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**Attachment 13 – Airbus Managing Severe Turbulence**

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# OPERATIONAL FACTORS

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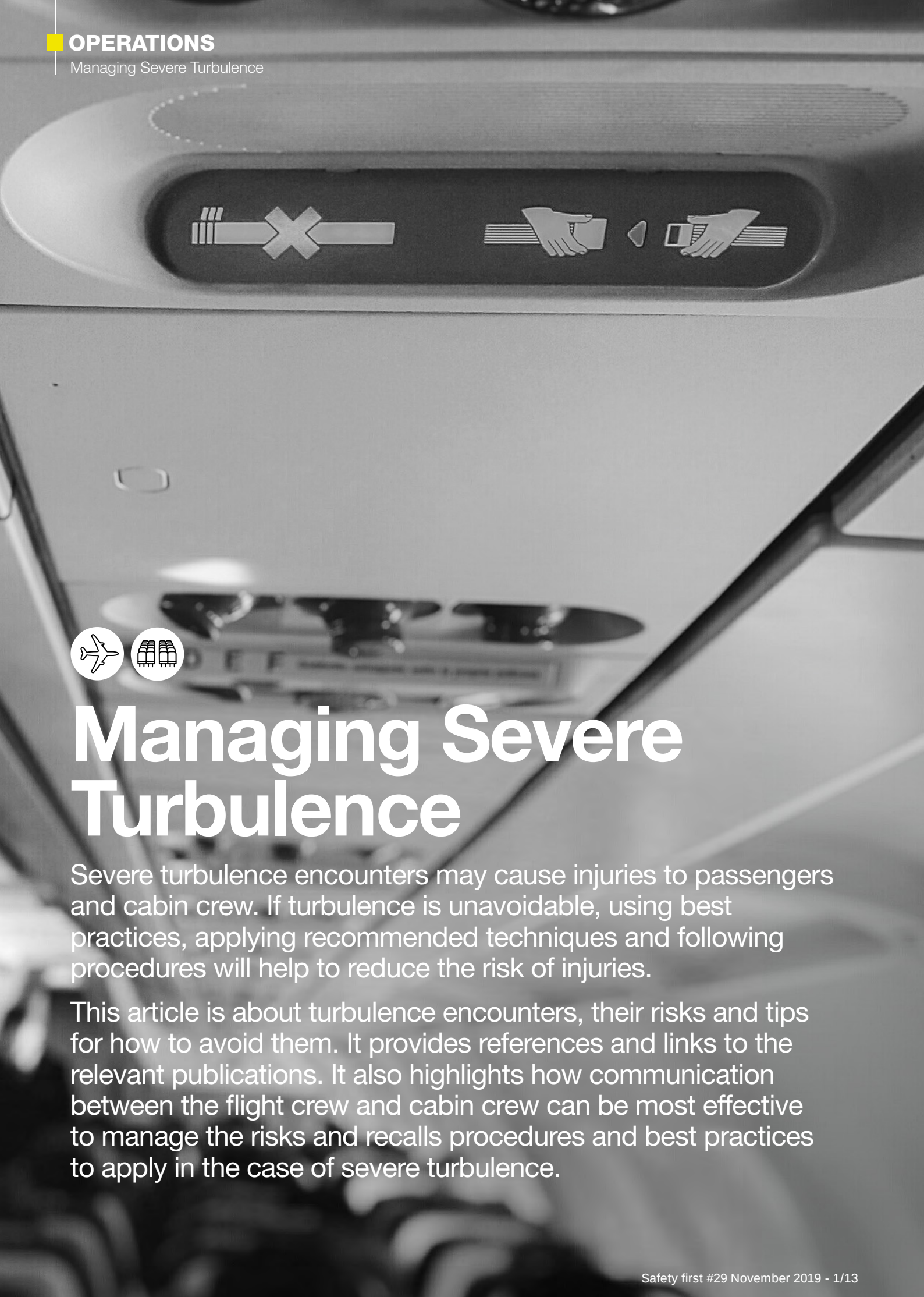

# Managing Severe Turbulence

Severe turbulence encounters may cause injuries to passengers and cabin crew. If turbulence is unavoidable, using best practices, applying recommended techniques and following procedures will help to reduce the risk of injuries.

This article is about turbulence encounters, their risks and tips for how to avoid them. It provides references and links to the relevant publications. It also highlights how communication between the flight crew and cabin crew can be most effective to manage the risks and recalls procedures and best practices to apply in the case of severe turbulence.

# ANALYSIS OF AN EVENT

## Severe turbulence during approach

An A320 aircraft was facing severe thunderstorms on approach into its destination airport. Trying to find their way to the final approach path, the crew passed the boundary of one of the thunderstorms by approximately 4 NM. The aircraft was suddenly caught by a significant updraft followed by a downdraft, resulting in a g-load close to zero and the disconnection of the autopilot. Both pilots were surprised by the shift of the g-loads but they did not react on the sidestick. Assessing and accepting the minor altitude deviations, the flight crew then reengaged the autopilot and landed safely. There were no injuries to any passengers or crew.

## Event analysis

The flight crew actions were in accordance with the FCTM recommended techniques when encountering turbulence. After the initial updraft and AP disconnection the flight crew resisted the potential instinctive reaction to use manual inputs on their sidesticks to fight against the turbulence. This limited the risk of over-control on the sidestick, allowing the A320's flight control laws to cope with the effects of the turbulence.

The cabin was already secured for landing with everybody seated and seatbelts fastened, which was a key factor in the prevention of injuries to passengers and cabin crew.

# WHAT CAUSES TURBULENCE AND HOW TO AVOID IT?

Several phenomenons create turbulence. Here is a list of the main contributors and how to anticipate, detect and avoid them when possible.

## Convective weather

The first and most obvious is the convective weather where air is heated by the earth's surface. Hot air rises and causes strong air displacements. Convection associated with high humidity leads to the formation of thunderstorms that can cause turbulence.

### Using weather forecasts to predict convective weather

Flight crew must anticipate any potential route deviation and plan extra fuel to avoid any expected storms shown on the weather forecast analysis during their pre-flight preparation. The weather forecast should be regularly updated, especially during long haul flights, because meteorological conditions can be changeable.

NOTE

For more information about the use of the on-board weather radar, refer to:

- FCOM AIRCRAFT SYSTEMS – SURVEILLANCE - Weather radar
- FCTM AIRCRAFT SYSTEMS – WEATHER RADAR
- Pilot's guide from the radar manufacturer
- *"Optimum use of weather radar"* article published in Safety first #22" in july 2016
- "Getting to grips with surveillance" brochure issue 2 (2018)
- *"RDR-4000 IntuVue™ Weather Radar Pilot Training for Airbus Aircraft"* video from HONEYWELL.

**Using the weather radar to detect and avoid convective weather**

Storms contain a large quantity of liquid water that can be detected with the on-board weather radar . Knowing the capabilities and limitations of the weather radar installed on the aircraft is essential as well as being familiar with the techniques for using the weather radar to optimize the chance to detect convective weather.

**Avoiding Storms**

Severe turbulence can be met inside a cumulonimbus cloud. However, it can also be met outside of the cloud as we have seen in the event described above where the aircraft was 4 NM outside the boundary of the storm. As a rule of thumb, storm cells should be avoided by 20 NM laterally and preferably upwind to avoid risk of encountering hail. A storm cell must not be overflown by less than 5000ft separation. Avoiding the storm cell by flying around it is preferred because turbulence can extend well above the visible top of a cumulonimbus. High vertical expansion cells with top over 25,000 ft should not be overflown due to potential of strong turbulence.

NOTE

For more information on avoidance of convective weather, refer to the *"Avoidance of convective threats"* video from the Airbus Destination 10X sharing platform.

## Clear Air Turbulence

Clear Air Turbulence (CAT) is due to the difference of speed of air masses at high altitude. Severe turbulence is generally encountered at altitudes higher than 15,000ft when flying across the boundary between the two masses.

**Using weather forecast and pilot reports**

The on-board weather radar cannot detect CAT as it does not contain water droplets. Using the weather forecast is the main method to predict when CAT may be encountered during a flight. Flight crews may also be informed of the potential to encounter CAT from pilot reports sent from aircraft that have previously flown through the affected areas to ATC and to the Operators' operations control centre. There are turbulence information sharing platforms that have been developed by airlines or third parties to share turbulence data and provide real time information to flight crews about the locations of turbulence.

**(fig.1)**
**Lenticular clouds indicating the presence of mountain waves**

## Mountain waves

Windy conditions in mountainous areas can cause air to be directed upwards by the face of the mountain that causes a wave effect downwind of the mountain range. Severe turbulence may be encountered when flying through theses waves. The effects of mountain waves can be felt up to 100 NM downwind of the mountain range and up to the cruise altitude of airliners.

### Anticipating mountain waves

Mountain waves are predictable in certain mountainous areas when there are specific meteorological conditions. it is important that operators inform flight crews when the conditions are likely to cause mountain waves on the planned flight path. Pilot reports are also invaluable to help inform other aircraft that may be approaching an area where there are mountain waves.

Lenticular clouds observed downwind of a mountain range is a good indicator that mountain waves may be encountered in the area.

## Wake vortices

The pressure difference between the upper and the lower side of an aircraft's wing creates a wake vortex at its wing tips. Wake vortex may cause severe turbulence depending on the weight of the aircraft generating the vortices and the distance from it. The typical signature of a severe wake vortex encounter is a small roll initiated in one direction followed by a much more significant roll in the opposite direction.

To reduce the risk of a wake turbulence encounter, the flight crew must comply with the aircraft separation minima.

An upwind lateral offset can be used to avoid entering wake turbulence if the flight crew suspects that the aircraft may encounter it.

NOTE

For more information on wake vortices, refer to:

- FCTM PROCEDURES-NORMAL PROCEDURES-Supplementary Procedures-Adverse weather-Wake Turbulence
- *"Wake vortices"* article published in Safety first #21 in january 2016.
- *"Wake vortices"* briefing on the Airbus Worldwide Instructor News (WIN) website.

### Perturbation due to ground obstacles and boundary layer effect

Ground obstacles such as mountains or buildings can create turbulence that can affect aircraft trajectory at lower altitudes in windy conditions during takeoff and landing phases.

Some airports are known to be susceptible to turbulence in certain wind conditions due to its surrounding infrastructure, hills or mountain ranges in close proximity . Operators should ensure that their pilots are kept informed when turbulent conditions are expected at the departure and/or arrival airports.

## EFFICIENT COMMUNICATION BETWEEN THE COCKPIT AND THE CABIN IS KEY

Efficient coordination and communication between flight crew and cabin crew is essential to safely manage turbulence. It begins with using common terminology in precise and specific communication, both before and during the flight.

### The Turbulence Scale

Turbulence is classified into three categories. To ease identification, each category is based on the impact to the aircraft's trajectory and the effects felt in the cabin. Using common terminology ensures that the flight crew and the cabin crew share the same understanding of the level of turbulence expected. This enables the cabin crew to perform the appropriate duties in order to effectively manage the cabin during turbulence.

| Light Turbulence | Moderate Turbulence | Severe Turbulence |
|---|---|---|
| Light turbulence momentarily causes slight, rapid, and rhythmic bumpiness without noticeable changes in aircraft altitude or attitude. | Moderate turbulence causes rapid bumps or jolts. | Severe turbulence causes large abrupt changes in aircraft altitude and attitude with large variations in airspeed. |
| **Cabin Condition** | | |
| • Liquids shake but do not splash out of cups<br>• Trolleys can still be maneuvered with little difficulty<br>• Passengers may intermittently feel a slight strain against their seat belts. | • Liquids splash out of cups<br>• Trolleys difficult to manoeuvre<br>• Difficulty walking in the cabin<br>• Difficulty standing without holding onto something<br>• Passengers feel definite strain against their seat belts. | • Items fall or lift off the floor<br>• Loose items are tossed about the cabin<br>• Impossible to walk<br>• Passengers are forced violently against their seat belts. |

## Preflight briefing

The preflight briefing is the opportunity for flight and cabin crews to discuss the forecasted weather and the possible effects on flight conditions together.

The flight crew will inform the cabin crew of any expected turbulence events and provide the estimated flight times and locations of possible turbulence.

## Anticipated severe turbulence

When approaching an anticipated area of turbulence:

- The flight crew should advise the cabin crew on how much time is available to secure the cabin and galleys, as well as informing them of the level and expected duration of the turbulence encounter.
- A Passenger Address announcement requesting the passengers to return to their seat and fasten their seatbelt should be made.
- The cabin crew should ensure they inform the flight crew when the cabin is secured.

## Unanticipated severe turbulence

When entering an unexpected area of turbulence, the flight crew must switch the seatbelt sign ON and make an announcement to the cabin requesting passengers and crew to fasten seatbelts immediately using the Passenger Address system.

## After a severe turbulence encounter

It is important that the flight crew informs the cabin crew when the aircraft is clear of the severe turbulence so that cabin crew can check for passenger injuries, give first aid if necessary, calm and reassure passengers and check for any cabin damage. The purser should then provide a cabin status to the flight crew detailing the number of injuries and any cabin damage.

# MANAGING SEVERE TURBULENCE FROM THE COCKPIT

> "Autopilot is designed to cope with turbulence"

Flying through turbulence is sometimes unavoidable despite the best efforts to prevent this. The flight crew must use the recommended procedure to limit the impact of the turbulence on the aircraft's trajectory and limit the risk of injury to passengers and cabin crew.

## Prepare the cockpit before entering an anticipated severe turbulence area

Any loose objects in the cockpit must be cleared or secured before entering an area where turbulence is expected. Shoulder harnesses should be firmly fastened and locked.

## Keep autopilot ON

Autopilot is designed to cope with turbulence and will keep the aircraft close to the intended flight path without the risk of overcorrection. The recommendation is to keep autopilot ON during a turbulence encounter. A pilot may be tempted to "fight against turbulence" when manually flying the aircraft and may overreact to sudden changes in the trajectory in some cases.

The flight crew should consider autopilot disconnection if autopilot does not perform as desired.

## Keep autothrust ON (except A300/A310) and use the QRH turbulence penetration speed if turbulence is severe

The turbulence penetration speed/Mach, also known as Rough Air speed/Mach ($V_{RA}/M_{RA}$), can be found in the QRH. This speed provides the best protection against reaching structural limits due to gust effect whilst maintaining a sufficient margin above $V_{LS}$.

$V_{RA}/M_{RA}$ should be used in severe turbulence. Managed speed can be kept when in light or moderate turbulence.

On A300/A310 aircraft, the flight crew should disconnect the autothrust and set the target thrust to maintain $V_{RA}/M_{RA}$.

## On fly-by-wire aircraft, use manual thrust when autothrust variations become excessive

If the autothrust variations become excessive on fly-by-wire aircraft, the flight crew should disconnect autothrust and manually adjust thrust to the value provided in the QRH.

## In cruise, consider descent to a lower Flight Level

Choosing a lower FL enables the flight crew to increase the aircraft's margins before buffet onset.

> "the pilot should only make careful and considered corrections to counter any significant deviation from the intended flight path"

## Advantage of the fly-by-wire technology in manual flight

If the autopilot disconnects on a fly-by-wire aircraft, the flight crew can still utilize the advantages of the fly-by-wire technology to cope with turbulence. If the sidestick remains in its neutral position, the aircraft's flight control system will compensate for turbulence effects by aiming for a 1g flight path and a constant roll attitude. Therefore, if the pilot is only making careful and considered corrections to counter any significant deviation from the intended flight path, this will allow the flight controls to stabilize the aircraft, whereas continuous pilot sidestick inputs could induce further destabilization.

## Do not "fight the turbulence"

The pilot must not "fight the turbulence" in manual flight to maintain the aircraft's trajectory or altitude. Only applying smooth sidestick/control column inputs and allowing some reasonable variations from the intended flight path will reduce the risk of overcorrection that can cause unnecessary accelerations, which may increase the risk of injury to passengers and cabin crew.

**NOTE**

For more information on the handling of turbulence, refer to the FCTM *"PROCEDURES - NORMAL PROCEDURES - Supplementary Procedures - Adverse weather - Weather Turbulence"*

NOTE

For more details on the handling of overspeed in cruise, refer to:

- FCTM PROCEDURES - ABNORMAL AND EMERGENCY PROCEDURES - Miscellaneous - Overspeed
- *"Management of Overspeed events in cruise"* article published in Safety first #28 in July 2019
- "*What About Overspeed Prevention and Recovery?*" briefing from the Airbus Worldwide Instructor News (WIN) website.

NOTE

For more information on the Ground Speed Mini function, refer to the *"Control your speed during descent, approach and landing"* article published in Safety first #24 in July 2017.

NOTE

For more information on turbulence event reporting, refer to the *"High Load Event Reporting"* article published in Safety first #26 in July 2018.

## Do not use rudder

Do not use rudder to counter the turbulence if in manual flight. Violent rudder inputs can cause additional aircraft trajectory destabilization and stress on the aircraft structure.

## Don't overreact to temporary overspeed excursion

The flight crew may observe temporary overspeed situations when encountering severe turbulence due to the changes in wind intensity or direction. The flight crew must not overreact to temporary overspeed excursion since the use of VRA/MRA ensures sufficient margins to structural limits. The recommendation is to keep the autopilot ON and autothrust ON and accept the temporary overspeed excursion.

## In final approach, use autothrust

The use of autothrust and managed speed in final approach enables the aircraft to benefit from the Ground Speed Mini function that will adapt the managed target speed to the wind variation close to the ground.

## Severe turbulence reporting

The flight crew must make a logbook entry to report any severe turbulence encounter so that maintenance crew are alerted to perform the necessary inspections of the aircraft before the next flight.

It is also recommended to report severe turbulence events to Airbus to assess the effects of the high loads on the aircraft and assess what checks may be necessary before commencing the next flight.

# MANAGING SEVERE TURBULENCE FROM THE CABIN

## Anticipated severe turbulence: a prioritized preparation

Once advised by the flight crew of an anticipated turbulence, the cabin crew should prioritize their duties based on the time available before the turbulence encounter in order to best prepare the cabin, as per CCOM recommended procedure:

- First, they must stow and secure large items such as trolleys and remove bottles from the cabin and galley surfaces. Any hot liquid must be safely disposed of
- The cabin crew must then secure the cabin and ensure all lavatories are unoccupied
- Once the cabin is secured, the cabin crew must secure the galleys
- Cabin crew must then return to their station, fasten their seatbelt and inform the purser that the passengers and themselves are secured
- Then the purser must inform the flight crew that the cabin is secured.

## Unanticipated severe turbulence: ensure personal safety first

Most injuries in the cabin happened to passengers or crew members not seated with their seatbelt fastened during severe turbulence. Cabin crews are more exposed to risk of injury due to sudden turbulence because they are often standing during service. The cabin crew must ensure their own personal safety first if sudden severe turbulence is encountered. The cabin crew must take the nearest available seat and securely fasten the seat belt. The nearest seat may be a passenger seat.

> “The cabin crew must ensure their own personal safety first if sudden severe turbulence is encountered.”

## BEST PRACTICE

**Tidy cabin and galleys for safe flights**

Any loose object in the cabin can become a projectile during turbulence. Keeping the cabin and galley tidy throughout the flight reduces the risk of injuries and damage to the cabin should an unexpected turbulence event occur.

**Passenger awareness on the use of seatbelt**

The most effective way to prevent injuries during turbulence is to keep seatbelts fastened. It is therefore key that passengers are aware of this and are encouraged to keep their seatbelt fastened at all times.

> “It is key that passengers are encouraged to keep their seatbelt fastened at all times.”

Passengers must be made aware that they are obliged to comply with the FASTEN SEATBELT sign at all times when set to ON.

NOTE

For more information on the handling of turbulence in the cabin, refer to:

- CCOM:
  - *ABNORMAL/EMERGENCY PROCEDURES – TURBULENCE MANAGEMENT*
  - *ABNORMAL/EMERGENCY PROCEDURES – SAFETY OPERATIONAL AWARENESS*
  - *TURBULENCE THREAT AWARENESS*
- *"TURBULENCE MANAGEMENT"* Chapter of the *"Getting to Grips with Cabin safety"* brochure published in 2015 by the Airbus Flight Operations Support department.

## An Analysis of Reported Severe Turbulence

240 severe turbulence events were reported to Airbus between 2014 and 2018.

Injuries to passengers and cabin crew occurred on:

- 30 % of long haul flights where severe turbulence events were reported
- 12 % of short haul flights where severe turbulence events were reported.

Passengers tend to unfasten their seatbelt during long haul flights to move around the cabin and use the lavatories more during long haul flights and this is likely to be the reason for the higher rate of injuries when compared to the figures for short haul flights. Furthermore, the majority of the injuries that are reported on short haul flights mainly affects cabin crew whereas both cabin crew and passenger injuries are reported for long haul flight severe turbulence events.

It is further evidence of the need to inform passengers on the importance of having their seatbelts fastened during the flight and for the crew to manage the cabin and secure themselves appropriately in anticipation of severe turbulence and during the event.

## Post turbulence cabin duties

When the flight crew confirms that the aircraft is clear of the turbulence, the cabin crew can leave their seat, check with passengers for any reports of injury, provide first aid if necessary and reassure other passengers. The cabin should then be checked for damage.

Once the situation assessment is done, the purser must report any injury or damage to the flight crew.

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Severe turbulence can cause injuries to passengers and cabin crew as well as damage to the cabin. Flight crew must ensure they are aware of and use all available means to prevent flying through areas where turbulence will be encountered. If turbulence is unavoidable then FCOM procedures and recommended techniques must be applied to limit risks of injury to passengers or cabin crew and damage to the cabin:

- Keep autopilot ON
- Keep autothrust ON and use the QRH turbulence penetration speed if turbulence is severe
- If the autopilot is disconnected, only use careful and considered inputs on the sidestick and take advantage of the fly-by-wire capability to cope with turbulence.
- Do not use rudder to counter turbulence
- Use manual thrust when autothrust variations become excessive
- In cruise, consider descent to a lower Flight Level and don't overreact to temporary overspeed excursion.
- In final approach, use autothrust to benefit from the ground speed mini function
- Report any severe turbulence encounter to the Maintenance at the end of the flight with a logbook entry.

Communication between the flight crew and the cabin crew enables safe and efficient management of the cabin before and during turbulence events.

Cabin crew should remember that they must first ensure their own safety by immediately seating in the closest available seat and securely fasten their seatbelt in the case of sudden severe turbulence. Assisting other cabin crew or passengers should only be resumed when the flight crew confirms that the aircraft is clear of turbulence.

Encouraging the passengers to keep their seat belts fastened at all times when they are seated and ensuring that the cabin and galleys remain tidy during the flight is the most effective means to limit the risk of injury to passengers and cabin crew in the case of unexpected turbulence.

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