Runway Excursion Case Studies:
Threat and Error Management (TEM) Framework
(RERR: 2nd Edition)
NOTE

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Introduction

The purpose of this document is to provide examples of runway excursion accidents for group discussion. These case studies are designed to be used in workshops and classroom sessions, where groups can review the accident and identify missed opportunities. Every accident has multiple potential opportunities, and in some cases the elimination of one or more of the factors may have prevented the event from becoming an accident.

This document was designed within a Threat and Error Management (TEM) framework. We would invite the reader to refer to the TEM presentation in the RERR toolkit workshop folder, and accomplish other research regarding TEM to further their knowledge of this important safety concept.

The origin of TEM is tied to the origin of the Line Operations Safety Audits (LOSA) which began with a simple question: “Do the concepts taught in training transfer to normal everyday flight operations?” The first LOSA observations were focused on observing Crew Resource Management behaviors, and were later expanded to address errors and error management. It became evident that knowing the conditions under which the errors occurred was crucial to fully understanding why the errors were committed. Hence the concepts of threat management were established and the Threat and Error Management (TEM) model was fully developed.

Threats, from a TEM perspective, are “challenges” that must be identified and properly handled by personnel. From a pilot perspective, threats are “factors external to the flight deck that increase the complexity of flight operations.” Threats are not necessarily caused by anything other than existing factors: for example; high terrain near a runway, wet runways, crosswinds, etc., are all threats that are common to the environment that can be managed through training and experience. A short summary of TEM follows:

Threat Management categories:

1. Missed (not identified)
   - Result: safety margin reduced or lost
   - This potential is reduced or eliminated with procedures, checklists, experience and training

2. Identified
   - Decision required

3. Identified threat management categories:
   - Monitor (for low risk threats)
     - Threat not considered to be a hazard, or very low risk
   - Avoid
     - Choose a course of action that eliminates the threat
   - Mitigate
     - Change actions that reduce the overall risk

4. Crew actions:
   - May be correct and mitigate threats, or lead to
   - Errors, which are “deviations from flight crew or organizational expectations.”

Errors are the consequences of an action or inaction

- Increase the probability of accidents or incidents
- NOTE: errors do not always result in accidents!
- Procedures should anticipate that humans will make errors, and therefore errors need to be identified and corrected (“trapped”)

Within the ICAO Safety Management System Framework (ICAO Safety Management Manual, Doc 9859 2nd edition-2009), the concept of error management is identical to the TEM concept. “Failures and operational errors will occur in aviation, in spite of the best and most accomplished efforts to prevent them. No human activity or human-made system can be guaranteed to be absolutely free from hazards and operational errors…. 

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Runway Excursion Case Studies 3 RERR 2nd Edition
Failures and operational errors will occur in aviation, in spite of the best and most accomplished efforts to prevent them. No human activity or human-made system can be guaranteed to be absolutely free from hazards and operational errors.”

Therefore the ability to identify threats (or operational risks, according to ICAO), manage these threats, and manage potential errors, offers great potential for reducing the overall accident rate.

Instructor notes

These case studies are divided in the following areas:
- Accident summary: This text was extracted from the official final accident report, which should be used as a primary reference if additional detail is desired.
- Threats, Errors, Controls, Defenses, and TEM strategies
- RERR Observations for Instructors (e.g., instructor notes)

Suggested use

Provide the participants with the accident summary text and copies of the threats, errors, and TEM strategies worksheets. Provide adequate time for discussion, and then ask them to list possible controls, defenses, and strategies for handling the existing threats. Note that mitigation strategies might include changes in many different operational arenas, changes in procedures, or changes in training programs.

Following that discussion, you might find the information in the section titled: “RERR Observations for Instructors” of value. It is collected from the comments identified during a number of workshops during 2009 and 2010. It is not intended to be an all inclusive list, provide any legal interpretation of the causes of the accident, criticize any organization or operator, nor modify in any way the judgement and conclusions of the final accident investigation reports.
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Take-off Runway Excursion
Boeing 747-200 Runway Excursion Accident
Brussels, Belgium

Case Study 1
Take-off Runway Excursion

Boeing 747-200 Runway Excursion Accident
Brussels, Belgium, 25 May 2008 - 0 Fatalities

The factual information on this accident is taken from the final investigation report of the Belgian Air Accident Investigation Unit, available at http://www.mobilit.fgov.be/data/aero/accidents/AA-8-5.pdf. The following study constitutes observations on the accident in the light of this report and does not purport to be an independent assessment of the accident. It is provided for the purpose of reducing the possibility of future runway excursions, and does not seek to apportion blame or liability.

The Accident

The 747-200 freighter was planned to operate from Brussels, Belgium to Bahrain with a crew of 2 pilots and a flight engineer.

The take-off was planned for a full length takeoff on runway 20 (2987 meters/9799 feet long). The runway was reported as ‘wet’, there was a light headwind, it was daylight and good visibility and the temperature 19°C. The captain advanced the throttles initially and then the flight engineer set the ‘reduced’ thrust setting calculated for the environmental and operational conditions. The aircraft accelerated normally to the $V_1$ of 138 knots and the associated callout was made. Shortly after the $V_1$ call later the number 3 engine ingested a bird and the engine stalled with a loud bang audible in the cockpit.

Seven seconds after $V_1$, at approximately 150 knots, the throttles were retarded to idle and the captain called “reject”. The aircraft began to decelerate but departed the upwind end of the runway paved surface at 72 knots. It crossed a 4 metre drop and the fuselage broke into 3 pieces, coming to rest above a further 20 metre drop to a railway line. There was no ensuing fire and all 3 crew safely evacuated via the crew service door on the right side of the aircraft.

The Investigation

After stopping at the runway 20 holding point, the tower asked for accident flight to “expedite” their line up due to traffic on a 7 mile final for the intersection runway 25L.

The investigation determined that the take-off performance had been calculated for the full length of runway 20 (2987 meters/9799 feet long), providing a 273 meter/897 ft safety margin for takeoff. The actual takeoff started at intersection B-1, some 312 meters/1,023 feet shorter than the full length of the runway. The calculation had been for a wet runway but the pilots perceived the runway to be dry on take-off. The headwind component at take-off was 4 knots less than planned during performance calculation.
The captain told the investigators that at the time of the engine stall he felt as though the aircraft had lost acceleration and would not get airborne in the remaining runway length. The aircraft had a history of engine problems and the captain had experienced an engine failure with similar audible signs on this aircraft before.

The number 3 engine had suffered no substantial damage during the stall and was recovering from the stall condition when the throttles were retarded. The aircraft was capable of continuing the take-off following the birdstrike and stall.

The thrust reversers were not deployed during the deceleration and although wet runway take-off performance does not take account of reverse thrust for stopping, use of the remaining available reversers would have been in accordance with standard procedures. The speed brakes/ground spoilers were found retracted with the spoiler handle in the retract position.

The captain reported that he had not eaten that day.

The Runway End Safety Area (RESA) dimensions conformed to ICAO minimum standards (90 metres/295 feet) but not to the recommended dimensions of Annex 14 (240 metres/787 feet).
Based on the foregoing, list the THREATS encountered by the crew:

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List the ERRORS made by the crew:
List some CONTROLS, DEFENSES and TEM strategies that could have been used to prevent the accident:

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<th>Strategy 1</th>
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RERR Observations for Instructors

This accident underlines what every large aircraft pilot should consider the most basic knowledge: do not attempt to reject the take-off if deceleration actions are not started by \( V_1 \), unless it is obvious that the aircraft won’t fly. Bearing in mind the time available to make that decision, pilots need to be absolutely clear in their own minds that in the absence of blatant indications that take-off is not an option (loss of 2 or more engines, gear collapse etc), then the only choice is to go, probably with the throttles firewalled.

The second significant issue is the misidentification of the takeoff point. The crew may have felt they had an additional margin due to using wet runway figures on what they judged to be a dry runway, but any gain was lost by starting the take off 1,000 feet from the runway end.

RESAs are the last line of defense from catastrophe after an overrun and it is a common feature of runways with hazards in the overrun area (banks, ravines, water) to have characteristically short RESAs.

Workshop participants should identify some or all of the following threats:

Organizational – aircraft history of engine problems, training

Airport Environment – short RESA, steep drop after runway end, absence of EMAS potential runway/taxiway signage issues

Meteorological – decaying headwind component

Procedural –No spoilers selected, no reverse thrust, abort above \( V_1 \)

Human – possible hypoglycemia, mindset due to exposure to engine problems, possible crew fatigue

ATC – Use of shorter runway for takeoff

And potential errors:

- Use of intersection for take-off using full length data
- Failure to request full length for takeoff (misunderstanding airport configuration)
- Misinterpretation of engine stall symptoms
- Decision to reject above \( V_1 \)
- Failure to use remaining available reverse thrust or speed brakes

TEM Strategies:

Airport – wherever practicable, the RESA should meet not just ICAO’s minimum standard but also the recommended dimensions. In cases where this is not possible and significant hazards exist in the overrun, consideration should be given to the installation of EMAS.

Operator – policy, procedures and training should leave pilots in no doubt that a decision to reject take-off after \( V_1 \) will almost certainly result in an overrun, and that no single engine problem encountered after \( V_1 \) should prevent the aircraft getting safely airborne. Pilots should be reminded that the audible symptoms of engine stall may be significantly louder than they would expect. Any continuing and higher than normal level of specific system problems on a given fleet or aircraft should be seen as a potential for conditioning pilots to adopt a mindset with regard to the reliability of the system or the aircraft as a whole, which may influence their behavior and decision making. Such conditions must be addressed as a matter of urgency.
**Individual** – most pilots will never experience an engine failure on take-off, or even an engine stall for real. This captain had already seen an actual failure on the same aircraft. This may or may not have influenced his behavior but it underlines the need to make decisions based on the information available and not to make unnecessary or unsupported assumptions. The accident also reinforces the need to for pilots to rely on trained principles – if it worked in the simulator it will probably work for real.

**Airport** – The runway was equipped with an ICAO compliant Runway End Safety Area (RESA), but not the recommended RESA, or an EMAS system. The report did note that the aircraft was intentionally steered off of the runway centerline to the right as it started to overrun to miss the approach lights.

Access to the full length of runway 20 was via an unusual configuration. The displaced threshold for runway 20 was painted on the runway immediately adjacent to taxiway B-1, possibly contributing to crew confusion as to where the runway began. To use the entire length of runway 20, the aircraft would have needed to taxi across runway 25 and then perform a nearly 180 degree turn. The accident report did not address airport taxi charts or taxiway signage regarding this unusual runway/taxiway configuration.
B737-400 Runway Excursion Accident
La Guardia Airport, Flushing, New York

Case Study 2
Take-off Runway Excursion

B737-400 Runway Excursion Accident
La Guardia Airport, Flushing, New York, 20 September 1989 – 2 Fatalities

The factual information on this accident is taken from the NTSB final investigation report available at http://www.airdisaster.com/reports/ntsb/AAR90-03.pdf. The following study constitutes observations on the accident in the light of this report and does not purport to be an independent assessment of the accident. It is provided for the purpose of reducing the possibility of future runway excursions, and does not seek to apportion blame or liability.

The Accident

The 737-400 and its crew arrived at La Guardia on the evening of 20 September 1989 from Baltimore after long departure delays, expecting to operate another sector to Norfolk. Further substantial delays at La Guardia led to a change of destination to Charlotte. The aircraft departed the terminal after several changes of plan and minor delays, with 2 pilots, 4 cabin crew and 57 passengers on board. The weather was overcast at 500 feet, good visibility (8 km/5 nm) in darkness, rain and fog, light winds and a temperature of 73°F. Runway 31 (2164 meters/7,100 feet long) was reported as wet.

The aircraft left the stand at 2252 local and the captain taxied to the runway. The first officer was the pilot flying, but completed the challenges of the before take-off checklist in accordance with standard procedures. The CVR indicated that the captain was somewhat hesitant in responding to some of the checks and he responded that the autobrake was off contrary to procedures.

The take-off commenced at 2320 as the first officer first pressed the auto throttle disengage button instead of the TO/GA and then advanced the throttles manually to what he perceived was an approximate flex thrust take-off position. The captain subsequently recognized the error and several seconds later made a statement which led the first officer to believe that he would set the power. The aircraft began to track to the left of the runway centerline and there followed a bang and a rumbling noise. Miscommunication between the pilots caused them both to believe that the other had directional control of the aircraft, whereas the first officer had ceased to make correctional inputs on the rudder and the captain was using the nose wheel steering tiller only.
Standard callouts from the captain of 80 knots and $V_1$ were not made. At 130 knots ($V_1 + 5$ knots) the captain made a non-standard call intended to imply that he was initiating a rejected take-off and closed the throttles. He applied differential manual braking to control the heading and retard the aircraft, and after several seconds reverse thrust was applied. The aircraft departed from the upwind end of the paved surface at 34 knots; the fuselage broke into 3 pieces and came to rest in water, partly supported by the pylons of the runway 13 approach light system. Two passengers died from injuries sustained and 23 other passengers and crew were injured.

The Investigation

The investigation identified that during the period at the parking stand in La Guardia, the rudder trim had been selected to full left deflection. This was not detected by the captain during the flight control check, during taxi out or when challenged in the checklist. Both pilots observed the aircraft veering left during the take-off and the first officer initially attempted to control this with rudder. However, at the same time the captain applied nosewheel steering without telling the first officer, and then made a comment leading the first officer to believe that the captain had directional control of the aircraft.

The bang and rumbling were probably caused by a nosewheel tyre coming off the rim due to side loads caused by use of the steering. The aircraft was directionally controllable had the correct technique (right rudder) been used.

The required accelerate/stop distance was significantly and unnecessarily increased by several factors including a takeoff thrust setting below maximum, slow retardation of thrust after the abort was started, and delayed braking. Had these factors not been present it would have been possible to stop within the runway length.

The runway was grooved and subsequent tests revealed that braking performance when wet was more than adequate to allow a correctly performed rejected take-off.

The captain had approximately 140 hours in command of the 737 and the first officer was on his first unsupervised line flight on the type, after 39 days without flying.
Based on the foregoing, list the THREATS encountered by the crew:

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List the ERRORS made by the crew:

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<th>Error Description</th>
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List some **CONTROLS**, **DEFENSES** and **TEM** strategies that could have been used to prevent the accident:

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**RERR Observations for Instructors**

The accident, initiated by an apparently inadvertent selection of full rudder trim, was perpetuated and exacerbated by a series of non-standard, non-compliant or erroneous actions by the pilots. The captain had at least 3 clear opportunities to recognize the incorrect setting but either failed to do so or through procedural deviation missed the opportunity. Non-standard communication during the take-off roll led to total confusion as to who had control of what function to the extent that neither pilot was controlling the rudder or setting thrust.

The perceived need for significant nosewheel steering at high speed, followed by a bang and rumbling should have caused the captain serious concern, probably to the extent that the take-off should have been rejected below 100 knots. Rejecting a take-off above $V_1$ is widely known to be a major factor in runway overruns.

**Workshop participants should identify some or all of the following threats:**

**Organizational** – crew scheduling procedures pairing two inexperienced pilots, implications of significant delay and schedule disruption, pilot training and supervision

**Airport Environment** – short runway, wet runway, no significant overrun/RESA, water hazard beyond paved surface, absence of engineered materials arrester systems (EMAS)

**Meteorological** – rain, darkness

**Procedural** – none

**Human** – procedural non-compliance, non-standard communications, stress from schedule disruption

**Other** – none

**And potential errors:**
- Repeated failure to recognise the incorrect rudder trim setting
- Incorrect checklist responses
- Incorrect procedure for selection of autobrake
- Incorrect procedure for setting take-off thrust
- Use of non-standard technique to control yaw (steering instead of rudder)
- Failure of the captain to positively take over control
- Non-standard communications leading to misunderstanding
- Failure to reject take-off when faced with multiple signals of non-standard aircraft behaviour
- Decision to reject take-off above $V_1$
- Late and incomplete application of braking (differential braking)
- Late application of reverse thrust
TEM Strategies:

**Airport** – explore the possibility of installing EMAS at the ends of runways with short overruns and removal of significant overrun hazards

**Operator** – training for rejected take-off must include scenarios other than engine failure and at speeds well below $V_1$. Above all training must emphasize the need to reject the take-off below $V_1$. Training and checking has to be vigilant to ‘practical drift’ from procedural compliance and operators should consider implementation of LOSA to measure compliance, as well as threat and error exposure in line operations. Crew scheduling procedures must take account of the relative experience of pilots operating together, as well as their recency on type.

**Individual** – adherence to standard operating procedures is fundamental to achieving a consistent performance in complex but repetitive tasks. Deviation from procedures risks missing vital actions as well as leaving colleagues in a limbo of uncertainty. The same is true of communication and individuals should resist any temptation to deviate from standard phraseology and callouts, even when interacting with close colleagues on a regular basis. Pilots must address and immediately clarify any confusion as to who is in control of vital aircraft functions, especially during critical phases of flight. The captain must ensure that positive command of the aircraft is clearly communicated at all times.
Boeing 747-200 Runway Excursion Accident
Halifax, Nova Scotia, Canada

Case Study 3
Take-off Runway Excursion

Boeing 747-200 Runway Excursion Accident
Halifax, Nova Scotia, Canada, 14 October 2004 – 7 Fatalities

The factual information on this accident is taken from the TSB Canada final investigation report available at http://www.tsb.gc.ca. The following study constitutes observations on the accident in the light of this report and does not purport to be an independent assessment of the accident. It is provided for the purpose of reducing the possibility of future runway excursions, and does not seek to apportion blame or liability.

The Accident

The 747-200 freighter was operating a sequence of flights, which originated from Luxembourg on 13 October 2004, via Bradley Airfield (USA), Halifax (Canada), Zaragoza (Spain) and back to Luxembourg, with an augmented flight crew (2 captains, 1 first officer and 2 flight engineers), a loadmaster and a ground engineer.

The aircraft commenced take-off from runway 24 (TORA 8800 feet, TODA 9800 feet) at Halifax at 0653 local time in darkness, light winds, good visibility, a temperature of 10 °C and overcast at 1800 feet. The thrust levers were advanced to the pre-selected EPR of 1.33 and the aircraft accelerated to 130 knots, at which point take-off rotation commenced some 5500 feet from the start of the take-off roll. The pitch attitude increased to 9°, then 11° and the aft fuselage contacted the runway with 800 feet remaining to the upwind threshold. Shortly thereafter the thrust levers were advanced further and the aircraft passed the runway end at 152 knots and 11.9° nose up, with the aft fuselage but not the wheels in contact with the ground.

The aircraft finally separated from the ground 670 feet beyond the end of the paved surface but seconds later the aft fuselage impacted upon an earthen berm, topped with a concrete plinth accommodating the ILS localizer antenna, 1150 feet beyond the runway end. The tail section detached from the aircraft, which then pitched down and impacted a wooded area nose first with severe structural break up and an intense fire. All seven crew members were killed.
The Investigation

The investigation determined that the crew had probably used a take-off weight of 240,000 kgs (529,109 lbs), which was equal to the take-off weight for the preceding sector, to calculate the take-off thrust EPR and V speeds. This was more than 100 tonnes less than the load sheet take-off weight of 350,698 kgs (773,156 lbs), which in itself was less than the actual weight due to some organizational and procedural deficiencies at the operator and at the ground handling service provider. The laptop application used for the take-off data calculation defaulted to the take-off weight value inserted for the previous calculation until such time as it was updated by the crew. The investigation suggested that crew members had not undergone any formal training in the use of the laptop application.

As a result of the incorrect defaulted take-off weight in the laptop, calculated engine thrust was insufficient to accelerate the aircraft to Vmu within the runway length and the calculated VR was significantly below Vmu. Company procedures required an independent cross-check of the take-off data from the laptop and a gross error check when setting the V speeds, but the investigation indicated that these may have been omitted.

At the time of the accident the flight crew had been on duty for almost 19 hours and were at a period of circadian low. The planned sequence of flights called for a total duty period in excess of the maximum permitted by the operations manual. The investigation also identified a level of personal stress amongst employees generally, due to prolonged absences from their families and the political/security situation at home.

The crew failed to observe that actual aircraft performance during the take-off roll was inadequate to permit it to get airborne within the runway length, until it was too late to prevent a runway excursion. The aircraft did actually get airborne beyond the end of the runway, and was probably capable of returning to a safe landing in the absence of the impact with the berm. However, the berm was not considered an obstacle for take-off performance as it did not penetrate the surface of the obstacle free zone.
Based on the foregoing, list the THREATS encountered by the crew:

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**RERR Observations for Instructors**

Accidents and incidents of this nature are shockingly common and it is contrary to the basic principles of risk management to allow a single error or omission to lead to such catastrophic outcomes. Whilst cross-check procedures should identify such errors, time pressure, fatigue, complacency and numerous other factors will inevitably circumvent them on occasion and they cannot alone constitute a safeguard.

The fundamental issue is that of using the unreliable human to provide the link for vital data transfer in and out of a sophisticated and relatively reliable machine; the laptop computer. Secondary to this is the absence of any automated gross error check by which a system as complex as a 747 cannot determine that the response it has been programmed to give is potentially fatal.

**Workshop participants should identify some or all of the following threats:**

**Organizational** – poor regulatory oversight; improper scheduling; inadequate fatigue risk management; inadequate training (laptop); insufficient oversight of service providers

**Airport Environment** – short runway, no RESA, ILS antenna berm in the overrun

**Meteorological** – none other than darkness

**Procedural** – inadequate safeguards built in, vulnerable to non-compliance

**Human** – fatigue and circadian low, personal stress, non-compliance

**Other** – (industry-wide) failure to recognize the implication of defaults in laptop applications, lack of measures to assist in recognition of inadequate aircraft performance

**And potential errors:**
- Failure to recognise or respond to symptoms of fatigue
- Failure to identify/address personal lack of understanding of laptop application
- Lack of recognition of incorrect take-off weight default value
- Apparent absence of laptop data cross-check
- Apparent absence of V speed gross error check
- Failure to identify/address inadequate aircraft performance in time

**TEM Strategies:**

**Regulator** – whilst accepting the principles of SMS under which operators have some autonomy in risk management, regulators must take ultimate responsibility for ensuring that individual systems are up to the task. This is particularly true in the case of fatigue because the concept of FRMS is still in its infancy and prone to misunderstanding or even abuse. The regulator has a duty of care to ensure through an audit and observation process that both regulatory compliance and industry best practices are met.

**Operator** – operators in general need to begin their risk management process by asking themselves what it is that they would least like to happen, and then identifying what are the precursors to these outcomes. In the fast moving aviation industry it is tempting to push forward in the matters of business, and hope that good business practices will engender good risk management. Time and resources must be set aside for the development and maintenance of a realistic and comprehensive risk register with associated management strategies, and genuine safety performance indicators against which to measure the operation. A non-punitive safety reporting system and a comprehensive flight data monitoring programme are essential to identify developing undesirable trends before they manifest themselves as accidents.
Individual – the primary responsibility of the individual engaged in complex and high risk tasks is to ensure that he is fit to carry them out. That includes fitness in terms of professional and procedural knowledge as well as medical health, and must be supported by a commitment to address the condition or withdraw from service until it is addressed. Also vital is to adopt what James Reason called ‘mutual mistrust’; a polite but ever-present desire to question the actions of those around you and the responses of the systems you operate. Self-discipline is required to combat the natural tendency to ‘practical drift’ (divergence from procedure over time), and ‘denial’ (the perceived dilution of risk through repeated harmless exposure). Finally, an intimate understanding of the ‘normal’ behavior of the aircraft will allow earlier recognition of abnormality.
Landing Runway Excursion
Airbus A320 Runway Excursion Accident
Warsaw Okecie, Poland

Case Study 4
Landing Runway Excursion

Airbus A320 Runway Excursion Accident
Warsaw Okecie, Poland, 14 September 1993 – 2 Fatalities

The factual information on this accident is taken from a translation of the Aircraft Accident Investigation Commission final investigation report available at http://sunnyday.mit.edu/accidents/warsaw-report.html. The following study constitutes observations on the accident in the light of this report and does not purport to be an independent assessment of the accident. It is provided for the purpose of reducing the possibility of future runway excursions, and does not seek to apportion blame or liability.

The Accident

The A320 and its crew of a captain under check in the left seat and a check airman in the right seat, was engaged in a sequence of flights from Frankfurt to Barcelona and back and then to Warsaw before returning to Frankfurt. The forecast weather for arrival in Warsaw included the possibility of clouds, thunderstorms, heavy rain and gusty winds.

During the approach to runway 11 (2890 meters/9186 feet long), a weather front passed over the airport and a heavy rain shower began to deposit several millimetres of water on the runway. ATC informed the crew that the aircraft ahead had reported windshear on the approach and then cleared them to land, reporting surface winds of 160°/15 knots (25 km/hr) [an indicated headwind of 11 knots, crosswind of 10 knots]. In accordance with their precautionary procedures for windshear, the crew increased the approach target speed by 20 knots. The ground spoilers were armed for automatic deployment, flaps were at Full (maximum setting), and the auto brakes were selected on.
On final approach the aircraft encountered a speed decay of 12 knots but the approach continued to touch down in heavy rain. The touchdown was approximately 770 meters/2,500 feet beyond the threshold, leaving 2130 meters/6686 feet of remaining runway. Only the right main gear made positive contact (oleo compression) for several seconds. The pilot applied pedal braking with no effect and called for the check pilot to assist. Nine seconds later and 5,000 feet from the touchdown threshold, when the left main gear oleo compressed, the ground spoilers and reversers deployed, and shortly afterwards the wheel brakes began to operate.

The aircraft overran the upwind threshold at 72 knots, continued for 300 feet until the left wing contacted the localizer antenna embankment, rotating the aircraft and collapsing the landing gear. A fire began due to the ruptured fuel tanks. The passengers were evacuated and although there were many injuries all but one survived. The check airman died in the impact.

The Investigation

The investigation determined that throughout the approach the groundspeed was significantly greater than the airspeed, indicating a tailwind, and this should have been apparent on the flight instruments. In fact the tailwind component on short final exceeded the maximum permitted for landing. The crew had increased the approach target speed but there was no record of a discussion with regard to the effect on landing distance. The actual surface wind at touchdown was 210°/19 knots, gusting to 29 knots [a calculated tailwind of 18 gusting to 27 knots]. As a result of the crosswind component the pilot maintained ‘into wind’ right control input during the flare and initial roll out, compressing the right oleo but minimizing compression to the left oleo for some time. The difference in potential ground speed between the 11 knot reported headwind and maximum actual tailwind (with gusts) was 38 knots.

Due to the aircraft design at that time, the conditions for automatic deployment of the ground spoilers and reversers were not met until both main gear oleos were compressed, and due to aquaplaning the main wheel rotation speed had not met the conditions for the braking system to be active until 13 seconds after right main gear touchdown. The aquaplaning also prevented the used of reverser thrust. Procedures for a normal brake system failure called for reversion to the alternate braking system, which would have allowed the pilot to apply pedal braking, albeit without anti-skid.

The windshear precautionary procedures included a number of other actions and considerations, apparently not applied by the crew. These included use of flap configurations other than full. A longer and more ‘into wind’ oriented runway, runway 15 (12,100 feet) was in use for departures at the time.
Based on the foregoing, list the THREATS encountered by the crew:

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<th>Category</th>
<th>Details</th>
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<td>Organizational</td>
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<tr>
<td>Human</td>
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<tr>
<td>ATC</td>
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List the ERRORS made by the crew:
List some **CONTROLS, DEFENSES** and **TEM** strategies that could have been used to prevent the accident:

| 1. |
| 2. |
| 3. |
| 4. |
| 5. |
| 6. |
| 7. |
| 8. |
RERR Observations for Instructors

An unfortunate combination of circumstances at touchdown led to a substantial delay in the application of retardation devices, to the extent that it was not possible to stop in the remaining runway length. However, there were numerous tell tale signs that could have suggested to the crew that the prevailing conditions were not conducive to a safe landing. Increased approach speed, a strong tailwind and a runway contaminated with water, together with a warning of windshear on approach, would indicate a cumulative risk of an undesirable outcome.

Nevertheless, having made the decision to continue to land, basic knowledge of aquaplaning dictates a firm touchdown to break through the layer of surface water and allow main wheel spin-up. Having identified that the normal brake system was not active, the crew could have reverted to alternate braking. Alternatively, use of a flap configuration other than full (as recommended in the windshear procedures) may have allowed immediate application of braking but would have led to a further increased approach speed.

ATC did not notify the crew of the significant change in the surface wind – perhaps this final piece of information might have drawn the pilots’ attention to the overall environmental situation. In the conditions it may have been appropriate to offer runway 15 for landing traffic.

Workshop participants should identify some or all of the following threats:

Organizational – training (possibly inadequate)

Airport Environment – contaminated runway, short RESA, localizer antenna embankment

Meteorological – thunderstorms, heavy rain, windshear, tailwind

Procedural – No fault go-around policy, mandatory go-around for long touchdowns, possible changes to windshear approach IAS additives

Human – non-compliance, poor situational awareness

ATC – allocation of runway, incorrect (or outdated) wind information

And potential errors:

- Failure to observe tailwind component
- Lack of consideration of effect of increased approach speed
- Long landing
- Soft landing on contaminated runway
- Continued application of excessive right control input after landing
- Lack of understanding of aircraft system logic
- Failure to recognise cumulative effect of several threats
- Decision to continue the approach
TEM Strategies:

**Operator** – the report isn’t clear with regard to the adequacy of crew training but the evolution of the accident suggests inadequate understanding of environmental threats, critical aircraft systems and operational procedures, all of which point to shortcomings in training.

Operational policy should also include clear guidance on risk assessment and threat management, especially when faced with multiple potentially hazardous conditions. There are tools and models available to provide real time risk assessments of any given operation, using all of the anticipated conditions, which in this case have been used to alert the crew to the seriousness of the forecast situation. Aircrews should be especially sensitive to the increase in risk when multiple factors are present, and aim for a higher performance standard. For example, the combination of windshear, increased approach speed, wet runway, and tailwind could result in a decision to touchdown in the first 300 meters/1000 feet or go-around.

**ATC** – The report does not explore the reasoning within air traffic control that allowed the aircraft to land on a less suitable runway. However, it suggests a lack of understanding of the significance of the accumulating threats to a safe landing – tailwind, windshear, contamination etc. Air traffic service providers should utilise every opportunity for controllers to interact with flight operational personnel, in training, simulators and even familiarization flights, to ensure that they are able to offer the best options in the face of specific threats. The preceding aircraft reported “severe windshear during approach” after landing. Although this report was passed on to the accident, no procedures existed to delay subsequent approaches to that runway.

**Individual** – pilots must ensure that they understand their aircraft’s systems intimately, so that they can respond to apparent system malfunctions quickly and appropriately. The concepts of situational awareness, risk assessment and threat management need to be embedded in every individual’s operational technique, especially when faced with mounting threat conditions. Above all, pilots actions should reflect the aim of every approach – to safely deliver the aircraft to the correct point on the runway, in the correct attitude and with speed and rate of descent appropriate to the prevailing conditions and runway length. If it is apparent that will not be achieved there is only one course of action: initiate a go-around and fly the published missed approach procedure. One example in this case is a cockpit crosscheck of groundspeed against IAS just prior to touchdown to validate reported winds would allow the crew to make an informed decision as to continuing the approach or making a go-around.

Aircrew should feel empowered to insist on the safest runway when multiple risk factors are present, or hold for a short period allowing severe weather to pass.

**Airport** – There was a functional ILS approach for the runway in use. No information in the report discussed whether the runway was equipped with an ICAO compliant Runway End Safety Area (RESA). The report did note that the aircraft was intentionally steered off of the runway centerline as it started to overrun, but ultimately the left wing hit a localizer antenna.

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1 There is a procedure in ICAO PANS-ATM to report without delay at commencement and during final approach significant change in mean surface wind direction and speed. ICAO PANS-ATM Chapter 6.6.4 a) & 6.6.5 b).

2 There is not a procedure in PANS-ATM to delay subsequent approaches to a runway when windshear is reported. The procedure is to report to aircraft at the commencement of the final approach among others, the information of windshear and/or turbulence area in the final approach area ICAO PANS-ATM (Chapter 6.6.4 b).
Airbus A320 Runway Excursion Accident
Sao Paolo Congholas

Case Study 5
Landing Runway Excursion

Airbus A320 Runway Excursion Accident
Sao Paolo Congholas, 17 July 2007 – 199 Fatalities

The factual information on this accident is taken from the Brazilian CENIPA final investigation report available at http://www.cenipa.aer.mil.br/cenipa/paginas/relatorios /pdf/3054ing.pdf . The following study constitutes observations on the accident in the light of this report and does not purport to be an independent assessment of the accident. It is provided for the purpose of reducing the possibility of future runway excursions, and does not seek to apportion blame or liability.

The Accident

The A320 was operating the return sector of a Sao Paolo-Porto Alegre-Sao Paolo flight sequence, with a flight deck crew of 2 captains. Arrival to Sao Paolo was in early evening darkness, light headwinds (8-12 knots) and moderate visibility in light rain; runway 35L (1945 meters/ 6,381 feet long) was reported by ATC and a previous aircraft as being ‘wet and slippery’. The runway had no RESA. The number 2 engine thrust reverser had been locked out due to a system fault and the aircraft was ‘tankering’ fuel and was close to maximum landing weight. The crew was aware that the #2 reverser was MEL’d and was unavailable.

Except for some lateral flight path deviations to avoid weather en route, the flight proceeded without incident to the flare. The runway was wet and slippery, and this information was provided by the tower to the crew. Just before touchdown the pilot responded to the normal ‘RETARD, RETARD’ auto callout (at 20 feet AGL) by moving the number one thrust lever from the climb (CL) detent to the idle stop. The main wheels touched down on the wet runway at 140 knots and the pilot selected the number one reverser lever through idle to full reverse,
at which point the ‘RETARD’ auto callout ceased. The number two thrust lever remained at CL with its reverser lever in the ‘stowed’ position.

Shortly afterwards the pilots observed that the aircraft was not decelerating as expected and that the ground spoilers had not deployed. Manual braking was applied 7 seconds after main wheel touchdown. The aircraft began to veer to the left and departed the left side of the runway close to the upwind end. It then collided with some buildings close to the runway at approximately 96 knots, and burst into flames. All 187 passengers and crew on board and 12 people on the ground were killed.

The Investigation

The CVR revealed that the pilots were concerned about the weather in general and in particular in relation to the approach and landing at Congholas, which they, in common with other pilots, regarded as demanding. This concern was compounded by the condition of the number two reverser and especially the ATC report that the runway was ‘wet and slippery’. This landing occurred at night.

The procedure for handling thrust levers on landing when one reverser was locked out had recently been changed – previously pilots were required to select reverse only on the side with an operational reverser, whereas the new procedure required selection of both reversers, regardless of their condition. The new procedure resulted in an additional 55 metres of required landing distance due to a momentary application of forward thrust during selection. The investigation concluded that the pilot reverted to the old procedure to avoid this landing distance penalty. This operator normally used thrust reverse as a factor in calculating required landing distance.

The crew used the correct ‘new’ procedure on the previous landing in Porto Alegre. However, in the landing flare at Congholas only the number one thrust lever was moved from the CL detent to idle, and after touchdown only the number one reverser was selected, while the number 2 thrust lever remained in the CL detent throughout.

There was no warning system to alert pilots to the fact that one thrust lever was in the CL detent and the other was selected to reverse. Furthermore, the logic of the RETARD auto callout allowed it to be inhibited when only one thrust lever was selected to reverse. The auto thrust system logic caused the number two engine thrust to advance in an attempt to maintain the last commanded speed target until the auto thrust was disconnected automatically by selection of number one reverser, at which point the ‘thrust lock’ function maintained approximately 1.18 EPR in forward thrust. This autothrust logic therefore increased thrust on the number two engine after landing.

Automatic ground spoiler deployment was inhibited by the absence of the condition ‘both thrust levers at idle’. According to the accident report: “the non-deflection of the ground spoilers significantly degrades the aircraft braking capability, increasing the distance necessary for a full stop of the airplane by about 50%, according to data provided by the manufacturer. As in a cascade effect, the autobrake function, although armed, was not activated, because the opening of the ground spoilers is a prerequisite for such activation. Thus, after the landing, there was neither deflection of the ground spoilers, nor activation of the autobrake.

Assuming a normal condition of the aircraft the required landing distance for the prevailing conditions was less than the landing distance available, although the margins were not large. The calculated actual landing distance was considerably shorter.

ICAO standards prescribe a RESA of 90 meters/295 feet and recommend 240 meters/780 feet. In locations where this is not possible, ICAO recommends that airports consider reducing some of the declared distances. Runway 35L had been reported as ‘slippery’ by pilots during the days preceding the accident.
The airline was undergoing a period of rapid growth and one result was an imbalance in crew numbers, there being many more captains than first officers. As a result it was not uncommon for two captains to fly together. The captain in the right hand seat (Second in Command, or SIC) was inexperienced on the A320 and his right seat experience was limited to a ‘right seat check’. The SIC had over 13,000 hours of flying time as an engineer, with only 238 hours of actual pilot time in the A320.

The accident investigation report noted the following regarding organizational safety culture:

“In the interviews conducted during this investigation, a huge disparity could be observed between the reality as perceived by the Safety sector and the reality as experienced by the crews. On account of the lack of feedback concerning their reports, the crew members eventually ceased to interact with that prevention sector, thus generating a vicious circle, because the growing shortage of reports contributed to reinforce the idea that all was well. By and large, the reports concerning the runway conditions were forwarded by the pilots only to the control tower and not to the safety (department) of the company.”

The airport had recently repaved this runway, covering the previously grooved surface. No rain had occurred after this work until two days before the accident. During those two days, several complaints were made by pilots regarding the slippery runway condition (when wet), and a runway excursion accident had occurred the previous day. No runway friction measurement was made by the airport after receiving those complaints. No NOTAM had been issued regarding the change in runway surface friction prior to the accident.

More than one year before the accident, the National Civil Aviation Agency (ANAC) was made aware of the need of the operator to have all braking devices operational when that runway was wet (including spoilers and thrust reversers), however there did not appear to be a published restriction regarding this. The same aircraft had landed twice that day at Congholas with a wet runway.

\(^{1}\) see CENIPA Final report A-No 67/CFEDNIPA/2009, page 72
Based on the foregoing, list the THREATS encountered by the crew:

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List the ERRORS made by the crew:
List some **CONTROLS**, **DEFENSES** and **TEM** strategies that could have been used to prevent the accident:

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RERR Observations for Instructors

This is a classic threat rich environment, which undoubtedly contributed to a single but critical error, the consequences of which were difficult to analyse quickly. It must be recognised that any significant change in procedure offers an opportunity for confusion and/or reversion under stress, and in this case the new procedure had a potentially undesirable impact on landing distance. The fact that the old procedure was safe was reinforced in pilots’ minds by the fact that it had ‘worked’ for them many times before. Change always engenders risk.

The pilot flying the aircraft was stressed by his shared perception of the difficulty of making a safe landing at Congholas, compounded by the weather, the landing weight, the inoperative thrust reverser and finally by ATC’s reference to a ‘slippery’ runway. Human performance is substantially and unpredictably degraded by stress and it is difficult for the individual to recognize his own condition. It is vital that pilots are able to identify mounting stress in a colleague, and if necessary take over control.

Telling a pilot that a runway is ‘slippery’ has little value – unless he chooses to divert as a result there is little he can do about it. It may even cause other conditions to be masked by an assumption that the aircraft is skidding. In this case the lack of deceleration may at first have been attributed to the runway state, delaying any attempt to trouble shoot in the cockpit. In this case, the organization’s policies regarding diversions may have also contributed to the accident.

Automation is undoubtedly able to reduce cockpit workload and allow pilots to concentrate on flying the aircraft. However, if the systems are illogical, inconsistent or not well understood by the operators there remains significant potential for an undesirable condition to go unrecognised or uncorrected until it is too late.

Workshop participants should identify some or all of the following threats:

Organizational – rapid expansion, crewing policy, change management, safety culture (lack of feedback to pilots after safety reports)

Airport Environment – short runway, recent construction without a follow up friction measurement, known ‘slippery’ condition, no RESA, buildings in the overrun

Meteorological – darkness, rain

Procedural – recent change requiring additional landing distance

Human – personal stress, non-compliance, inadequate system knowledge

Other – ATC non-standard aerodrome information (slippery runway), aircraft design; inadequate warning logic, inappropriate system logic, automation3

3 ICAO PANS-ATM, Chapter 12 Phraseologies, 12.3.1.10 Aerodrome information.
And potential errors:
- Inadequate threat recognition and management
- No identification of a “critical runway” with restrictions on operations
- Reverting to the old procedure
- Failure to retard number two thrust lever at ‘RETARD’
- Failure to recognise that the thrust lever was at CL after landing
- No response to absence of automatic ground spoiler activation
- Late response to no autobrake activation

TEM Strategies:

Operator – any change or deviation from ‘normal’ operations has the potential to introduce unexpected threats, and should always be preceded by a thorough risk assessment. Times of expansion are especially prone to unintended consequences as the organisation focuses on business opportunities rather than any attendant risks. Threat analysis and management must also be applied at the tactical level to identify cumulative risk in individual operations – for example, tankering fuel to a destination with a short runway, known to have poor braking characteristics, during the wet season, using an aircraft with one reverser inoperative, may be technically achievable but probably constitutes at least one threat too many.

Standardization of operations was also an identified factor: in the previous 20 flights on this aircraft (with the inoperative thrust reverser), 5 different procedures were used by flight crews.

The accident investigation issued many recommendations, including the following:

- To set procedures for operators to insert in the briefing of descent an analysis of the runway length necessary for landing and the actions to be taken in case of nonfunctioning of the ground spoilers and/or brakes. Such analysis has the objective of defining the immediate start of a go-around, if necessary.
- To study the viability of setting norms for the operators to insert, in the procedure after the touchdown, the confirmation of the functioning of the ground spoilers before the activation of the thrust reverser. This sequence has the objective of allowing a touch-and-go landing, in case of non-functioning of the ground spoilers.
- To establish procedures for operators to do training in flight simulators of touch-and-go landings after the non-functioning of ground spoilers and/or brakes, with the objective of demonstrating the characteristics of the aircraft performance under those conditions.
- To study the convenience of adjusting the operation of their aircraft at airports defined by them as “airports operation under special condition” (or “critical runways”), while considering the possibility of not making landings and takeoffs in situations with pinned thrust reversers.

Airport – the value of a RESA is seldom recognised until it is needed. The constrained location of many airports precludes any construction beyond the existing runway surface, which leaves the airport two options:

- reduce the declared distances as recommended by ICAO, but this may restrict the operational capability of the airport, or
- install engineered materials arrester systems (EMAS) as has been successfully achieved elsewhere.

The friction characteristics of any runway are critical to aircraft landing performance and it is vital that any identified deficiencies are addressed as a matter of urgency, and NOTAM’d until corrected.

Construction can potentially create many hazards, such as the loss of grooving, and this should be considered in airport maintenance and construction plans.
ATC – any practice to offer pilots extraneous or non-standard information should be avoided, to prevent inducing erroneous or unhelpful perceptions.

Pilots – threat identification and risk management are an essential part of the operation from planning, through preparation to implementation, and pilots must be alert to the implication of cumulative threats. If the number and magnitude of threats is approaching a point at which it causes an individual stress then something must be done immediately to manage the attendant risk. However, this should not be achieved by the use of non-standard practices, as it may not be possible to envisage all of the likely consequences with the information available. When things do start to go wrong there is no substitute for intimate knowledge and understanding of all aircraft systems, especially those with some level of automated functionality.

Aircrew should “raise their standards” regarding landing performance (e.g., touchdown point, IAS control, quick deployment of reverse thrust, quick deployment of ground spoilers, etc) when multiple risk factors are present, and be quicker to make a go-around decision when the “higher performance standards” are not achieved. The non-flying pilot is a valuable resource who can monitor all deceleration resources (spoilers, engine reversers, use of braking, etc) and make appropriate, very firm and clear callouts, when the flying pilot fails to use all available braking.
Airbus A340-300 Runway Excursion Accident
Toronto, Ontario, Canada

Case Study 6
Landing Runway Excursion

Airbus A340-300 Runway Excursion Accident
Toronto, Ontario, Canada, 2 August 2005 – 0 Fatalities – Aircraft Destroyed

The factual information on this accident is taken from the TSB Canada final investigation report available at http://www.tsb.gc.ca/eng/rapports-reports/aviation/2005/a05h0002/_a05h0002.pdf. The following study constitutes observations on the accident in the light of this report and does not purport to be an independent assessment of the accident. It is provided for the purpose of reducing the possibility of future runway excursions, and does not seek to apportion blame or liability.

The Accident

The A340-300 was inbound to Toronto from Paris with a flight deck crew of two pilots. The First officer flew the approach and landing. Thunderstorms had been forecast for Toronto for the ETA and approaching the airfield the aircraft was instructed to hold due to arrival delays on account of the weather. With diminishing fuel reserves the crew changed their chosen alternate to one closer but when they were eventually released from the hold the crew became concerned that fuel margins were very tight should they not be able to land.

The ATIS continued to report thunderstorms, heavy rain and poor visibility (no wind information was available because the wind sensors had been damaged by the storm) as the aircraft was cleared for arrival, to expect landing on runway 24L (2,743 meters /9,000 feet long). The aircraft joined the ILS approach and was stabilised in the landing configuration by 8 miles from touchdown. The aircraft landing ahead reported the wind as 290°/15-20 knots and the braking action ‘poor’.

The rest of the approach was flown in variable conditions, including heavy rain, thick cloud and turbulence. The crew had visual contact with the ground when the aircraft was 2 to 3 nm from the runway at approximately 1,100 feet above the runway. At an altitude between 1000 and 1500 feet above ground level (AGL), about half of the runway was visible and at times part or all of the ramp area was clearly visible. The runway was observed to have a wet, ‘glassy’ appearance. They also saw lightning striking frequently around the airfield and a red return on the weather radar over the upwind end of the runway.
At 323 feet AGL the autopilot and autothrust were disengaged and the aircraft began to deviate above the glideslope; at the same time the wind changed from a crosswind from the right to include a tailwind component of 10 knots. The aircraft crossed the threshold approximately 40 feet high of the glideslope and encountered very heavy rain, and visual contact with runway environment was severely reduced. The landing flare began at 40 feet and the aircraft levelled for 2.5 seconds at 25 feet, with thrust being reduced progressively between 50 and 20 feet. The aircraft touched down 1,158 metres/3,800 feet from the landing threshold at 143 knots (150 knots groundspeed) and the ground spoilers deployed automatically. The crew applied maximum manual braking, overriding the selected medium autobrake. Reverse idle was selected 12.8 seconds after touchdown with 670 metres/2,200 feet of runway remaining, with full reverse selected 3.5 seconds later.

The aircraft departed the upwind threshold at approximately 80 knots and came to rest in a ravine a short distance from the runway. The fuselage broke into several pieces and was quickly consumed by fire, but all 297 passengers and 12 crew escaped.

The Investigation

The investigation found that 24L was in use because the ILS on the longer 24R had been damaged by lightning and 23 had been rejected by other pilots due to proximity of bad weather. An inspection had cleared the 24R ILS 30 minutes before the aircraft arrived but ATC had not been informed. The failure of a single wind sensor on the ground deprived the crew of vital surface wind information.

The pilots’ arrival briefing had included windshear procedures and go-around actions but there was no evidence that they made any landing performance calculations for the expected conditions on arrival. The approach was stable up to the point at which the autopilot and autothrust were disconnected; thereafter thrust in excess of that required to maintain target speed was manually applied. Had the autothrust remained engaged, it would likely have reduced the thrust to maintain close to the correct speed. The intensity of the weather radar returns in the missed approach area led the pilots to discard the option of a go-around. The procedure states that the captain to call either “we continue” or “we go-around” at Decision Height (DH). The Airbus A330/340 operations manual indicates that both pilots will monitor the localizer and glideslope below 500 feet agl. The tolerances listed are plus or minus one dot on the localizer and glideslope between 500 and 300 feet agl and plus or minus ½ dot on the localizer and plus or minus one dot on the glideslope between 300 and 200 feet agl. There is no requirement to monitor the localizer and glideslope below 200 feet agl.

Figure 1; TSB final accident report page 5.
Crossing the threshold the aircraft entered the boundary of a convective cell, with an associated change in wind vector and reduced visibility in heavy rain. The tailwind component increased the groundspeed and ‘float’ distance and the crosswind component exceeded the maximum permitted for contaminated runways.

Standard callouts for ground spoiler and reversers by the non-flying pilot were omitted and the investigation concluded that the delay in selecting reverse was a function of pilot workload controlling the aircraft trajectory after touchdown.

Although the runway overrun had a short obstacle free area before the perimeter fence, there was no RESA. The runway was not grooved, however there was no evidence that hydroplaning had occurred. The report noted that while grooving improves water drainage, “grooving allows accumulation of ice and snow in the grooves, which can lead to runway deterioration and the creation of foreign objects on the runway.”

Most of the initial damage to the aircraft resulted from impact with concrete supports for the approach lighting system in the ravine.
Based on the foregoing, list the THREATS encountered by the crew:

<table>
<thead>
<tr>
<th>Threat Type</th>
<th>Details</th>
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<tbody>
<tr>
<td>Organizational</td>
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<tr>
<td>Airport environment</td>
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<td>Meteorological</td>
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<td>Human</td>
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<td>Other</td>
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List the ERRORS made by the crew:

...
List some CONTROLS, DEFENSES and TEM strategies that could have been used to prevent the accident:

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**RERR Observations for Instructors**

The pilots found themselves with what they perceived to be a gradually narrowing range of options. Having changed to a closer alternate to allow more fuel for holding, they subsequently began to have concerns as to whether they had enough reserves to make it to the new one should they not land in Toronto. Their increasing focus on commencing and later completing an approach to Toronto appears to have distracted them from the growing number and magnitude of the threats to achieving a safe landing. In the end they discarded the final defense available to them, a go-around, believing that the weather in the missed approach area was too bad and they were committed to landing. They entered a blind alley with no escape route.

**Workshop participants should identify some or all of the following threats:**

**Organizational** – Need for a more focused attention on IAS when autothrust is disconnected/inop

**Airport Environment** – inoperative wind sensors, short runway, contaminated runway, braking action ‘poor’, no significant overrun/RESA, hazards beyond paved surface, absence of engineered materials arrester systems (EMAS), single wind sensor failure deprived crew of wind information, 24R ILS serviceability not notified

**Meteorological** – thunderstorms, heavy rain, poor visibility, tailwind, crosswind, significant wind change (direction and speed) during final portion of approach

**Procedural** – Go-around decision at or below DH.

**Human** – procedural non-compliance, distraction, workload

**And potential errors:**
- Decision to hold rather than divert with diminishing reserves and bad weather
- Continuing approach with braking action reported ‘poor’
- Continuing approach with no go-around option
- Disconnecting autothrust (may have been company SOP) and not monitoring IAS
- Deviating above slope
- Long flare
- Failure to go-around from the flare
- Landing long (especially on contaminated runway)
- Late reverse

**TEM Strategies:**

**Individual** – distraction and workload use up cognitive capacity; the ability to process information and make good decisions. It is vital to recognize the onset of both and take action to reduce the debilitating effects on human performance. Tasks and the factors influencing their outcome must be prioritised, analysed and actioned in an orderly fashion, using all of the information and resources available at the time. Most important of all pilots must recognize the serious implications of cumulative threats, especially in an environment conducive to distraction and consequent errors. With the exception of unforeseen emergencies, pilots should never commence or continue an approach, or any other significant course of action, if there is no way out when the plan goes wrong.

Aircrew should “raise their standards” regarding landing performance (e.g., touchdown point, IAS control, quick deployment of reverse thrust, quick deployment of ground spoilers, etc) when multiple risk factors are present, and be quicker to make a go-around decision when the “higher performance standards” are not achieved. The non-flying pilot is a valuable resource who can monitor all deceleration resources (spoilers, engine reversers, use of braking, etc) and make appropriate, very firm and clear callouts, when the flying pilot fails to use all available braking.
Airport – systems which provide vital information to pilots need to be safeguarded to ensure that a single failure is not be sufficient to disable them. In recognition that runway overruns DO occur, especially on shorter runways, every effort should be made to include a RESA, ideally conforming to the ICAO recommendation of 240 meters. If this isn’t feasible then consideration should be given to the installation of engineered materials arrester systems (EMAS).

Operator – all pilots should receive recurrent training in threat and error management to ensure that they are able to recognize situations in which the cumulative threats are no longer acceptable, and to understand when they are likely to be most prone to error and poor judgement. SOPs and training must emphasize that, with the exception of extreme emergencies, pilots should never commit to an intended outcome without an option to abandon it and take an alternative course of action. Training programs should practice go-arounds, including below the approach minimum altitude and after touchdown (before thrust reverser deployment).

Organizations should consider identifying runways that are not grooved and identifying the higher level of risk on these runways during moderate and heavy rain showers. In these cases, a short delay to allow water to drain may significantly mitigate this particular risk.

Organizations should consider identifying a set of conditions that make a particular landing a high risk landing (these are already identified in the Runway Excursion Risk Awareness Tool – an appendix to the Reducing the Risk of Runway Excursions report). This would then result in pilots using maximum flaps/minimum approach speeds, the optimum runway for the conditions, maximum auto brakes, maximum/automatic ground spoilers, while aiming for very precision touchdown point control. Many relatively low speed runway excursions could be prevented if a maximum effort stop was pre-planned in events with multiple risk factors.