COMANDO DA AERONÁUTICA

CENTRO DE INVESTIGAÇÃO E PREVENÇÃO DE ACIDENTES AERONÁUTICOS

FINAL REPORT
A - 501/CENIPA/2015

OCCURRENCE:	**ACCIDENT**
AIRCRAFT:	**N988AR**
MODEL:	**MD-11F**
DATE:	**13 OCT 2012**

NOTICE

According to the Law nº 7565, dated 19 December 1986, the Aeronautical Accident Investigation and Prevention System – SIPAER – is responsible for the planning, guidance, coordination and execution of the activities of investigation and prevention of aeronautical accidents.

The elaboration of this Final Report was conducted taking into account the contributing factors and hypotheses raised. The report is, therefore, a technical document which reflects the result obtained by SIPAER regarding the circumstances that contributed or may have contributed to triggering this occurrence.

The document does not focus on quantifying the degree of contribution of the different factors, including the individual, psychosocial or organizational variables that conditioned the human performance and interacted to create a scenario favorable to the accident.

The exclusive objective of this work is to recommend the study and the adoption of provisions of preventative nature, and the decision as to whether they should be applied belongs to the President, Director, Chief or the one corresponding to the highest level in the hierarchy of the organization to which they are being forwarded.

This Report does not resort to any proof production procedure for the determination of civil or criminal liability, and is in accordance with item 3.1, Annex 13 to the 1944 Chicago Convention, which was incorporated in the Brazilian legal system by virtue of the Decree nº 21713, dated 27 August 1946.

Thus, it is worth highlighting the importance of protecting the persons who provide information regarding an aeronautical accident. The utilization of this report for punitive purposes maculates the principle of "non-self-incrimination" derived from the "right to remain silent" sheltered by the Federal Constitution.

Consequently, the use of this report for any purpose other than that of preventing future accidents, may induce to erroneous interpretations and conclusions.

N.B.: This English version of the report has been written and published by the CENIPA with the intention of making it easier to be read by English speaking people. Taking into account the nuances of a foreign language, no matter how accurate this translation may be, readers are advised that the original Portuguese version is the work of reference.

SYNOPSIS

This the Final Report of the 13 October 2012 aeronautical accident with the MD-11F aircraft, registration N988AR. The accident was classified as “system/component failure”.

The aircraft took off from KMIA (Miami International Airport) destined for SBKP (Viracopos Airport). Upon landing at the destination, the left main gear collapsed when the aircraft touched down on the runway. Before coming to a stop, the aircraft skidded on the runway for approximately 800 meters.

The aerodrome firefighters successfully applied a chemical agent with the purpose of preventing fire from catching up.

The two pilots and the mechanic got out uninjured. The aircraft sustained substantial damage to the left main gear assembly, left wing and left engine.

An accredited representative of the National Transportation Safety Board – NTSB (USA) was designated for participation in the investigation in accordance with the NSCA 3-13 and ICAO Annex 13.

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GLOSSARY OF TECHNICAL TERMS AND ABBREVIATIONS

ADC	Air Data Computer
AGL	Above Ground Level
ANAC	(Brazil's) National Civil Aviation Agency
AOM	Aircraft Operating Manual
ATC	Air Traffic Control
ATIS	Automatic Terminal Information Service
ATS	Air Traffic Services
CENIPA	Aeronautical Accident Investigation and Prevention Center
CHT	Technical Qualification Certificate
CVR	Cockpit Voice Recorder
DCTA	Aerospace Technology and Science Department
FAA	Federal Aviation Administration
FAR	Federal Aviation Regulations
FCC	Flight Control Computer
FCOM	Flight Crew Operating Manual
FDR	Flight Data Recorder
IFR	Instrument Flight Rules
ILS	Instrument Landing System
Lat	Latitude
Long	Longitude
METAR	Aerodrome routine weather report
NTSB	National Transportation Safety Board
KMIA	ICAO location designator – Miami International Airport
PF	Pilot Flying
PM	Pilot Monitoring
RWY	Runway
SBKP	ICAO location designator – Viracopos Airaport
SIPAER	Aeronautical Accident Investigation and Prevention System
TWR	Control Tower
UTC	Coordinated Universal Time
Vapp	Target Approach Airspeed

1. FACTUAL INFORMATION.

Aircraft	**Model:** MD-11F **Registration:** N988AR **Manufacturer:** McDonnell Douglas	**Operator:** Centurion Cargo
Occurrence	**Date/time:** 13 OCT 2012 / 21:52 UTC **Location:** Viracopos Aerodrome (SBKP) **Lat.** 23º00'27"S **Long.** 047º08'04"W **Municipality – State:** Campinas – SP	**Type(s):** System/component failure

1.1 History of the flight.

On 13 October 2012, the Centurion Cargo-operated MD-11F aircraft of American registration (N988AR) took off from Miami International Airport (KMIA), destined for Viracopos Airport (SBKP), with two pilots and a mechanic on board, on a non-regular cargo transport flight. The flight was uneventful up to the moment its landing in SBKP.

On the approach for landing on runway 15, the crew performed the IFR ILS Z procedure. The weather conditions were VMC, with the wind coming from 140º at 19kt. When the aircraft was granted clearance to land, the wind strength was 20kt, gusting up to 29kt. The copilot was the Pilot Flying (PF), and the captain was the Pilot Monitoring (PM) at the moment of landing.

When the aircraft touched down on the runway after the flare, the left main landing gear collapsed, causing the aircraft to skid on the runway for approximately 800 meters before stopping. There was substantial damage to the left main gear assembly, to the left wing, and left engine.

The aircraft stopped within the runway limits.

1.2 Injuries to persons.

Injuries	Crew	Passengers	Others
Fatal	-	-	-
Serious	-	-	-
Minor	-	-	-
None	3	-	-

1.3 Damage to the aircraft.

The aircraft sustained substantial damage to the left main gear assembly, left wing, and left engine.

Figure 1 – Position of the aircraft on the runway, showing the damage to the left main gear, left wing and left engine.

1.4 Other damage.

None.

1.5 Personnel information.

1.5.1 Crew's flight experience.

Hours Flown		
	Pilot	Copilot
Total	12,900:00	5,198:00
Total in the last 30 days	38:50	44:40
Total in the last 24 hours	07:30	07:30
In this type of aircraft	Unknown	1,368:00
In this type in the last 30 days	38:50	44:40
In this type in the last 24 hours	07:30	07:30

N.B.: Data relative to the hours flown were provided by the aircraft operator.

1.5.2 Professional formation.

The aircraft captain studied at the Edward Pace High School (graduated in 1985 with Diploma) and at Saint Thomas University (Sixty college credits).

The Copilot had a College of Aeronautics Associate Degree.

1.5.3 Category of licenses and validity of certificates.

The captain was certified as an Airline Transport Pilot by the FAA (last issuance 27 June 2012), and was qualified in the following aircraft: A-320, B-727, B-747, B-757, B-767, DC-10, and MD-11.

The copilot was certified as a Commercial Pilot by the FAA (last issuance 24 AUG 2010), and was qualified in the following aircraft: C-172, PA-28, PA-44 and MD-11. He also had a flight engineer license for B-727 and DC-10 aircraft.

1.5.4 Qualification and flight experience.

The captain was part of the Centurion Cargo team of professionals since March 2003.

The Copilot was part of the Centurion Cargo team of professionals since July 2005.

Both pilots had valid technical qualification certificates for MD-11 aircraft. They had qualification and enough experience for the flight proposed by the aircraft operator.

1.5.5 Validity of medical certificate.

The pilots had valid First Class Medical Certificates issued by the FAA.

1.6 Aircraft information.

The Boeing MD-11F aircraft (Serial Number 48434), American registration N988AR, was manufactured by McDonnell Douglas in 1991, and had an airworthiness certificate valid until 6 October 2026.

1.7 Meteorological information.

The aerodrome routine weather reports (METAR) of SBKP around the time of the accident were the following:

SBKP - 132000Z 13020KT 9999 FEW025 SCT030 BKN090 19/14 Q1020

SBKP - 132100Z 14018KT 9999 FEW018 SCT030 BKN090 18/14 Q1020

SBKP - 132200Z 13018G31KT 9999 FEW018 SCT045 BKN090 18/13 Q1020

The prevailing weather conditions were VMC.

The wind reported by the control tower when the aircraft was on the final approach was 150 degrees at 19kt, and when the aircraft was granted landing clearance, the wind was 140 degrees at 20kt, gusting up to 29kt.

The meteorological information transmitted by the Automatic Terminal Information Service (ATIS), and received by the crew approximately 15 minutes before landing, indicated the following:

- wind 150 degrees, 20kt, gusting up to 29kt;
- Visibility more than 10km;
- Cloud cover broken, with ceiling at 9,000ft;
- QNH 1020;
- Temperature 17ºC.

1.8 Aids to navigation.

Operating normally, as expected.

1.9 Communications.

Two-way radio communications with ATC units were adequate.

1.10 Aerodrome information.

SBKP is a public aerodrome under INFRAERO administration. It operates VFR/IFR during day- and night-time.

The runway is covered with asphalt, thresholds 15/33, measuring 3,240m x 45m, at an elevation of 33ft.

1.11 Flight recorders.

The aircraft was equipped with a Flight Data Recorder (FDR) and a Cockpit Voice Recorder (CVR).

The pieces of information contained in the FDR and CVR were retrieved and analyzed at the CENIPA's Data Laboratory (LABDATA). The result of the analysis was the following:

- The pilots complied with the prescriptions of the aircraft manuals;
- The aircraft was adequately configured, and maintained a speed which was appropriate for its weight, considering the wind strength informed at the moment the aircraft was cleared to land by the control tower (20kt, gusts up to 29kt);
- The aircraft maintained a speed of 165kt on the final approach;
- On the approach, upon passing 50ft, the Pilot Flying reduced the throttles and started the flare, with a pitch of 5.5 degrees;
- The aircraft was stabilized with 5.5 degrees of pitch at the moment of touchdown;
- Upon touching down on the runway, the aircraft had approximately 1 degree of roll-attitude to the left at a roll-rate of 1 degree per second;
- The aircraft sink rate was 10ft./sec;
- The energy absorbed by the left main gear (Left MLG Energy) was 287,200ft/lb;
- The energy absorbed by the right main gear (Right MLG Energy) was 360,300ft/lb; and
- The energy absorbed by the center main gear (Center MLG Energy) was 360,300 ft/lb.
- When the aircraft touched down on the runway, the left main gear collapsed.

The analysis of the FDR data at the NTSB provided the same pieces of information already obtained by the CENIPA's LABDATA.

1.12 Wreckage and impact information.

Nil.

1.13 Medical and pathological information.

1.13.1 Medical aspects.

Not investigated.

1.13.2 Ergonomic information.

Nil.

1.13.3 Psychological aspects.

Not investigated.

1.14 Fire.

No signs of either inflight or post-impact fire.

1.15 Survival aspects.

Nil.

1.16 Tests and research.

The left main gear structure, the cylinder, and the set of parts composing the left main gear were taken to the Materials Analysis Laboratory of the Aerospace Technology and Science Department (DCTA) for analysis of failures. The figures below make it possible to understand the cause of the cylinder fracture.

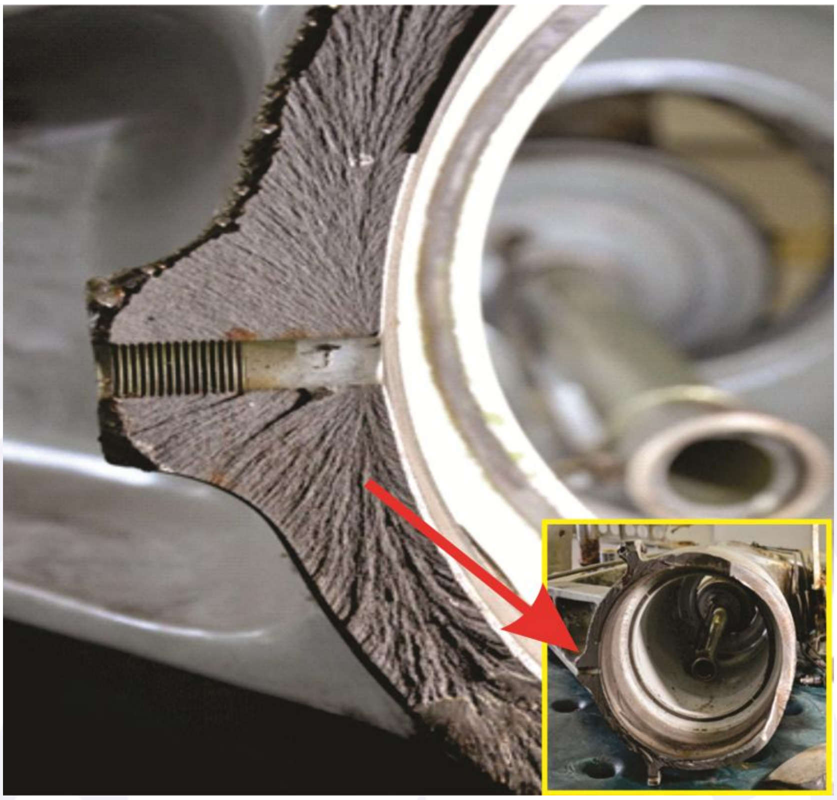

Figure 2- Fractured cylinder. Fracture surface with chevron markings.

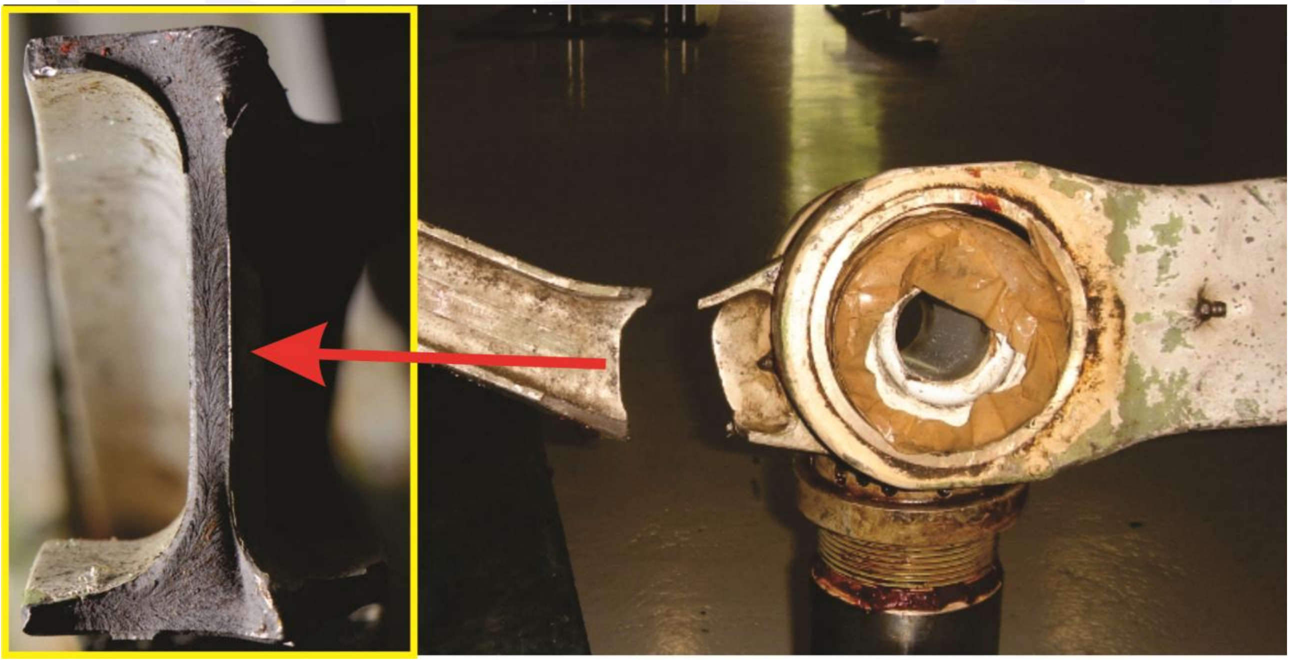

Figure 3 – Fractured articulated-arm seen from the side and from the front. The fracture occurred on account of overload.

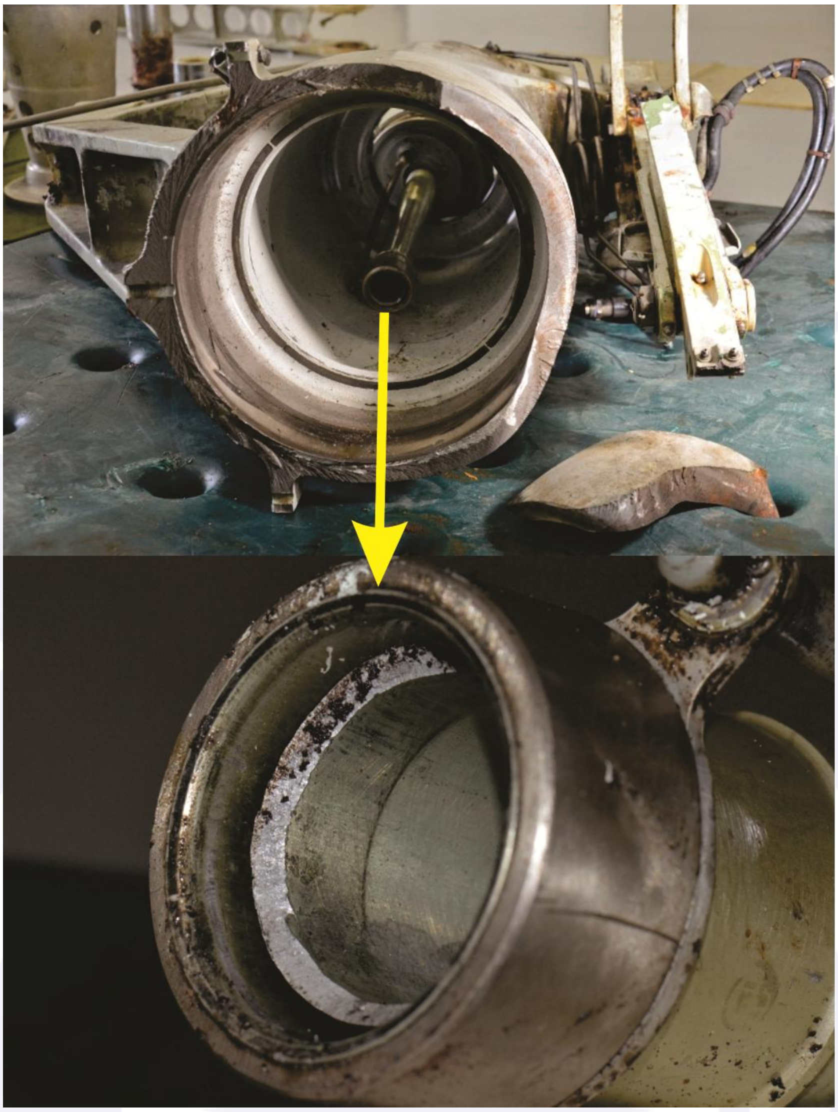

Figure 4 – General view of the cylinder interior and a fracture with a 45-degree incline in the interior of the tube (typical fracture due to overload).

Following the analysis, the DCTA report described that the “failure of the landing gear was due to overload in the structure of the cylinder. The fracture started in the rear section of the cylinder in a connection hole (bolt hole), which served as a tension concentration point, and ended in the front part of the cylinder which broke into two parts. The chevron markings on the fracture surface point toward the origin of the failure, and are typical of ductile overload”.

The same parts were then sent to Boeing (*Boeing-Long Beach Materials, Processing and Physics* [MP&P]) Laboratories), in Huntington Beach, California, USA, for metallurgical analysis. The exams conducted were observed by CENIPA investigators and DCTA specialists, besides FAA and NTSB investigators.

The technical report issued by Boeing in January 8, 2015 highlighted that, in one of the points of origin of the failure, the analysis had identified characteristics similar to a seemingly previous point of fracture, which was likely to have resulted from previous overload. According to the technical report, it was not possible to affirm that this was the reason for the collapse, but the possibility should be considered.

The exams reached the following conclusions:

- The failure of the cylinder occurred due to overload in its structure; and

- The “pre-crack signs resulting from and earlier overload condition which might have served as a tension concentration point.

The Boeing technical report was later evaluated by DCTA engineers, who considered the possibility as plausible. According to the DCTA professionals, the hypothesis of a pre-crack serving as a tension concentrator was viable.

Two Flight Control Computers (FCCs) and two Air Data Computers (ADCs) were sent for analysis at the Honeywell premises in the USA, under request and supervision of the NTSB, following an agreement with the CENIPA. The tests were carried out at the Product Safety and Integrity Investigation Laboratory in April 2013. The results did not bring information considered relevant for the investigation.

1.17 Organizational and management information.

Nil.

1.18 Operational information.

The *Aircraft Operating Manual (AOM*) is composed of four volumes which contain the information necessary for the operation of the MD-11.

According to the AOM (*01 NP Binder*):

> It is recommended that the Descent/Approach Checklist be completed as early as possible to permit all crewmembers to monitor navigational aids and aircraft performance during the approach and landing phase of flight.

The AOM (*Chapter PD, Section 00*), contains the table shown below:

CENTURION CARGO
MD-11 Aircraft Operating Manual

Performance Data **Chapter PD**
Performance **Section 10**

Normal & Abnormal Configuration Reference Speeds (VREF)

LDG WT (1000 KG)	NORM CONF VREF		ABNORMAL CONFIG VREF									
	FLAP/SLAT		FLAP/SLAT									
	35/EXT (1,4)	50/EXT (1)	UP/RET (2)	0/EXT (3)	10/EXT (1)	15/EXT (1)	20/EXT (1)	25/EXT (1)	28/EXT (1,4)	15/RET	25/RET	28/RET (1)
130	131	129	169	137	136	130	129	127	127	158	153	152
140	131	129	175	142	138	135	133	132	131	165	159	158
150	134	132	181	147	143	140	138	137	136	171	165	164
160	138	135	187	152	148	145	142	141	140	176	171	170
170	142	139	193	157	152	149	147	146	145	181	176	175
180	147	143	198	161	156	154	151	150	149	187	181	180
190	151	146	204	166	161	158	155	154	153	192	186	185
200	155	150	210	170	165	162	159	158	157	197	191	189
210	159	153	215	174	169	166	163	162	161	202	195	194
220	162	156	220	178	173	170	167	166	165	207	200	199
230	165	160	225	182	177	173	171	169	169	212	205	204
240	169	163	229	186	181	177	174	173	173	216	209	208
250	173	166	234	190	185	181	178	177	176	221	214	*
260	176	169	239	194	188	185	182	180	179	225	218	*
270	179	172	243	198	192	188	185	183	182	229	*	*
280	183	175	248	201	195	191	189	187	186	234	*	*
290	186	178	252	205	199	195	192	190	189	238	*	*

NOTES:

1. Vapp is the greater of Vref + 5 or Vref + wind additive (see note 5).
2. Vapp is Vref + 5. DO NOT ADD WIND.
3. Vapp is the greater of Vref + 15 or Vref + wind additive (see note 5).
4. If HYD 2 & 3 failure, Vapp is the greater of Vref + 8 or Vref + wind additive (see note 5).
5. Wind additive is 1/2 of the steady state wind greater than 20 knots or full gust, whichever is greater (max 20 knots).

* Exceeds flap placard.

Rev. 02- 08/03/09 CENTURION CARGO PD.10.1

Figure 5 - Aircraft Operating Manual (COM). Reference speed V_{REF}.

According to the AOM (*Chapter NP Section 70*), the descent preparation procedures prescribe the following:

PM - acquire the destination weather information from destination ATIS or other appropriate source.

FMS Set for Approach .... PF/PM

Select/confirm destination, STAR, and runway. Verify landing flap setting. Edit Vapp speed as needed. Edit CLB THRUST, ACCEL and EO ACCEL to 1500 ft. AGL on GO AROUND page.

NOTE: <u>Vapp is the greater of Vref + 5 or Vref + wind additive. Wind additive is one-half of the steady state wind greater than 20 kts or full</u> gust, whichever is greater (maximum 20 kts)".

The approach and landing procedures established the following:

Approach and Landing.. PF/PM

Perform appropriate approach as cleared. Refer to Supplemental Procedures and Procedures & Techniques sections of FCOM for AUTO FLIGHT operation and approach procedures.

CENTURION CARGO

MD-11 Aircraft Operating Manual

Normal Procedures — **Chapter NP**

Landing Procedures — **Section 80**

LANDING ROLL PROCEDURE

PILOT FLYING	PILOT MONITORING
At 50 feet AGL, verify throttles retard to idle.	Ensure throttles are retarded to idle.
After touchdown, fly nosewheel to the runway while raising reverser levers to reverse idle, apply reverse thrust and verify ground spoiler deployment.	Monitor spoiler operation. If SPOILERS do not auto deploy PM will call "No SPOILERS" and manually deploy SPOILERS. If the SPOILERS still do not deploy call "No SPOILERS" Monitor REV Thrust operation.

<u>WARNING:</u> After reverse thrust is initiated, a full stop landing must be made.

NOTES: Below 10 feet with aircraft fully flared (sink rate approximately 200 to 300 feet/minute), the basic technique is to maintain attitude by applying the required control wheel pressures. A more advanced technique is to actually begin lowering the nose (approximately 1°) prior to main gear touchdown.

Ground spoiler deployment causes a nose up pitching moment. This effect is most noticeable at aft centers of gravity. It is important to resist any pitch up tendency with forward pressure on the control column and smoothly lower the nosewheel to the runway. The LSAS, on aircraft with FCC 908 and subs will assist the pilot in the nose lowering task.

Pilots must be aware that if the number 2 engine throttle is not at idle at main gear wheel spinup, it is possible that immediately after AGS deployment the ground spoilers will retract. If this occurs, ground spoilers must be manually extended.

Apply reverse thrust as runway and conditions dictate. Verify autobrake application; apply manual braking if required.	

Rev. 05 - 08/14/11 CENTURION CARGO NP.80.1

Figure 6 - Aircraft Operating Manual (AOM). Landing procedures.

The AOM (*Chapter L Section 00*), "*Limitations*", listed several limits that had to be respected during the operation of the aircraft, such as:

DEMONSTRATED CROSSWIND

For takeoff and landing, the maximum demonstrated crosswind value is 35 knots.

This value is valid with normal hydraulic systems operating or with one hydraulic system inoperative.

Also, according to this chapter of the AOM, the maximum Landing weight of the MD-11 was 222,941kg.

The AOM (Chapter NP Section 100), "Normal Procedures – Callouts" established the CALLOUTS for the approach in VMC, mainly:

LANDING OPERATION

Visual approach callouts:

When conducting a visual approach, at the discretion of the PF, callouts by the PM should be limited to those at 1000 ft. and 500 ft. This must be clearly defined in the Approach Briefing.

At 1000 ft. AFE the PM calls:... 1000 feet, GREEN BOX

At 500ft. AFE the PM calls: .... 500 feet

Additionally, callouts pertaining to the descend path of the aircraft should be mentioned as well.

When below or above the glide-path: .... Check Path

The AOM (Chapter PT Section 30), "Procedures & Techniques – Approach and Landing Profiles" listed the procedures and techniques to be complied with during the approach and landing, such as:

Landing Characteristics and Techniques

NOTE: Whether using the auto flight systems or manually controlling the aircraft during approach and landing, the PF is responsible for assuring the airplane path, speed and sink rate are acceptable. At any time, particularly during the approach and landing, the PF should be prepared to assume authority of the flight controls or thrust levers if the automated systems are not performing adequately. This is especially critical below approximately 500 feet AGL.

Visual Approach

Aircraft should be stabilized in the final landing configuration, on descent flight path, and on speed with appropriate wind and gust corrections applied to Vref by 1,000 feet AGL. If aircraft is not stabilized by 500 feet AGL, a missed approach should be executed. Rate of descent should not exceed 1,000 feet/minute below 1,000 feet AGL. Visual aim point to provide a threshold clearance height of 47 feet on a 3.0° glideslope should be approximately 1,700 feet past the threshold. This will provide a no-flare touchdown point approximately 900 feet from threshold. Aircraft should not deviate from visual glide path in an attempt to touch down early.

Crosswind Landings

Crosswind landings are best achieved when the aircraft longitudinal axis is aligned with the runway centerline. Landing with a crab angle at touchdown is not recommended. The maneuver recommended for crosswind landing requires cross-controlling, using the rudder to align the aircraft fuselage with the runway and aileron input sufficient to arrest crosswind induced drift.

Landing in this manner minimizes side load stresses on the main landing gear and tires. It also orients inertial moments along the runway centerline, permitting early detection of lateral drift, which may be especially important when landing on runways with reduced coefficients of friction.

Accomplish a crosswind as follows: Roll out on final with a crab angle that will track the extended runway centerline. Landing with a crab angle at touchdown is not recommended.

At approximately 200 feet AGL, gradually apply rudder so as to align with longitudinal axis (heading) of the aircraft with the runway centerline. Control lateral drift by applying aileron into the wind (the upwind wing will be lower), while continuing to apply opposite rudder to maintain fuselage alignment with the centerline of the runway.

A roll tendency can be expected as downwind rudder is applied. Application of upwind aileron sufficient to prevent undesired roll should be applied simultaneously with rudder input.

An increased sink rate can be expected as cross controls are applied due to increased drag resulting from the maneuver. Adjust pitch and thrust as required.

Aircraft may touchdown on upwind wheels first.

Ailerons will have increased effectiveness (sensitivity) in ground effect. Avoid over-controlling.

Smoothly and gradually remove rudder cross-control as aileron input is reduced.

Maintain wings level with upwind aileron as necessary during landing roll.

Do not use nose wheel steering except to keep nosewheel straight on icy or slippery runways, while corrective rudder inputs are being made.

Use normal reverse thrust.

NOTE: Approach and touchdown speeds will possibly be higher than normal due to wind additives or gust factors. Do not hold the aircraft off attempting to achieve a smooth touchdown. Fly the aircraft to a positive touchdown and do not delay lowering the nosewheel.

<u>Flare</u>

Auto throttles may be used for all landings and will begin to retard after passing 50 feet AGL. The PF should adjust thrust as necessary and touchdown with thrust at idle. If ATS is not engaged, manual control of thrust should follow the ATS profile. The proper flare point will vary with environmental conditions, airport physical properties and aircraft parameters such as gross weight, CG, flap setting, etc. Typically, a slight flare (approximately 2 degrees) should be initiated between 50 and 30 feet.

CAUTION: The aft fuselage will contact runway at approximately 10° pitch attitude with struts compressed.

NOTE: Below 10 feet with the aircraft fully flared (typical sink rate approximately 200 to 300 feet per minute), the basic technique is to maintain attitude by applying the required control column pressures. An alternate technique is to reduce back pressure allowing the nose to drop 1 degree prior to main gear touchdown.

The AOM (*Chapter NP Section 00*), "*Normal Procedures*" presents situations and/or conditions requiring, according to the Aircraft Maintenance Manual (Chapter 5), a special inspection. One of the situations mentioned is the "*<u>Hard Landing</u>*".

The aircraft performed the IFR ILS Z procedure on the approach for runway 15 of SBKP. The aircraft weight for landing was 434,000lb. (197,036kg). The wind reported by the control tower to the aircraft on final was 150º/19kt. When the aircraft was cleared to land, the wind informed was 140º/20kt, with gusts up to 29kt.

The aircraft was configured for landing in accordance with the AOM. On the final approach, it maintained an average speed of 165kt, and the crew did all the callouts prescribed in the manual.

Considering the aircraft landing weight (approximately 197 tons), the setting of the flaps at 35º, the gusts of wind (ATIS: 150º/20G29kt), and also the AOM (Chapter PD, Section 00), the aircraft Vapp should have been approximately 168kt.

When the aircraft passed 50ft on the descent, the PF started to reduce the power levers and began the flare with a pitch of 5.5º. The touchdown took place with a sink rate of about 10ft/sec, with 1º-roll of the wing to the left (1 deg LWD roll attitude), at a rate of roll to the left of 1 deg/sec.

1.19 Additional information.

According to the FAR Part 25 – Airworthiness Standards: Transport Category Airplanes, Subpart D – Design and Construction, § 25.723 Shock Absorption Tests, […] (b):

> The landing gear may not fail in a test, demonstrating its reserve energy absorption capacity, simulating a descent velocity of 12 f.p.s. at design landing weight, assuming airplane lift not greater than airplane weight acting during the landing impact.

According to the NTSB Safety Recommendation Letter of 12 July 2011, the MD-11 Flight Crew Operating Manual (FCOM) issued by Boeing on 15 August 2010, in the section of landing procedures, establishes that:

> the sink rate in the flare should be 2 to 4 feet per second (fps) and that MD-11s are certified to be able to land at maximum landing weight at a sink rate of 10 fps (600 feet per minute), with an ultimate sink rate of 12.3 fps.

Boeing defines “hard landing” as:

> the landing that exceeds 10 fps and a “severe hard landing” as one that exceeds 12.3 fps or that involves rapid derrotation after initial touchdown.

Boeing defines “derrotation” as:

> the act of lowering the nosewheel to the runway following main gear touchdown.

On 20 October 2009, this same aircraft (N988AR) operated by Centurion Cargo operated flight WE-431 from Miami (USA) to Montevideo (Uruguay) with five crewmembers on board. The crew performed and ILS IFR procedure for runway 24. The aircraft made a hard landing, which resulted in breakage of the right main landing gear. The crew also vacated the taxiway and shut down the engines upon vacating the main runway.

Figure 7 – Aspect of the aircraft after the accident in Montevideo (2009).

There was substantial damage to the right main gear and to the right wing. The technical report issued after the analysis of the right landing gear cylinder at the Boeing laboratory in Huntington Beach, California, stated that the failure of the component was due to overload. It is deducted that such overload resulted from the “Hard Landing”.

The right landing gear replacement took place in Montevideo and was conducted by Varig Engineering & Maintenance (VEM). The investigation commission did not identify in the records the organization responsible for the research of the damage sustained by the aircraft, the specification of the services necessary for the restoration of airworthiness, and the provision of all the services that enabled the restoration of the aircraft airworthy condition in Montevideo.

The aircraft records were not searched for the occurrence of other events in which the left landing gear structure could have been compromised, and the possibility that the resulting damage might have been neither fixed by means of the repair services provided, nor identified in subsequent periodic inspections of the aircraft.

On 27 July 2010, a Lufthansa Cargo MD11F caught fire after making a hard landing in King Khalid International Airport, Riyadh, Saudi Arabia. The two pilots on board the aircraft were injured. The aircraft was totally destroyed by fire.

According to the NTSB, which participated in the investigation of this accident and other similar ones involving MD-11 aircraft, fourteen accidents at the landing phase occurred since this type of aircraft began operating in 1990.

MD-11 Severe Hard Landings

Date	Location	Operator	Event
Apr. 30, 1993	Los Angeles	Delta Air Lines	Bounced hard landing
Aug. 19, 1994	Chicago	Alitalia	Landing bounce and porpoise
July 31, 1997	Newark	FedEx	Wing spar break and rollover
Aug. 22, 1999	Hong Kong	China Airlines	Wing spar break and rollover
May 22, 2000	Taipei, Taiwan	Eva Air	Hard landing and go around
Nov. 20, 2001	Taipei, Taiwan	Eva Air	Bounce and nose landing gear (NLG) strike
June 7, 2005	Louisville, Kentucky, U.S.	UPS	Hard NLG strike
March 23, 2009	Tokyo	FedEx	Wing spar break and rollover
June 3, 2009	Urumqi, China	China Cargo	Hard landing and tail strike
June 9, 2009	Khartoum, Sudan	Saudi Arabian Airlines	Hard landing
Sept 13, 2009	Mexico City	Lufthansa Cargo	Hard landing and NLG strike
Oct. 20, 2009	Montevideo, Uruguay	Centurion	Hard landing and main landing gear collapse
July 27, 2010	Riyadh, Saudi Arabia	Lufthansa Cargo	Hard landing and fuselage failure
Sept. 22, 2010	Kabul, Afghanistan	World Airways	Hard NLG strike

Source: U.S. National Transportation Safety Board

Table 1

Figure 8 – Accidents with the MD-11 at landing (Source: *Aero Safety World Magazine - Flight Safety Foundation*, AUG/2011)

On 12 July 2011, the NTSB issued the “*Safety Recommendation Letter* (A-11- 68/-69)”, dealing with the following topics: (Refer to http://www.ntsb.gov/recsletters /DisplayLetters.aspx?FolderYR=2011):

> *“Although it is not uncommon for jet transport aircraft to experience a small skip or bounce during landing, since it was entered into service in 1990, the MD-11 has had at least 14 events of such severity that the aircraft sustained substantial damage, including 4 events that were complete hull losses”*
>
> “*The number and severity of these events raise concerns that MD-11 flight crews are not effectively trained to recognize and arrest high sink rates during landing or to properly control pitch attitude following a hard landing*”

"Regarding normal landing procedures, the Boeing MD-11 Flight Crew Operating Manual (FCOM), dated August 15, 2010, states that the sink rate in the flare should be 2 to 4 feet per second (fps) and that MD-11s are certified to be able to land at maximum landing weight at a sink rate of 10 fps (600 feet per minute), with an ultimate sink rate of 12.3 fps";

"Avoiding high sink rates at touchdown requires pilots to manage energy by applying appropriate combinations of power and pitch, and operators employ certain techniques to assist pilots in determining when to flare

"Although the pilot monitoring also has a role in recognizing and responding to high sink rates (for example, calling out the sink rate and calling for a go-around), the ability to appropriately judge when to initiate the flare is a fundamental pilot skill that is learned in training and checked periodically";

"A few of the hard landing events listed […] provide examples of MD-11 flight crews' failure to avoid high sink rates at touchdown";

"Following its investigation of the FedEx flight 14 accident at Newark, the NTSB issued Safety Recommendation A-00-93 to the Federal Aviation Administration (FAA) addressing the need for pilot training on these concepts. The NTSB classified this recommendation "Closed—Acceptable Action" on October 22, 2002";

"Despite the corrective action taken in response to Safety Recommendation A-00-93, MD-11 crews continue to have difficulty in judging the flare maneuver and in making appropriate pitch and power changes after hard landings; four of the eight events that occurred after the recommendation was closed involved U.S. operators. The frequency of MD-11 hard landing accidents suggests that generic guidance on these concepts is not sufficient or effective. As the investigative agency representing the state of manufacture of the MD-11 airplane, the NTSB continues work to evaluate the factors that contribute to these accidents";

"NTSB believes that enhanced operational guidance and recurrent training will provide near-term improvements that reduce the risk of MD-11 landing accidents. Therefore, the NTSB recommends that the FAA require Boeing to revise its MD-11 FCOM to reemphasize high sink rate awareness during landing, the importance of momentarily maintaining landing pitch attitude after touchdown and using proper pitch attitude and power to cushion excess sink rate in the flare, and to go around in the event of a bounced landing (Safety Recommendation A-11-68)";

"The NTSB recommends that, once Boeing has completed the revision of its FCOM as recommended in Safety Recommendation A-11-68, the FAA require all MD-11 operators to incorporate the Boeing-recommended bounce recognition and recovery procedure in their operating manuals and in recurrent simulator training (Safety Recommendation A-11-69)".

On 22 October 2010, Boeing, with the support of the F*ederal Aviation Administration* (FAA), held a conference with MD-11 operators for the discussion of operational and training aspects, in the wake of the July/2010 accident and earlier events. After the conference, Boeing issued a revision (15 February 2011) of the "*Landing Characteristics and Techniques*" contained in the "*Flight Crew Operational Manual*" ***to clearly highlight MD-11 operational considerations and techniques, and to provide special emphasis on high sink rate approaches***. Some of these changes are shown in the Figures 9 and 10 below. These items of information were made available to all MD-11 operators, including *Centurion Cargo*.

BOEING

MD-11 Flight Crew Operating Manual

Procedures & Techniques — **Chapter PT**

Approach and Landing Profiles — **Section 30**

Landing Characteristics and Techniques

NOTE: Whether using the autoflight systems or manually controlling the aircraft during approach and landing, the PF is responsible for assuring the airplane path, speed and sink rate are acceptable. At anytime, particularly during the approach and landing, the PF should be prepared to assume authority of the flight controls or thrust levers if the automated systems are not performing adequately. This is especially critical below approximately 500 feet AGL.

Visual Approach

Aircraft should be stabilized in the final landing configuration, on descent flightpath, and on speed with appropriate wind and gust corrections applied to Vref by 1,000 feet AGL. If aircraft is not stabilized by 500 feet AGL, a missed approach should be executed. Rate of descent should not exceed 1,000 feet/minute below 1,000 feet AGL.

Visual aimpoint to provide a threshold clearance height of 47 feet on a 3.0° glideslope should be approximately 1,700 feet past the threshold. This will provide a no-flare touchdown point approximately 900 feet from threshold. Aircraft should not deviate from visual glidepath in an attempt to touch down early.

Crosswind Landings

Crosswind landings are best achieved when the aircraft longitudinal axis is aligned with the runway centerline. Landing with a crab angle at touchdown is not recommended. The maneuver recommended for crosswind landing requires cross-controlling, using the rudder to align the aircraft fuselage with the runway and aileron input sufficient to arrest crosswind induced drift.

Landing in this manner minimizes side load stresses on the main landing gear and tires. It also orients inertial moments along the runway centerline, permitting early detection of lateral drift, which may be especially important when landing on runways with reduced coefficients of friction.

Accomplish a crosswind landing as follows:

(CONTINUED)

February 15, 2011 DGL PT.30.1

Figure 9 - Boeing FCOM PT.30.1

Procedures & Techniques -
Approach and Landing Profiles

BOEING

MD-11 Flight Crew Operating Manual

Landing Characteristics and Techniques (Continued)

Flare

Autothrottles may be used for all landings and will begin to retard after passing 50 feet AGL. The PF should adjust thrust as necessary and touchdown with thrust at idle. If ATS is not engaged, manual control of thrust should follow the ATS profile. The proper flare point will vary with environmental conditions, airport physical properties and aircraft parameters such as gross weight, CG, flap setting, etc. Typically, a slight flare (approximately 2 degrees) should be initiated between 50 and 30 feet.

CAUTION: The aft fuselage will contact runway at approximately 10° pitch attitude with struts compressed.

NOTE: Below 10 feet with the aircraft fully flared (typical sink rate approximately 200 to 300 feet per minute), the basic technique is to maintain attitude by applying the required control column pressures. An alternate technique is to reduce back pressure allowing the nose to drop 1 degree prior to main gear touchdown.

Bounced Landing Recovery

CAUTION: Tail strikes or nosewheel structural damage can occur if large forward or aft control column movements are made prior to touchdown.

When a bounced landing occurs, consider initiating a go-around by use of normal go-around procedures. Do not retract the landing gear until a positive rate of climb is established because a second touchdown may occur during the go-around.

It may not be possible to determine whether or not the aircraft is in the air after a firm touchdown or a slight skip. Hold or re-establish the landing attitude until it is determined that the main landing gear will remain on the runway. Avoid rapid pitch rates when establishing a normal landing attitude. If the aircraft bounced, add thrust as necessary to control subsequent sink rate. If the situation is in doubt, perform a go-around.

(CONTINUED)

PT.30.4 DGL February 15, 2011

Figure 10 - Boeing FCOM PT.30.4

In May 2012, Boeing issued a new revision of the FCOM (Figure 9) dealing with the following topics: "*Flare, Touchdown, Bounced Landing Recovery, and Rollout characteristics and techniques*".

Procedures & Techniques -
Approach and Landing Profiles
BOEING
MD-11 Flight Crew Operations Manual

Landing Characteristics and Techniques (Continued)

Flare

Autothrottles may be used for all landings and will begin to retard after passing 50 feet AGL. If ATS is not engaged, manual control should nominally follow the ATS profile. However, the PF should adjust thrust as necessary to maintain proper path, speed, and sink-rate during the flare, and plan to touchdown with throttles at idle.

Flare altitude will vary depending upon factors such as aircraft speed, sink rate, weight, CG, flap setting, as well as environmental factors, airport physical properties, etc. Typically, a slight flare (approximately 2 degrees) should be initiated between 50 and 30 feet.

CAUTION: The aft fuselage will contact runway at approximately 10° pitch attitude with struts compressed.

NOTE: Below 10 feet with the aircraft fully flared (typical sink rate approximately 200 to 300 feet per minute), the basic technique is to maintain attitude by applying the required control column pressures. An alternate technique is to reduce back pressure slightly, allowing the nose to drop 1 degree prior to main gear touchdown.

Touchdown

CAUTION: Tail strikes or nosewheel structural damage can occur if large column movements are made prior to flying the nosewheel to the runway.

After touchdown, monitor ground spoiler deployment and be prepared to counter any pitch-up tendency as spoilers extend. Maintain touchdown pitch attitude until certain main landing gear will remain on the runway, then fly the nosewheel to the runway, avoiding a rapid derotation rate.

If auto ground spoilers do not fully deploy upon nosewheel touchdown, manually deploy spoilers. Pitch-up tendency is more pronounced at aft CG. Use of auto brakes will help counter any pitch-up tendency. LSAS will assist the pilot in avoiding nose pitch-up after touchdown and in lowering the nose to the runway.

(CONTINUED)

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PT.30.4 DGL May 4, 2012

Figure 11 - Boeing FCOM PT.30.4 (MAY/2012 Revision)

1.20 Useful or effective investigation techniques.

Nil.

2. ANALYSIS.

On 13 October 2012, the MD-11F aircraft registered in the USA as N988AR, operated by Centurion Cargo, departed from Miami Airport (KMIA) destined for Viracopos Airport (SBKP), with two pilots and a mechanic on board, on a non-regular cargo transport flight. The copilot was the Pilot Flying (PF), and the captain was the Pilot Monitoring (PM). The flight was uneventful up to the moment of landing in Viracopos.

The crew performed the IFR ILS Z procedure for Landing on runway 15 of SBKP. The meteorological information transmitted via the automatic terminal information service (ATIS) approximately 15 minutes before the landing referred to a wind of 150º at 20kt, gusting to 29kt; visibility more that 10km; broken clouds, with ceiling at 9,000ft; QNH 1020 and temperature 17ºC. Prevailing weather conditions were VMC.

At landing, on the first contact with the runway, the left main gear sustained total collapse, and the aircraft skidded on the runway for approximately 800 meters before coming to a stop still on the runway, sustaining substantial damage to the left main gear assembly, to the left wing, and to the left engine.

The weight of the aircraft at landing was 434,000lb (197,036kg). The wind informed to the aircraft on the final approach by the control tower (TWR) was 150º at 19kt. Was the aircraft was cleared to land, the wind informed was 140º at 20kt, gusting up to 29kt. According to the aircraft manual (AOM - Chapter L Section 00), “Limitations”, the maximum crosswind for landing is 30kt, that is, the wind condition did not limit the operation of the aircraft.

Based on the AOM (Chapter PD, Section 00), and considering that the aircraft was configured for landing with flaps/slats at 35º, its Vref would be 153kt. Still according to the manual, the Vapp is the higher one between Vref + 15 or Vref + wind additives.

The wind additives value is equal to half the constant wind when this latter is higher than 20kt, or half the strength of the gust wind, whichever is higher. In other words, should the wind be constant at 20kt, the Vapp would be 153+20/2=163kt.

In the case of the accident, the wind had peak gusts of 29kt, and, therefore, the Vapp should have been 153+29/2= 168kt. It is worth pointing out that the information of wind received by the crew via ATIS was 150º at 20kt, gusting to 29kt, and this was the value considered by the crew for the selection of their Vapp.

The aircraft was configured for landing in accordance with the AOM prescriptions. On the final approach, it maintained 165kt (3kT below the calculated and not significant for landing), and the crew performed all the prescribed callouts. Upon passing 50ft, the PF started the reduction of the thrust levers, and began the flare, with a pitch of 5.5º. The aircraft touched down on the runway with a sink rate of 10ft/sec, at a roll-attitude of 1 degree to the left (1 deg LWD roll attitude), and with a LWD roll-rate of 1 deg/sec.

Considering: - that the touchdown took place with a sink rate of 10 fps, within the limits prescribed in the Boeing MD-11 Flight Crew Operating Manual (FCOM) [“the sink rate in the flare should be 2 to 4 feet per second (fps)”], and that MD-11s are certified to be able to land at maximum landing weight at a sink rate of 10 fps (600 feet per minute), with an ultimate sink rate of 12.3 fps”); - that Boeing defines “hard landing” as the one that “exceeds 12.3 fps or that involves rapid derrotation after the initial touchdown; - that the weight of the aircraft for landing was 434.000lb (197,036kg), i.e., below the MD-11 maximum landing weight of 222,941kg, and that there were not any problems during the landing of that aircraft, even taking into consideration that the speed on final was slightly below the one prescribed in the aircraft manual for landings with crosswind/gusts, the conclusion is that the aircraft was correctly operated.

On 20 October 2009, the N988AR aircraft operated by Centurion Cargo made a hard landing in Montevideo, Uruguay, sustaining substantial damage to its right main landing gear. The crew also managed to vacate the taxiway and shut down the engines upon vacating the main runway.

There was substantial damage to the right main gear and right wing. A technical report issued by the Boeing Laboratories of Huntington Beach, California, after analysis of the right main landing gear cylinder suggested that the failure of the component occurred on account of overload. It is deduced that such overload was a result of the hard landing.

The investigation commission verified that, after the accident in Montevideo, the aircraft right main landing gear was replaced in that same location by VARIG Engineering & Maintenance (VEM). However, the commission did not manage to identify in the records the organization responsible for the research of the damage sustained by the aircraft, the specification of the services necessary for the restoration of airworthiness, and the provision of all the services that enabled the restoration of the aircraft airworthy condition in Montevideo.

The aircraft records were not searched for the occurrence of other events in which the left landing gear structure could have been compromised, and the possibility that the resulting damage might have been neither fixed by means of the repair services provided, nor identified in subsequent periodic inspections of the aircraft.

After the accident in Viracopos, the left main gear structure, the cylinder, and the set of parts of the left main gear were sent to the DCTA Laboratory of Materials for analysis of the failures.

According to the DCTA technical report, the landing gear failure occurred on account of overload in the structure of the cylinder. The fracture started in the rear section of the cylinder in a connection hole (bolt hole), which served as a tension concentration point, and ended in the front part of the cylinder with its breakage into two parts.

The parts were later sent to the Boeing-Long Beach Materials, Processing and Physics [MP&P]) Laboratories, in Huntington Beach, California, for metallurgical analysis. The exams were observed by CENIPA investigators and DCTA specialists. The analysis identified, in one of the points of origin of the failure, characteristics of an earlier point of fatigue, probably due to overload. According to the Boeing technical report, the pieces of evidence gathered do not allow affirming that this was the cause for the left main gear collapse, but the possibility cannot be ruled out.

The exams reached the following conclusions:

- The failure of the cylinder was due to overload in the structure of the cylinder; and

- There were signs of pre-crack resulting from a previous overload condition, which may have functioned as a tension concentration point.

The tests also showed that there were not any problems of dimensional nature, similarly to the DCTA exams, and that the material duress was within the prescribed limits. They also showed, by means of electron microscopy, that there were not any signs of corrosion or fatigue. The breakage was solely on account of overload.

The Boeing technical report was later evaluated by DCTA engineers, who considered the possibility as plausible. According to them, the hypothesis that a pre-crack served as a tension concentrator was viable. In this case, one has to consider that the accident of this aircraft in Uruguay might have caused the pre-crack, which was not identified at the time, and that it would have contributed to the event with the N988AR in Campinas (Viracopos Airport).

Considering that the crew complied with the prescriptions of the aircraft manuals, and that the data retrieved from the flight recorders corroborate with the fact that the aircraft did not make a hard landing, the hypothesis of a pre-crack resulting from an earlier condition of overload, which would have functioned as a tension concentration point, was regarded as the main hypothesis related to this accident.

Thus, the idea of a tension concentrator generated by the pre-crack is potentially representative, since the existence of such concentrator would drastically reduce the load necessary for breaking the landing gear. In other words, even a landing made within the aircraft limits, or outside of hard landing parameters, could lead to a failure of the landing gear component and to its eventual collapse.

3. CONCLUSIONS.

3.1 Facts.

a) On 13 October 2012, the MD-11F aircraft (American registration N988AR), operated by Centurion Cargo, departed from Miami (KMIA) destined for Viracopos (SBKP), with two pilots and a mechanic on board, on a non-regular cargo transport flight;

b) The copilot was the Pilot Flying (PF), and the captain was the Pilot Monitoring (PM);

c) The crew had valid licenses, certificates and ratings;

d) The pilots had qualification for the type of flight, as well as enough experience in relation to the route and aircraft;

e) The aircraft was airworthy;

f) The flight crew performed the IFR ILS Z procedure for runway 15. The prevailing weather conditions were VMC. The wind was 140º/19kt. When the aircraft was cleared to land, the wind strength was 20kt, with peak gusts at 29kt;

g) The aircraft was adequately configured, and maintained the speed prescribed for its weight, considering the wind informed;

h) At landing, on the first contact of the aircraft with the runway, there was total collapse of the left main landing gear, and the aircraft skidded along the runway for 800 meters before the final stop, sustaining damage to the left landing gear, left wing, and left engine;

i) After analysis, the DCTA concluded that the “the landing gear failed due to overload in the cylinder structure”. The fracture started in the rear section of the cylinder in a connection hole which served as a tension concentration point, and ended in the front part of the cylinder with its breakage into two parts;

j) On 20 October 2009, the right main gear of the N988AR aircraft broke after a hard landing in Montevideo, Uruguay;

k) the right main landing gear was replaced by VARIG Engineering & Maintenance (VEM), but the organization responsible for the research of damage, the specification of the services necessary for the restoration of airworthiness, and the provision of the services that enabled the restoration of the aircraft to an airworthy condition was not identified;

l) The same aircraft parts were subjected to metallurgical analysis at the Boeing-Long Beach Materials, Processing and Physics [MP&P] Laboratories, in Huntington Beach, California, USA; and

m) The technical report issued by Boeing highlighted that in one of the points of origin of the failure, the analysis had identified characteristics similar to a pre-crack point, which would have begun earlier, probably due to overload.

3.2 Contributing factors.

- **Aircraft maintenance – undetermined.**

In the tasks that led to the restoration of the aircraft airworthiness after the accident in Uruguay in 2009 (Hard-Landing), and also in subsequent periodic inspections, the existence of pre-crack traces resulting from a previous overload condition may not have been identified, something that could have resulted in a point of stress concentration.

4. SAFETY RECOMMENDATION.

A measure of preventative/corrective nature issued by a SIPAER Investigation Authority or by a SIPAER-Link within respective area of jurisdiction, aimed at eliminating or mitigating the risk brought about by either a latent condition or an active failure. It results from the investigation of an aeronautical occurrence or from a preventative action, and shall never be used for purposes of blame presumption or apportion of civil, criminal, or administrative liability.

In consonance with the Law n°7565/1986, recommendations are made solely for the benefit of the air activity operational safety, and shall be treated as established in the NSCA 3-13 "Protocols for the Investigation of Civil Aviation Aeronautical Occurrences conducted by the Brazilian State".

None.

5. CORRECTIVE OR PREVENTATIVE ACTION ALREADY TAKEN.

None.

On April 15th 2016..