be expended, all external fuel, and 25% internal fuel. For cargo aircraft, LLDGW = maximum flight weight minus: all external fuel and 50% internal fuel. For combat aircraft, LLDGW = maximum flight weight minus: all external fuel and 60% internal fuel.

MLG: Main Landing Gear

MLW: Maximum Landing Weight (commercial) – The term MLW, used in a commercial environment, is synonymous with the DLW and corresponds to the highest gross weight for a 10 ft/s (3.05 m/s) landing for transport airplanes. The limit sink rate for part 23 aircraft is 7 to 10 ft/s. It is NOT the same as the military definition of Maximum Landing Weight.

MLW: Maximum Landing Weight (military) – The highest allowable weight for any landing. Typically, it is established by maximum flight weight minus any droppable external fuel tanks and fuel consumed or dumped during one go-around or 3 minutes, whichever provides the lightest aircraft weight. The military MLW term corresponds to the highest gross weight for a 6 ft/s (1.83 m/s) or 8.5 ft/s (2.59 m/s) landing depending on aircraft type.

MTOGW: Maximum Takeoff Gross Weight

NDI: Non Destructive Inspection

NLG: Nose Landing Gear

NTSB: National Transportation Safety Board

OEM: Original Equipment Manufacturer

Overload: A condition or event which may have subjected the landing gear or airframe structure to damaging loads.

Overweight Landing: A touchdown event occurring at a landing weight above the maximum certified landing weight for that aircraft. Other landing parameters such as the sink rate, side loads, strut servicing condition, etc. are not factors in declaring an 'overweight landing'.

S: As used in FAR 23 sink rate equation, S is the reference wing area in units of square feet for English units or square meters for SI units

SI: System Internationale

SAWE: International Society of Allied Weight Engineers

USN: United States Navy

W: As used in FAR 23 sink rate equation, W is the aircraft gross weight in units of lb. for English units or kg for SI units

3. BACKGROUND OF LANDING DESIGN REQUIREMENTS

The table below describes the limit sink rates and aircraft gross weights used for various types of aircraft. For the land based fixed wing aircraft, these limit sink rates are for zero roll angle, zero roll rate, and 100% lift conditions.

TABLE 1 – LANDING DESIGN REQUIREMENTS

Aircraft Type	**Gross Weight**	**Limit Sink Rate, ft/s**	**Limit Sink Rate, m/s**
FAR 23	Design / Maximum Landing Weight	$4.4\ (W/S)^{0.25}$ Must be ≥7 Need not exceed 10	$0.902\ (W/S)^{0.25}$ * Must be ≥2.133 Need not exceed 3.05 m/s
FAR 25	Design / Maximum Landing Weight	10	3.05
	Max Takeoff Gross Weight	6	1.83
US Land Based Fighter / Bomber	DLW (Landplane Landing Design Gross Weight)	10	3.05
	Maximum Landing Weight	6	1.83
US Land Based Trainer	DLW (Landplane Landing Design Gross Weight)	13	3.96
	Maximum Landing Weight	8.5	2.59
US Ship Based Fixed Wing	Carrier Landing Design Gross Weight	See note**	N/A
FAR 27	Max Takeoff Gross Weight	8	2.44
FAR 29	Max Takeoff Gross Weight	6.55	2.00
US Military Rotorcraft	Various; refer to applicable requirements	12 (design)	3.66 (design)

* Note: Gross weight (W) must be in kg and reference wing area (S) must be in m^2 for this equation
** Note: landing sink rates are design values, unique to the aircraft, based on multivariate analysis accounting for approach speed, roll rate, ship motion, etc. Typical values for design sink rate are 25 – 28 ft/s.

For commercial transport applications, landing gear design landing loads are governed by the following regulations. The first part of FAR 25.473 states "the airplane is assumed to contact the ground 1) in the attitudes defined in 25.479 and 25.481; 2) with a limit descent velocity of 10 ft/s (3.05 m/s) at the design landing weight; and 3) with a limit descent velocity of 6 ft/s (1.83 m/s) at the design take-off weight. This requirement and those defined for side and drag loads in 25.479, 481 and 485 establish the threshold above which hard landing events occur.

For commercial small airplane applications, landing gear design landing loads and the threshold above which hard landings occur, are governed by the following regulations: FAR 23.471, 23.473, 23.479, 23.481 and 23.485.

On land based US military applications, the design loads are given in AS8860 (formerly the MIL-L-886X series). Background information is also available in JSSG 2006 and JSSG 2009 Appendix A. For trainers, the limit sink rates are 13 (3.96 m/s) and 8.5 ft/s (2.59 m/s) at LLDGW and MLW respectively. All other classes of aircraft have limit sink rates of 10 (3.05 m/s) and 6 ft/s (1.83 m/s) for those same weights. Also, the landing gear design limits shall not be exceeded by landing at 15% higher sink rates as long as the weights are 15% lower. The conventional military aircraft criteria differ slightly from the commercial requirement in that the 6 ft/s sink rate applies at a Maximum Landing Weight and not necessarily at the takeoff weight.

US Navy design requirements for landing loads also come from AS8860, section 3.1.4.8. For carrier based aircraft, the analysis involves a complex multivariate check of probabilities of various factors to establish a design sink rate. The typical sink rate is between 25 and 28 ft/s (7.62 and 8.53 m/s). Note that USN carrier applications treat landing loads as design loads, not as limit / ultimate loads like US Air Force and commercial applications.

4. HARD LANDING EVENT SEQUENCES

4.1 Civil (Part 25) Aircraft

The typical hard landing inspection sequence for commercial aircraft is shown in Figure 1.

The upper section of the figure addresses those conditions normally reported by the flight crew. One set of causes is what is commonly thought of when referring to hard landings. They include conditions during the touchdown event: high sink rate, high roll angle or roll rate, bounced landing, or high de-rotation rate onto the nose gear. Another set of causes listed are secondary events which may require a hard landing inspection. They include skidding during rollout, overrunning the end of runway, landing short, etc. These are sometimes referred to as ‘high drag / side load landings’. Another unique source of a hard landing declaration is having a tricycle configuration airplane touchdown on its nose gear first. Often, the aircraft maintenance manuals have separate, specialized inspection procedures for those occurrences. Although not strictly a hard landing event, the flight crew will report instances when the maximum certified landing weight was exceeded, known as an overweight landing. These events may result in the same damage and may have the same inspection procedures as hard landings. There may be additional inspections required for overweight landings, such as tires and brakes, due to the high landing speeds involved. In some cases, inspections may be waived for overweight landings if the sink rate is low.

After the flight crew, another source for hard landing declarations is an on-board automated system to identify such events. These systems generally rely upon processing aircraft CG acceleration, sink rate, roll data, etc. A similar system used by the USN is described in Section 4.3. Another possible approach for an automated system is to use instrumentation on the landing gear itself. By monitoring strut stroke, strut dynamic pressure, or calibrated strain gages, a more accurate assessment can be made of the landing conditions. Using such instrumentation is commonplace during flight testing. However, in fleet service, most operators recognize that additional landing gear instrumentation results in higher maintenance requirements.

The third source of hard landing declarations comes from the maintenance personnel. If damage is found during other routine activities, the ground maintenance crew can report the occurrence and formally call for a set of hard landing inspections.

A final possible driver of hard landing declarations and resulting actions is the post flight review of flight data. Although this is seldom done without one of the other causes, there are exceptions. Recently, some aviation authorities began calling for hard landing inspections months after the actual flight following post-flight review of flight data.

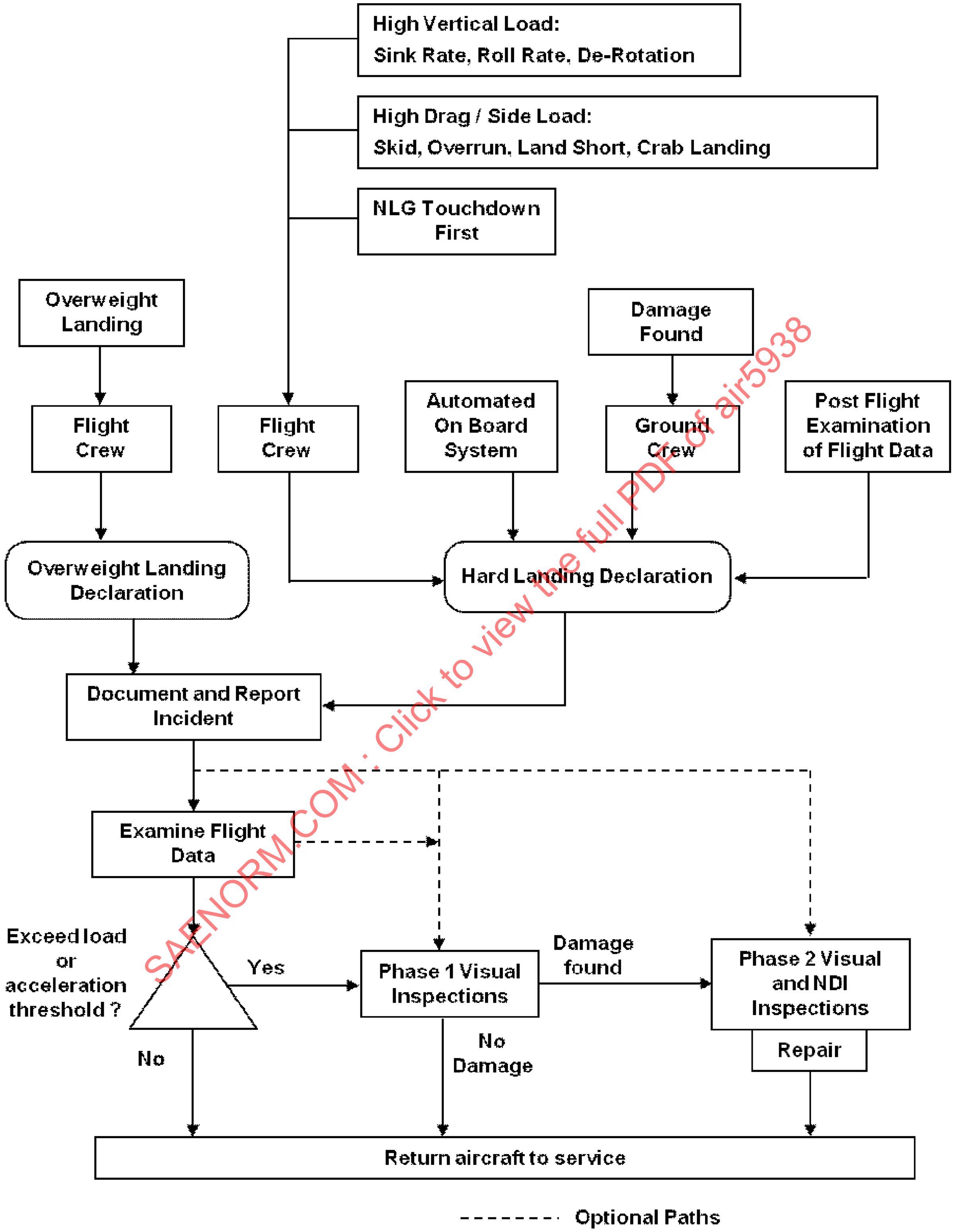

FIGURE 1 - COMMERCIAL HARD LANDING EVENT SEQUENCE

As shown in Section 3, vertical sink rate and aircraft gross weight are the primary parameters driving hard landings. However, sink rate data accurate enough to assess hard landings is not always available. As a result, most aircraft use acceleration load factors obtained with data from inertial navigation systems. If the load factor threshold is exceeded, the operator may choose to contact the airframe manufacturer for consultation. In most cases, the inspections are conducted regardless. An exception to this is when an onboard hard landing indication system is used. For this case, if the threshold(s) are not exceeded, no inspection is performed.

The accelerometer data usually comes from sensors associated with the flight data recorder, not sensors that are dedicated to hard landing detection. But, systems with dedicated hard landing acceleration sensors are being developed. The measured vertical load factors at which a hard landing is indicated, are generally 1.3 – 2.5g for a 2 point MLG touchdown with small roll and crab angles. The acceleration levels depend on the specific location, filtering, and sample rate of the accelerometer. Some models provide different thresholds dependent on the sample rate. The load factors are usually provided in the AMM. A typical landing envelope can be described by the graph in Figure 2.

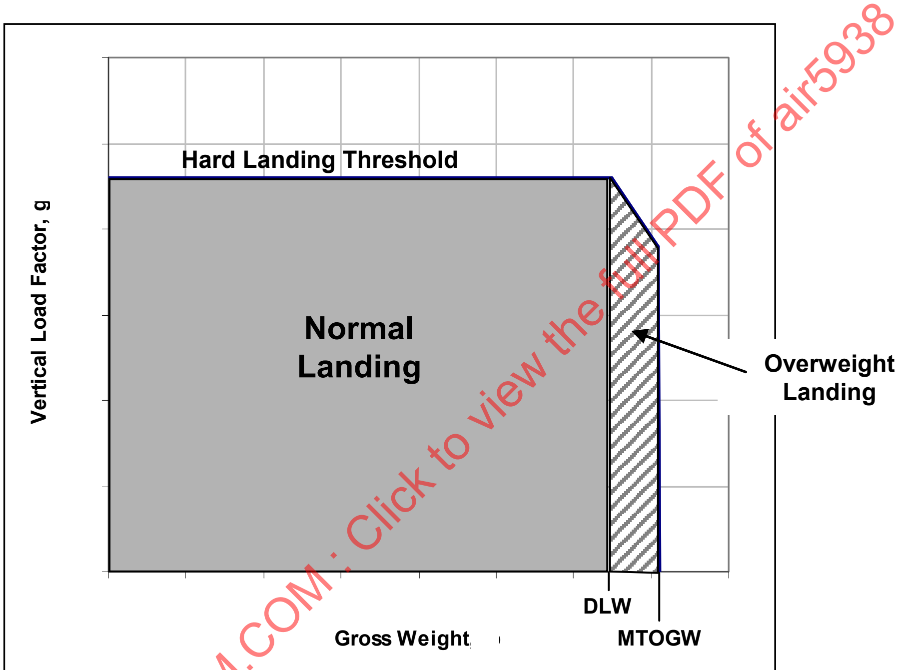

FIGURE 2 - EXAMPLE OF COMMERCIAL AIRCRAFT LANDING ENVELOPE

Also, some aircraft have two hard landing thresholds. Instead of load factor versus gross weight, one aircraft OEM includes a chart of aircraft vertical load factor versus sink rate in their AMMs. This chart includes 3 regions to categorize the severity of the landing. Using the load factor and sink rate parameters, the operator will determine where the particular landing falls on the chart. In the lowest severity region, there is no overload and the aircraft can be returned to service without inspections. In the middle region, a report must be made to the aircraft OEM and inspections carried out. Then, the aircraft is released to service for 30 days while the aircraft OEM performs analysis of the data to determine the final disposition. The third region is the most severe and requires that a report be made, inspections be carried out immediately, and the aircraft be grounded pending analysis by the aircraft OEM to determine the final disposition. In some cases, landing gear components could be scrapped based on analysis alone and not on inspection results.

Most major aircraft manufacturers have a dynamic aircraft model, validated by drop test and flight test measurements, that is used to simulate the hard landing event and predict ground loads, landing gear shock absorber strokes, etc. The hard landing event flight data is input into the model and the aircraft vertical sink rate is iterated until the aircraft acceleration is matched. The predicted ground loads, landing gear shock absorber strokes, and other data are supplied to the landing gear OEM for assessment of overload to allow the disposition of landing gear parts to be determined.

The Figure 1 flowchart refers to two sets of inspections: Phase 1 and Phase 2. Phase 2 inspections are more thorough and are usually done only if damage is found in the Phase 1 inspections or the OEM requests a deeper inspection based on the severity of the event. For example, NDI is only performed in the Phase 2 inspections for most aircraft. Also, some AMMs call for the aircraft to be put on jacks or even have the landing gear removed completely for the Phase 2 inspections.

Some inspections are quite unique. For example, one aircraft has a levered bogie design where the lower articulation link is specially designed to be a hard landing overload indicator. Following a severe hard landing, the link can be subjected to precision inspection to measure its permanent deformation. This deformation is used to confirm the landing loads. Given the precision of the inspection and the design data required, this assessment is only carried out by the landing gear OEM.

Also, some aircraft have used a follow up inspection of the gear to be carried out some period of time after the affected hardware was returned to service. The purpose of this inspection was to verify that cracks did not develop afterwards in the overstressed areas.

4.2 USAF Aircraft

Hard landing declarations within the US Air Force are generally made by the flight crew. Service information on many tactical and transport aircraft show that hard landings have not been a significant problem for the USAF.

Figure 3 shows the typical USAF flowchart for hard landing inspections. There are just minor differences from the commercial sequence. First, the USAF usually has only one level of inspections. Second, the USAF usually only performs NDI if damage is found in the visual inspections or if the flight crew comments are severe, although there are cases where NDI inspections are immediately called for. And finally, the examination of flight data from hard landings is not usually done.

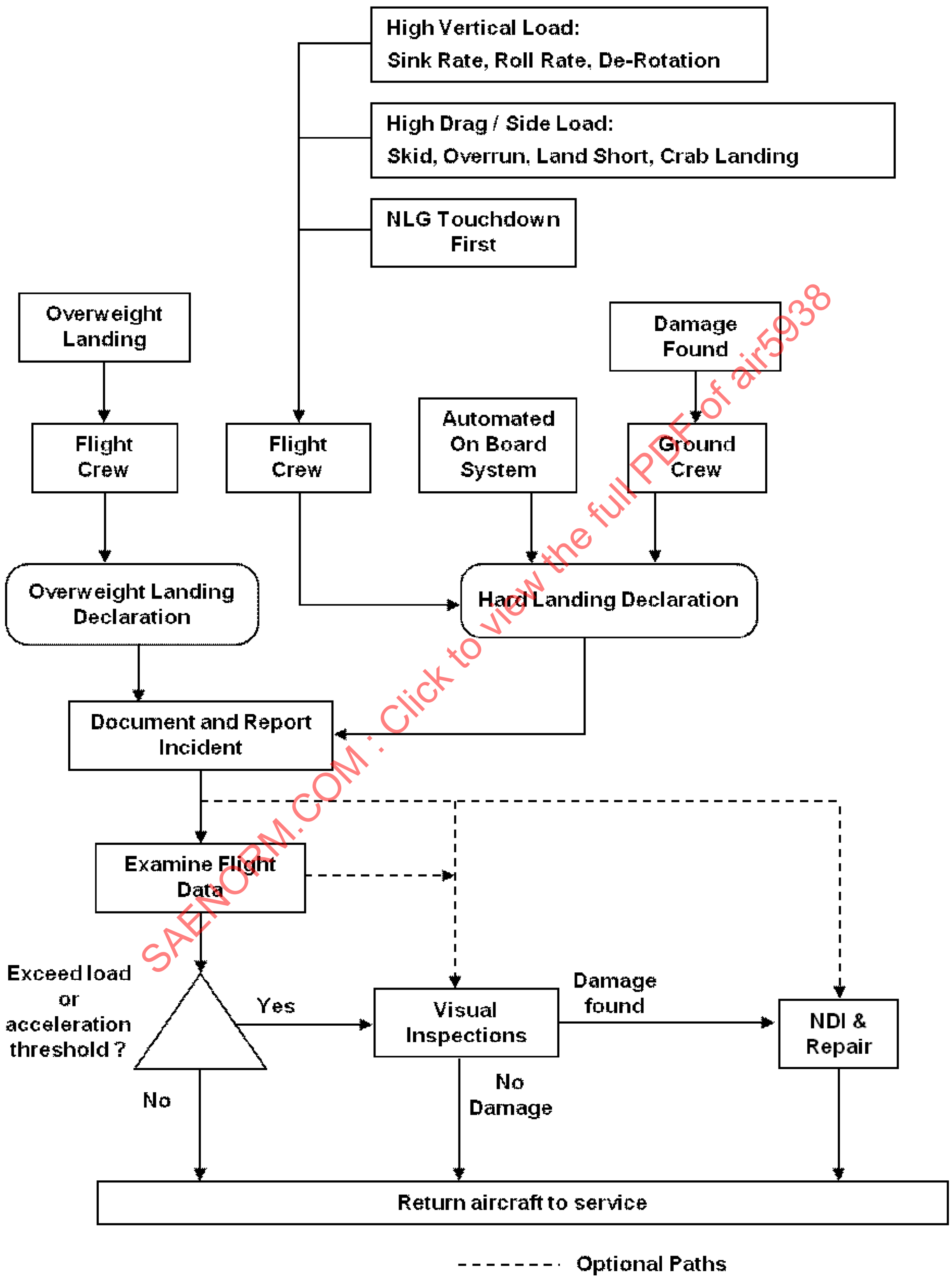

FIGURE 3 - US AIR FORCE HARD LANDING EVENT SEQUENCE

4.3 USN Carrier Based Aircraft

The USN has been particularly prone to problems from hard landings during carrier operations. Older aircraft relied upon flight crew declaration, but carrier landings are often violent enough that an accurate differentiation is not possible. As a result, damage to the landing gear and airframe sometimes went undetected. Parts would suffer yielding in compression resulting in high tensile residual stresses leading to catastrophic stress corrosion cracking failures at a later time. Some USN carrier based aircraft have implemented an automated system for detection of hard landings. This system was developed with the goal of not adding any additional sensor hardware to the aircraft. Instead, the data from existing accelerometers is evaluated by a sophisticated software algorithm that determines if a hard landing declaration is warranted. The US Navy system typically has two levels of hard landing severity expressed in terms of acceleration level. These two levels determine which series of inspections should be performed. See Figure 4. Since implementation of the automated system, the Navy has experienced a significant reduction in latent failures from earlier hard landings.

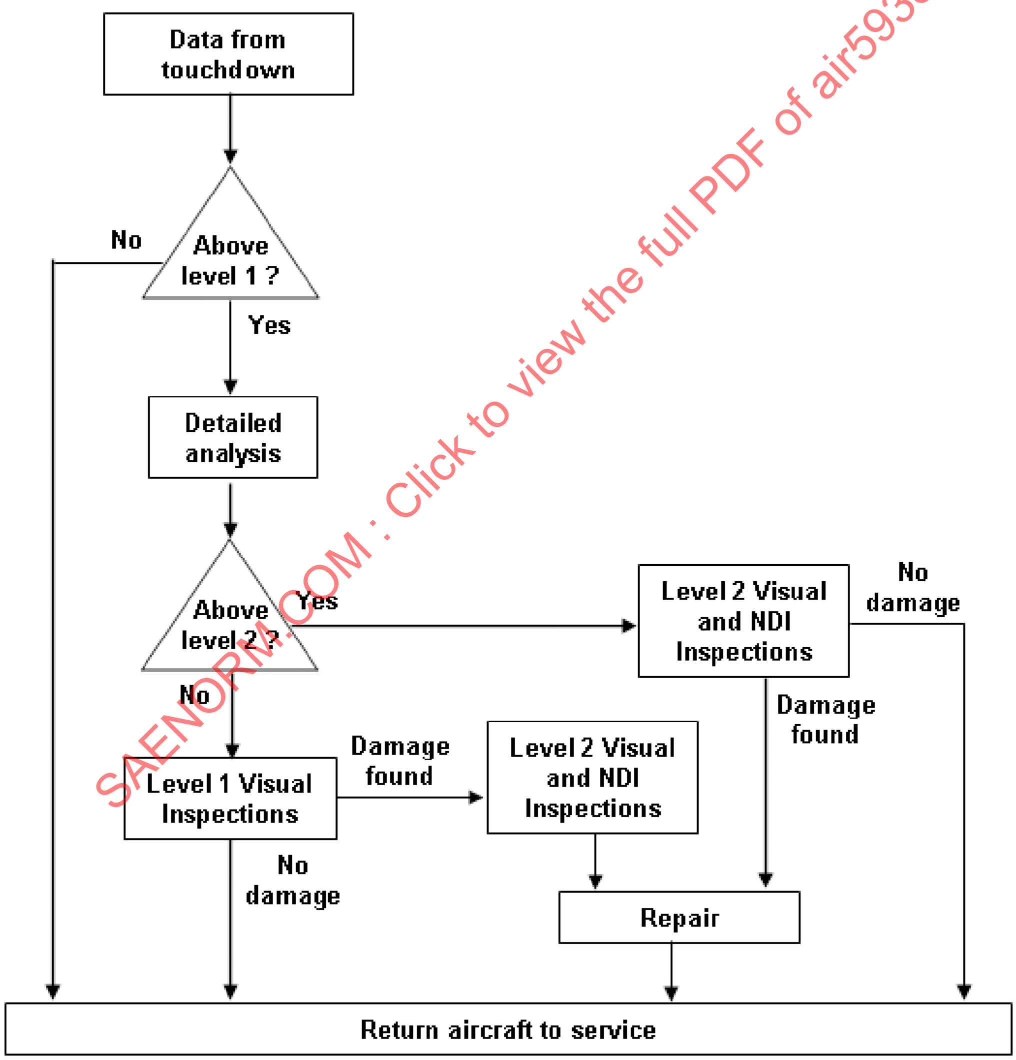

FIGURE 4 - USN CARRIER HARD LANDING EVENT SEQUENCE

4.4 Rotorcraft

The standard landing requirements for helicopters are given in Table 1 above. Many newer US military helicopters are also designed for stringent crash landing conditions with sink rates up to 42 ft/s. While this is an aircraft level requirement, the landing gear designs for these aircraft are used to absorb a large portion of the total energy for these emergency cases. They can use structural fuse type designs including honeycomb core, shear pins, etc. When failed, these components need to be replaced to restore the crashworthiness of the aircraft. For information on crashworthiness requirements, refer to AIR 4566. Otherwise, rotorcraft will undergo the same inspections as fixed wing aircraft, with the addition of rotorcraft mechanisms (main rotors, rotor hubs, and tail rotors).

4.5 Others

Some international aircraft have hard landing indication systems. The Mirage 2000 employs an acceleration indicator on the MLG. Some Mikoyan aircraft have used a small thin aluminum plate mounted so that a piece of the landing gear structure would make an indentation in the plate if the strut bottomed. The Russian civilian aviation authorities report no special hard landing device on any transport aircraft.

Unmanned aircraft cannot rely upon the flight crew for reporting of hard landings and frequently use a visual indicator much like the rotorcraft. Often, a thick rubber washer or 'donut' is used that gets damaged or partially extruded through an opening if the strut bottoms.

One major landing gear supplier has developed a generic hard landing detection system for determining the precise landing conditions of an aircraft and whether a given landing event exceeds the design or regulatory limits. The system uses high-speed inertial (6 degrees of freedom) data.

5. INSPECTIONS

5.1 Types of Damage

The following is a listing of damage looked for in both the landing gear and non landing gear series of inspections. Although it should be noted that many AMMs are somewhat ambiguous in describing the types of damage.

Cracks

Twisted / bent parts

Paint cracked / chipped / flaking

Loose fasteners

Elongated fastener holes

Delaminations

Fluid leakage

Wrinkled skins/ webs

Misalignment

Galling

5.2 Landing Gear Visual Inspections

As mentioned above, some commercial aircraft divide the inspections into two Phases. The first Phase inspections are typically carried out directly on the aircraft. Special NDI procedures are usually not employed. Most military aircraft simply call out a single series of inspections.

Note: This list is an overall compilation of inspections from various aircraft. It is unlikely that any aircraft explicitly requires all these inspections.

Axles

Shock strut leakage

Shock strut integrity

Drag braces / side braces

Jury links and lock links

Door linkages

Fusible pins (if applicable)

All a/c attach fittings

Adjoining airframe structure

Truck beams / positioners

Actuators

Bungees

Landing gear alignment

Special components designed to serve as hard landing indicators

On commercial aircraft, Phase 2 inspections are carried out if the Phase 1 inspections indicate damage. The inspections are generally performed with the aircraft on jacks because there is usually a need to remove some components for access. The following list is typical of the Phase 2 inspections.

Assembly dimensional checks

Gear extend / retract test

Strut fluid level check

Brake assemblies

Outer cylinder lugs

All bolts / pins

Remove and inspect NLG piston

Test performance and rigging of nose wheel steering system

Test flight control cables for proper rigging

Check joint lubrication

Note, some aircraft operators that use only a single (Phase 1) set of inspections may include dimensional checks in those procedures.

5.3 Landing Gear Non Destructive Inspections

NDI methods are not always called for in the inspection procedures. However, a number of military aircraft do specify various NDI tests and they are sometimes included in commercial Phase 2 inspection procedures. These tests are performed on the most critical components (pins, bolts) or high stress locations such as small radii on larger parts. The NDI tests may include:

Component dimensional checks for yielding

Rollscan - a measurement of residual stresses and microstructure changes in common steel alloys using the magnetic Barkhausen noise method

Fluorescent penetrant inspection (FPI)

Magnetic particle inspection - used on steels only

Eddy Current testing

Ultrasonic inspection - can be required for composite airframe structure

5.4 Rolling Stock Inspections

The tires and wheels are subject to various inspections when hard landings are reported or suspected. These are often the same inspections performed on a scheduled basis at a specified number of tire changes. These inspections are listed below.

Tire tread

Tire sidewall

Inflation valve and threads

Pressure relief valve threads

Tie bolt visual inspection

Tie bolt FPI

Bearing cup and cone visual inspection

Wheel halves visual inspection

Wheel roundness shop inspection

Wheel halves eddy current inspection

Wheel halves FPI

Fuse plug visual inspection

Drive keys visual inspection

5.5 Non Landing Gear Inspections

The following areas are typically inspected along with the landing gear assemblies under both Phase 1 and Phase 2 inspections. Damage types are the same.

MLG bay

NLG bay

Wing skins

Wing to fuselage fittings

Fuselage underside

Fuselage skin

Fuselage stringers

Engine struts / nacelles / cowl doors

Engine strut fuse pins

Tail bumpers

Empennage

Elevators

Stabilizers

Rudders

Cargo / cabin areas (if applicable)

Auxiliary power unit support structure

Vertical tail support structure

6. INCIDENCE DATA ON HARD LANDINGS FOR COMMERCIAL TRANSPORTS

Note, this section presents commercial fixed wing aircraft data from various sources taken during very limited timeframes. The data are included to help provide a basic understanding of the frequency of hard landing occurrences. The data are not intended to be used for aircraft design purposes or as planning guidance for airplane operators.

6.1 NTSB Accidents and Incidents

The first set of data on hard landings was collected from the NTSB Accident / Incident database for the period of 1997 – 2006. The data in Table 2 covers type 121 common carriers and type 135 air taxi and commuters. Data were also gathered for overruns and overweight landings. There did not appear to be duplication of events between those reported as hard landings and those for overruns or overweight landings. In this same period, there were 39 incidents listed as major accidents. 6 of those were related to hard landings or landing related overloads described in Figure 1. It is noted that these statistics only include landing events leading to damage, and do not include hard landings reported by pilots that incurred no damage.

TABLE 2 - HARD LANDING INCIDENT DATA FROM NTSB ACCIDENT / INCIDENT DATABASE

	Departures	Hard Landings	Hard Landings per M Depart	Overruns	Overruns per M Depart	Overweight Landings	Overwt Ldgs per M Depart
Part 121							
1997	9925058	2	0.202	2	0.202	0	0.000
1998	10535196	1	0.095	0	0.000	0	0.000
1999	10860692	3	0.276	1	0.092	0	0.000
2000	11053826	3	0.271	2	0.181	0	0.000
2001	10632880	2	0.188	1	0.094	1	0.094
2002	10276107	0	0.000	1	0.097	1	0.097
2003	10227924	0	0.000	2	0.196	0	0.000
2004	10782989	1	0.093	1	0.093	0	0.000
2005	10910460	1	0.092	0	0.000	0	0.000
2006	11200000	1	0.089	0	0.000	0	0.000
		Avg	0.131				
Part 135							
1997	1394096	0	0.000	2	1.435	0	0.000
1998	707071	3	4.243	2	2.829	0	0.000
1999	672278	1	1.487	1	1.487	0	0.000
2000	603659	3	4.970	1	1.657	0	0.000
2001	558052	0	0.000	0	0.000	0	0.000
2002	513452	1	1.948	4	7.790	0	0.000
2003	572260	3	5.242	2	3.495	0	0.000
2004	538077	3	5.575	2	3.717	0	0.000
2005	527267	4	7.586	1	1.897	0	0.000
2006	500875	2	3.993	1	1.997	0	0.000
		Avg	3.504				

6.2 FAA/USN Landing Parameter Surveys

In 1994, the FAA and US Navy began conducting a series of video landing parameter surveys at various commercial airports to acquire a better understanding of typical landing conditions. These surveys are described in Table 3.

TABLE 3 - SCOPE OF FAA/USN LANDING SURVEYS

Aircraft Type	Aircraft Models	Total # Landings	Airports
Narrow		978	JFK, DCA, ACY
	B727	218	
	B737	150	
	B757	140	
	MD-90-30	190	
	DC-9	254	
	A320	26	
Wide		328	JFK, LHR
	B767	217	
	A300	81	
	A310	30	
Heavy Wide		786	JFK, HNL, LHR
	B747	376	
	B777	92	
	L-1011	73	
	DC-10	163	
	MD-11	28	
	A330	22	
	A340	32	