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**Formal Error Prediction: The Evaluation of Standard
Operating Procedures in a Large Commercial
Transport Aircraft**

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Abstract

This research applies the latest formal technique for human error prediction - Human Error Template (HET) - to evaluate standard operating procedures for performing a go-around in a large commercial transport aircraft. HET was originally developed in response to the requirement for formal methods to assess compliance with the new large civil aircraft human factors certification rule introduced to reduce the incidence of design-induced error on the flight deck (EASA Certification Specification 25.1302). A total of 67 Aircraft B pilots participated in this study including 25 captains and 42 first officers. This research finds that there are three types of errors with high likelihood committed by pilots during performing go-around, 'Fail to execute'; 'Task execution incomplete'; and 'Task executed too late'. Therefore, there is a raising need to investigate further impact to flight safety for such errors occurred. Many of the errors that were found were the types of errors that most pilots were aware of and have simply had to accept on the flight deck. It is hoped that human factors certification standards would help to ensure that many of these errors are not included on future aircraft.

Key Words: Design Induced Human Errors, Hierarchical Task Analysis, Human Error Identification, Standard Operation Procedures

Introduction

For the past thirty years there has been a steady decline in the commercial aircraft accident rate. However, over the last two decades it has been noticeable that the serious accident rate has remained relatively constant at approximately one per million departures at American/European (Boeing, 2000). If this accident rate remains unchanged, with the currently increase in the demand on flight services for travel, it will mean that there will be one major accident almost every week by the year 2015. As the reliability and structural integrity of aircraft has improved, the number of accidents directly resulting from such failures has reduced dramatically, hence so has the overall number of accidents. However, the reliability of human beings has not improved to the same. Figures vary but it is estimated that up to 75% of all aircraft accidents now have a major human factors component. Human error is now the primary risk to flight safety (CAA, 1998).

International Air Transport Association (IATA) have analyzed 240 member airlines and found about 50% of airline accidents took place during the phases of final approach and landing in 2007, in which only covers 4% of the total flight time. Many of those accidents could have been avoided if pilots made a second attempt at the runway, or if obstacles on the ground were properly cleared, according to a safety report by the Geneva-based industry group. Most pilots are taught that executing a go-around is the prudent course of action if the landing is not progressing normally and a safe outcome is not assured. That is a good practice but it isn't always that simple. The pilot must be proficient in executing the go-around properly in the particular airplane being flown and must make the decision to execute the go-around in a timely manner. Pilot's decision on whether to execute a go-around is rather important, sometimes might be life saving. Knowing how to execute the go-around maneuver and being proficient at it are extremely important but still more is required. Pilots must possess the skill and knowledge to decide when to execute a go-around. Many accidents have happened because the pilot waited too long before deciding to abort the landing. The Human Error Template (HET) is a new formal approach to predict human errors, especially during the design stages of the flight deck to help prevent design-induced error leading to accidents. Therefore, the purpose of this research is to identify human errors occurred during go-around in a large commercial aircraft for developing accident prevention strategies (Li & Harris, 2009).

Literature Review

The roots of human error are manifold and have complex interaction with all aspects

of the operation of a modern aircraft. However, during the last decade ‘design induced’ error has been a factor of key concern for the airworthiness authorities, particularly in the new generations of highly automated aircraft. Chapanis (1999) noted that back in the 1940s that many aspects of ‘pilot error’ were really ‘designer error’. This was a challenge to the contemporary viewpoint at the time and but demonstrates that good design is all-important in human error reduction. New generation, modern technology aircraft have implemented automated systems and computerized cockpits. However, human factors accidents have become the most significant concern of researchers in the aviation industry. According to accident investigation reports, inappropriate system design, incompatible cockpit display layout, and unsuitable SOPs were the major factors causing accidents (Stanton & Baber, 2002) . The approach focuses upon the identification and classification of the errors that operators made at the so-called ‘sharp-end’ of system operation, and seeks to identify the internal or psychological factors (e.g. inattention, loss of vigilance and carelessness) involved in error occurrence. According to the person approach errors arise from aberrant mental processes such as forgetfulness, inattention, poor motivation, carelessness, negligence, and recklessness (Reason, 1990). Li & Harris (2006 & 2007) found that 30% of accidents relevant to ‘violations’ included intentionally ignoring standard operating procedures (SOPs); neglecting SOPs; applying improper SOPs; and diverting from SOPs. Dekker (2001) has proposed that human errors are systematically connected to features of operators’ tools and tasks, and that error has its roots in the surrounding system: the question of human or system failure alone demonstrates an oversimplified view of the roots of failure. The important issue in a human factors investigation is to understand why pilots’ actions made sense to them at the time the accident happened.

Initial efforts to enhance aircraft safety were aimed at system reliability, structural integrity and aircraft dynamics. Human Error Identification (HEI) techniques are used to predict potential human or operator error in complex, dynamic systems. A number of different types of HEI approach were identified, including taxonomy based techniques, error identifier techniques, error quantification techniques, cognitive modeling techniques and cognitive simulation techniques. HEI techniques have previously been employed in a number of different domains, including the Nuclear power and petrol-chemical processing industry (Kirwan, 1994), air traffic control (Shorrock & Kirwan, 2002), aviation (Marshall et al, 2003), naval operations, military systems, space operations (Nelson et al, 1998), medicine and public technology (Baber & Stanton, 1996). The utility of HEI techniques lies in their ability to identify potential errors before they occur, allowing pro-active remedial measures to be taken. This also allows them to be applied early in the design process, before an operational

system actually exists. Human Error Template (HET) is a checklist style approach to error prediction that comes in the form of an error pro forma containing twelve error modes. The HET methodology is applied to each bottom level task step in a hierarchical task analysis (HTA) of the task in question. The technique requires the analyst to indicate which of the HET error modes are credible for each task step, the probability of error and the criticality of error, based upon their judgment for developing effective accident prevention strategies (Harris, Stanton, Marshall, Young, Demagalski & Salmon, 2005) .

The HET error taxonomy consists of 12 basic error modes that were selected based upon a study of actual pilot error incidence and existing error modes. For each credible error the analyst provides a description of the form that the error would take. The analyst has to determine the outcome or consequence associated with the error and estimates the likelihood of the error using three levels, low, medium or high; and the criticality of the error using three levels, low, medium or high. If the error is given a high rating for both likelihood and criticality, the aspect of the interface involved in that task step is then rated as a 'fail', meaning that it is not suitable for certification. The main advantages of the HET method are that it is simple to learn and use, requiring very little training and it is also designed to be a convenient method to apply in a field study. The error taxonomy used is comprehensive as it is based on existing error taxonomies from a number of HEI methods. The HET method is also easily auditable as it comes in the form of an error pro forma (Stanton, Salmon, Walker, Baber & Jenkins, 2005).

The high levels of automation in the new generation airliners have without a doubt offered considerable advances in safety over their forbearers, however new types of error have begun to emerge on these flight decks. This was exemplified by accidents such as the Nagoya Airbus A300-600 accident, where the pilots could not disengage the go-around mode after inadvertent activation as a result of a combination of lack of understanding of the automation and poor design of the operating logic in the auto-land system. The airworthiness regulations governing the design of commercial aircraft, for example Federal Aviation Regulation (FAR) part 25: Airworthiness Standards still reflect these earlier concerns. As aircraft's reliability and structural integrity have improved over the last 50 years, the number of accidents resulting from such failures has reduced dramatically. However, there were up to 75% of all aircraft accidents have a human factors component in them. Human error is now the primary risk to flight safety (Civil Aviation Authority, 1998). It would appear that the human component is now the most 'unreliable' component in the system. Li, Harris & Yu (2008) suggested that to reduce accident rate the 'paths to failure' relating

to those organizational influence and human factors must be addressed. Shackel (1990) advised a definition of *usability* comprising effectiveness (level of performance), learn ability (the amount of training and time taken to achieve the defined level of effectiveness) and attitude (the associated costs and satisfaction). These criteria together with comprehensiveness, accuracy, consistency, theoretical validity, usefulness and acceptability (Kirwan, 1992), could be used to assess HEI techniques in a systematic and quantifiable manner.

Reason (1990) proposed that human behavior is governed by the interplay between psychological and situational factors. Human error is a problem of great concern within complex sociotechnical systems and has consistently been implicated in a high proportion of accidents and incidents. Recognizing that most accidents are caused by human error, industry and government both have focused resources on studying human-factor issues in recent years. While ongoing, these efforts already have produced improvements in training, in the design of flight decks and in the management of tasks in the cockpit. Sherry et al. (2001) advised that having multiple modes on the same control interface is unwise and can lead to mode confusion and design-induced errors.

Method

The methodology applied in this research is to identify Aircraft B pilots' operational behavior and the consequence during go-around based on the method of Human Error Template (HET). It is applied hierarchical task analysis (HTA) to decomposition the task to each bottom level task step in question. The technique requires the analyst to indicate which of error modes are credible for each task step, the probability of error and the criticality of error, based upon their judgment. Hierarchical task analysis involves identifying tasks, collecting task data, analyzing the data, and producing a documented representation of the analyzed tasks, such as standard operation procedures (Annett, Duncan and Stammers, 1971). Typically HTA method is used for understanding the required human-machine and human-human interactions, and for breaking down task into component task steps or physical operation. According to Annett (2005) a survey of defense task analysis studies demonstrated its significant use in system analysis, manpower analysis interface design, operability assessment and training specification. The purpose for this research was to evaluate the potential risks and interactions between the design of Aircraft B standard operation procedures and pilots during go-around.

1. Participants: A total of 67 Aircraft B pilots involved in this study. The age ranges

of participants were between 28 and 60. There were 25 captains and 42 first officers. Participants volunteered to take part in the study and consisted of 62 male and 5 female airline pilots.

2. Define tool and task: The first step in conducting a HTA is to clearly identify the task under analysis and to define the task under analysis. The purpose of the task analysis for this study is reviewing the Aircraft B standard operations procedures and pilots' reactions during go-around.
3. Go-around Task decomposition: Once the overall task goal has been specified, the next step is to break this overall goal down into meaningful sub-goals (usually four or five items), which together form the tasks required to achieve the overall goal. In the task, 'Aircraft B safely operation for go-around', the overall goal of operating Aircraft B aircraft go-around was broken down into the sub-goals, for example, 1.1 Press TO/GA Switches; 1.2 Set Flaps Lever to 20; 1.3 Rotate to go-around Attitude; 1.4 Verify Thrust Increase; and 1.8 Follow Miss Approach Procedures.

The analysis of task goal should break down the sub-goals. This process should go on until an appropriate operation is reached. The bottom level of any branch in a HTA should always be an operation. Whilst everything above an operation specifies goals, operations actually specifically what needs to be done. Therefore go-around operations are actions to be made by an agent in order to achieve the associated goal and based on the SOPs (Table 1). For example, in the HTA of the flight task 'Aircraft B safely operation for go-around', the sub-goal 1.6 Select Roll Mode is broken down into the following operations: 1.6.1 Select Roll Mode; 1.6.2 Verify Roll Mode Annunciation; and 1.6.3 Turn into Correct Track (see Figure 1).

4. Modes of Error: Within the 8 sub goals for Aircraft B performing go-around safely, there are contained 17 bottom level tasks shown as the sub-goals underlined in figure 1. These bottom level tasks are broken down into 65 operational items evaluated by all participants. There are 12 basic error modes based on Human Error Template (Harris, Stanton, Marshall, Young, Demagalski & Salmon, 2005) as following, "Failure to execute", "Task execution incomplete", "Task executed in the wrong direction", "Wrong task executed", "Task repeated", "Task executed on the wrong interface element", "Task executed too early", "Task executed too late", "Task executed too much", "Task executed too little", "Misread Information", and "Others".
5. The design of evaluating format: The questionnaire of 65 operational items was to ask participants if they had ever made the reported error (tick 'ME') and if they knew of anyone else who had made the error rather than rate the frequency with which they believed the error had occurred (tick 'OTHER'). It was also hoped that this increased the participant's confidence in being able to report errors. If they

had made the error themselves but had no desire to admit making the error, they could tick the “OTHERS” box and the research team would still get a mark that the error had been made during performing go-around.

Table 1: Aircraft B Go-Around Procedures

“GO-AROUND” ----- ANNOUNCE A Go-Around is a normal procedure which should be applied without hesitation if required. If using manual throttle the command GO-AROUND” means set Go Around thrust.	
PF	PM
TO/GA Switches PUSH* Commands “FLAPS TWENTY” Verify speed above Bug speed.	Repeats “FLAPS TWENTY” and selects Flaps 20.
Verify rotation to Go Around attitude and thrust increase (FMA indication THR or THR REF)	
	“ GO-AROUND THRUST SET”
Positive climb (VSI and RA) command: “GEAR UP”	Verify positive climb (VSI and RA) repeat: “GEAR UP” and place Gear Lever to UP.
Above 400 feet AAL select a Roll Mode by selecting LNAV or HDG SEL or when flying manually by commanding: “LNAV” or “HDG SEL”	Engage commanded Roll Mode.
Above 1,000 feet AAL select a Pitch Mode VNAV, FLCH or V-SPEED or when flying manually by commanding: “VNAV” or “FLCH” or “VERTICAL SPEED”	Engage commanded Pitch Mode.
Follow published missed approach procedure or ATC clearance.	Advise ATC.
* A single push on the TO/GA switches provides thrust for approximately 2,000 ft/min rate of climb. FMA indicates THR. A second push on the TO/GA switches gives full thrust and THR REF on the FMA.	

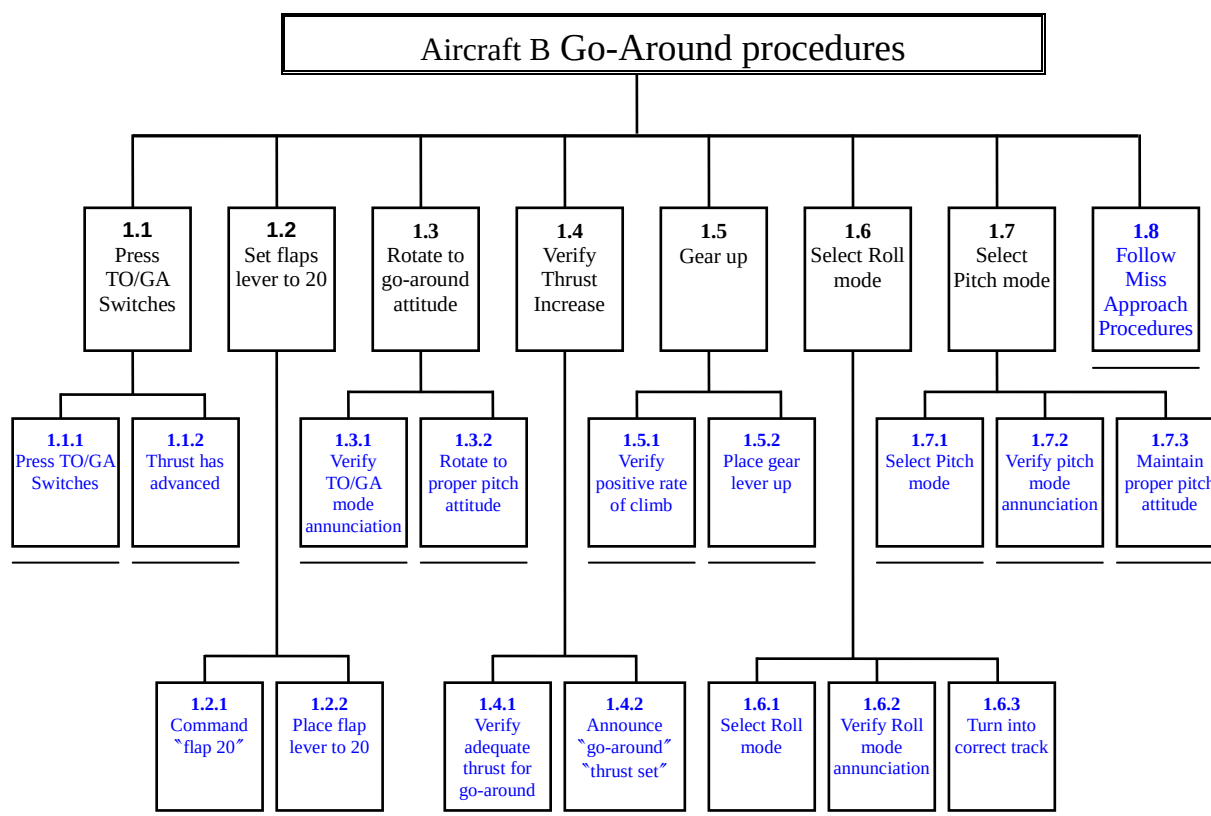


Figure 1: The Example of SOPs for Aircraft B Performing Go-around Safely by HTA

Result and Discussion

The participants had evaluated 17 operational steps for performing go-around which each step consisted by 12 different types of human errors. A total of 67 Aircraft B pilots participated in this research including 57 national pilots and ten expatriate pilots. There were 25 captains and 42 first officers by job description. The range of pilots' age between 25 and 60, there were half of pilots (34 participants) between 31 and 40 years old. The training background of pilots included 38 Ab-initio pilots, 15 ex-military pilots, ten other background pilots, and four CPL pilots (pilots who acquired Commercial Pilot License before entering the company). The flying experience of participants were 21 pilots above 10,000 hours, 18 pilots between 5,000 and 9,999 hours, 17 pilots between 2,000 and 4,999 hours, 11 pilots below 1,999 flying hours. There were 30 instructor pilots and 37 first officers by teaching experience.

Figure 1 and Table 1 show the result of operational step 1.1 Press TO/GA Switches which contains two sub-goals, '1.1.1 Press TO/GA switches' and '1.1.2 Thrust has advanced'. The first operational step indicates there were 34% of 'Fail to execute'; 27% of 'Task execution incomplete'; and 25% of 'Task executed too late'. The second

operational step reveals there were 27% of ‘Fail to execute’; and 48% of ‘Task execution incomplete’. There are including 8 questions (Q1 to Q8) related to errors occurred at this stage, each operational step over 40% either by ‘ME’ or ‘OTHER’ shown as Table 2. The results show that accidents may occur during go-around caused by not having enough lift due to lack of thrust. Takeoff/Go-around (TO/GA) Switches are designed for activating Auto-throttle system. Pushing either one of the TO/GA switches activates go-around. PF (pilot flight) presses TO/GA switches during go-around and advance thrust lever automatically or manually. PM (pilot monitor) verifies Auto-throttle system is being activated during go-around and monitor advanced thrust lever. With the first push of the TO/GA switch, Auto-throttle system activates in thrust to establish a 2000 FPM (feet/minute) climb. With the second push of the TO/GA switch, Auto-throttle system activates in thrust reference (THR REF) at full go-around thrust. Failed to press TO/GA switches may cause aircraft climbing without thrust and caused serious consequences. Failed to press TO/GA switch will not activate go-around thrust and flight director will display wrong pitch guidance to confuse pilots’ following decision and may cause serious consequences. When pressed TO/GA switches, PF should check whether thrust lever is moving forward in case of system malfunction. Rotation without adding go-around thrust will cause aircraft to lose airspeed; it is possible to go into stall.

Table 2: The occurred rate of errors break down by detail operational steps for Aircraft B Performing Go-around

Operational Steps of Go-around Procedures	Description of Errors Occurred during Go-Around	Occurrence rate		Modes of Error
		ME	OTHER	
Operational Step 1.1 Press TO/GA Switches	Q1. Failed to press TO/GA switch due to pilot’s negligence.	20.90%	53.73%	Fail to execute
	Q4. Accidentally pressed TO/GA switch during normal approach	29.85%	44.78%	Wrong task execute
	Q5. Failed to check thrust level	38.81%	56.72%	Fail to execute
	Q8. Thrust lever were not advanced manually when the auto-throttles became inoperative	29.85%	53.73%	Task execute incomplete
Operational Step 1.2 Set Flaps Lever to 20	Q9. Failed to command “flap 20” due to pilot’s negligence	25.37%	67.16%	Fail to execute
	Q14. Forgot to place flap lever to 20 until being reminded	16.42%	50.75%	Fail to execute
Operational Step 1.3 Rotate to Go-around Attitude	Q15. Failed to check whether TO/GA mode was being activated	44.78%	46.27%	Fail to execute
	Q17. Late rotation, over / under rotation.	46.27%	50.75%	Task execute too late
	Q18. No check for primary flight display	26.87%	56.72%	Task execute incomplete
Operational Step 1.4 Verify Thrust Increase	Q23. Failed to check go-around thrust setting	53.73%	52.24%	Fail to execute
	Q25. Did not identify and correct speed deviations on time	46.27%	47.76%	Task execute too late
	Q26. Forgot to call “go-around thrust set”	68.66%	70.15%	Fail to execute
	Q27. Did not identify and correct	35.82%	58.21%	Task execute too late

	go-around thrust deviations on time			
Operational Step 1.5 Gear Up	Q28. Did not check for positive climb indications before calling “gear up”	13.43%	55.22%	Task execute incomplete
	Q30. Forgot to put the landing gear up until being reminded	40.30%	59.70%	Fail to execute
Operational Step 1.6 Select Roll Mode	Q33. Did not engage LNAV mode on time failed to capture	49.25%	58.21%	Task execute too late
	Q37 Failed to check whether LNAV/ HDG was being activated	31.34%	64.18%	Fail to execute
	Q39. Mixed up the IAS/HDG bugs on the MCP	34.33%	49.25%	Task execute on wrong interface elements
Operational Step 1.7 Select Pitch Mode	Q42. Did not engage VNAV mode on time failed to capture	44.78%	62.96%	Fail to execute
	Q46. No check whether VNAV or FLCH was being activated	38.81%	56.72%	Task execute incomplete
	Q48. Did not monitor the altitude at appropriate time	38.81%	55.22%	Task execute incomplete
Operational Step 1.8 Follow Miss Approach Procedures	Q56. Entered the wrong altitude on the MCP and activated it	29.85%	41.79%	Task execute on wrong interface elements
	Q57. Failed to anticipate flight director commands when intercepting miss approach altitude	16.42%	41.79%	Fail to execute
	Q62 Poor or slow instrument scan	43.28%	55.22%	Task execute too late
	Q65. Not using auto-flight system when available and appropriate.	55.22%	65.67%	Task execute too little

The operational step of 1.2 Set Flaps Lever to 20 consists of ‘1.2.1 Command flap 20’, and ‘1.2.2 Place flap lever to 20’. Pilots’ operational step of the former advises there were 43% of ‘Fail to execute’; and 43% of ‘Task executed too late’; the latter shows there were 20% of ‘Fail to execute’; and 20% of ‘Task executed too late’ (Figure 1 and Table 1). There are including 6 questions (Q9 to Q14) related to errors occurred at this stage, each operational step over 40% either by ‘ME’ or ‘OTHER’ shown as Table 2. The climb gradient performance is determined by thrust and lift. Flap is usually set at 30 for landing. When executing a go-around, retract flap to 20 position can reduce drag and increase lift during go-around. On Aircraft B flight deck, there is a “Flap Gate” which is designed to prevent inadvertent retraction of flaps to past go-around position. When PF commands “flap 20” during go-around should spoke loudly and clearly, PM should place flap lever to 20 immediately. The common errors including unclear command by PF will cause confusion or delay PM’s proper operation; misunderstanding between crew members, and it may cause incidents or accidents.

The operational step of 1.3 Rotate to Go-around Attitude consists of ‘1.3.1 Verify TO/GA mode annunciation’ and ‘1.3.2 Rotate to proper pitch attitude’. Pilots’ operational step of the former advises there were 48% of ‘Fail to execute’; and 27% of ‘Task

execution incomplete'; the latter shows there were 40% of 'Task execution incomplete'; 25% of 'Task executed too late'; and 36% of 'Task executed too much' (Figure 1 and Table 1). There are including 8 questions (Q15 to Q22) related to errors occurred at this stage, each operational step over 40% either by 'ME' or 'OTHER' shown as Table 2. The results reveal that Aircraft B installed two primary flight displays (PFDs) on instrument panel and they present dynamic color displays of parameters necessary for flight path control. PFDs provide clear go-around information when pilot pressed the TO/GA switch. Go-around initial climb performance depends on sufficient thrust and proper rotating rate. Late / early rotation, over / under rotation may cause airspeed too fast or too slow. Over rotation occurs most frequently during go around. When PF performed go-around both pilots must verify TO/GA mode annunciation on the PFDs. PF should rotate the control column to Go-around attitude and increases the thrust simultaneously. If pilots operate too early and over rotation will affect more on flight safety, such as pulled back too much on the control column will cause airspeed drop dramatically, it may cause aircraft into stall. Rotation before adding go-around thrust will cause aircraft to lose airspeed, it is possible to cause stall.

The operational step of 1.4 Verify Thrust Increase consists of '1.4.1 Verify adequate thrust for go-around' and '1.4.2 Announce go-around thrust set'. Pilots' operational step of the former advises there were 54% of 'Fail to execute'; and 39% of 'Task execution incomplete'; the latter shows there were 63% of 'Fail to execute'; and 27% of 'Task execution incomplete' (Figure 1 and Table 1). N1 (Engine low speed compressor) and EPR (engine pressure ratio) are primary engine indications and always display on primary EICAS (Engine indication and crew alerting system). Normally go-around thrust is around 104.7 % N1 (CF6 engine) or EPR1.51 (PW4056 engine) which appears on primary engine indications. There are including 5 questions (Q23 to Q27) related to errors occurred at this stage, each operational step over 40% either by 'ME' or 'OTHER' shown as Table 2. The common errors including wrong EPR or N1 setting does not happen when auto thrust system being used, it only happens when pilot controls thrust manually. Standard callout should be loud and clear. PF should closely monitor adequate thrust for go-around. When go-around thrust is set, PM should call "go-around thrust set". Good teamwork can assure flight safety. Less go-around thrust setting will cause airspeed decreased. If airspeed is below target speed, pilot should add thrust immediately. Improper airspeed at this stage will cause stall or over flap operation limit. If airspeed is below target speed, pilot should correct it immediately.

The operational step of 1.5 Gear Up consists of ‘1.5.1 Verify positive rate of climb’ and ‘1.5.2 Place gear lever up’. Pilots’ operational step of the former advises there were 32% of ‘Fail to execute’; and 23% of ‘Task executed too late’; the latter shows there were 39% of ‘Fail to execute’; and 42% of ‘Task executed too late’ (Figure 1 and Table 1). There are including 5 questions (Q28 to Q32) related to errors occurred at this stage, each operational step over 40% either by ‘ME’ or ‘OTHER’ shown as Table 2. Aircraft must remain above the positive rate of climb before retracting gear. The landing gear is controlled by the landing gear lever. When the landing gear lever is moved up, the landing gear begins to retract and automatic braking occurs. After retraction, the main gear is held in up position by uplocks. PM should make sure aircraft remains a positive rate of climb before retracting gear. PF commands “gear up”, PM rechecks gear. If pilot forgets to put the landing gear up, it will cause lots of drag and decrease the climb gradient performance. Giving incorrect command by PF will cause misunderstanding between crew members, and it may cause serious consequences. If pilot retracts gear when aircraft stays at a negative rate of climb, it will trigger GPWS warning.

The operational step of 1.6 Select Roll Mode consists of ‘1.6.1 Select roll mode’; ‘1.6.2 Verify roll mode annunciation’; and ‘1.6.3 Turn into correct track’. Pilots’ first operational step advises there were 27% of ‘Fail to execute’; and 52% of ‘Task executed too late’; pilots’ second operational step advises there were 36% of ‘Fail to execute’; and 23% of ‘Task execution incomplete’; pilots’ third operational step shows there were 29% of ‘Task execution incomplete’; and 41% of ‘Task executed too late’ (Figure 1 and Table 1). There are including 9 questions (Q33 to Q41) related to errors occurred at this stage, each operational step over 40% either by ‘ME’ or ‘OTHER’ shown as Table 2. The MCP (Mode control panel) provides control of the autopilot, flight director, altitude alert, and auto-throttle systems. The MCP selects and activates AFDS (Auto flight display system) modes (roll mode and pitch mode) and establishes altitudes, speeds, and climb/descent profiles. There are 14 switches or selector install on MCP panel. Most modes activate with single push. Roll modes include LNAV (Lateral navigation) and HDG (Heading) switches. PF uses roll modes (HDG or LNAV) to turn the airplane into the correct track. PM should monitor closely. When autopilot is engaged, PF selects a Roll Mode of LNAV or HDG SEL. When flying manually, PF calls out “LNAV” or “HDG SEL” and PM selects the commanded roll mode. Late or forget to engage LNAV will cause aircraft unable to capture the planning track. It may cause ATC violation. Failed to engage LNAV will cause aircraft unable to capture the planning track. If LNAV is disengaged by mistake, it should be reengaged right away in order to heading the right direction. Pilots should closely monitor the change of annunciation. During go-around aircraft should

follow miss approach procedure or ATC instruction. Either LNAV or HDG is selected, pilot should monitor flight director commands to be sure aircraft intercepting miss approach course. Mixed up the IAS/HDG bugs on the MCP is the most common mistake made by pilots operating MCP. If the mistake has not been detected it may cause airspeed decreased or turn onto wrong heading.

The operational step of 1.7 Select Pitch Mode consists of '1.7.1 Select pitch mode'; '1.7.2 Verify pitch mode annunciation'; and '1.7.3 Maintain proper pitch attitude'. Pilots' first operational step advises there were 23% of 'Fail to execute'; 27% of 'Task execution incomplete'; and 50% of 'Task executed too late'; pilots' second operational step advises there were 27% of 'Fail to execute'; 27% of 'Task execution incomplete'; and 21% of 'Task executed too late'; pilots' third operational step shows there were 46% of 'Task execution incomplete'; and 21% of 'Task executed too late' (Figure 1 and Table 1). There are including 11 questions (Q42 to Q52) related to errors occurred at this stage, each operational step over 40% either by 'ME' or 'OTHER' shown as Table 2. Aircraft B with three pitch modes can be selected during go-around: VNAV (Vertical navigation), V/S (Vertical speed), and FLCH SPD (Flight level change speed). VNAV is full automation function and connected with FMC (Flight management computer). When VNAV switch is selected aircraft will commence climb or descent automatically. Pushing V/S switch opens the vertical speed window and displays the current vertical speed. Pitch commands maintain IAS/MACH window airspeed or Mach. Pushing FLCH SPD switch opens the IAS/MACH window and displays command speed. Pitch commands maintain IAS/MACH window airspeed or Mach. PFDs provide clear and easy-to-read pitch mode information when pilot pressed any pitch mode switches. When executing miss approach procedures, there is a specific requested altitude should be followed. If aircraft deviates from ATC require altitude, it may cause near miss which will lead to ATC violation or air collision. PF uses pitch modes (VNAV, V/S, or FLCH SPD) to maintain proper pitch attitude. PM monitors closely. When autopilot is engaged, PF selects a Pitch Mode of VNAV, V/S, or FLCH SPD. When flying manually, PF calls out "VNAV", "V/S", or "FLCH SPD" and PM selects the commanded pitch mode for crew task sharing. The common errors identified at this stage as followings, late or forget to engage VNAV on time will cause aircraft unable to capture the climbing path, it may cause aircraft level at improper altitude; pressed the wrong switch such as THR won't cause any problem, it will delay the right timing of selecting the correct pitch; VNAV is disengaged by mistake, it should be reengaged right away in order to get back to the correct climbing path. Pilots should closely monitor the change of annunciation. If aircraft is deviated from target altitude, pilot should correct it immediately. Junior pilots tend to make excessive corrections. Excessive corrections for small deviations on pitch control

usually happens when pilots either not familiar with automation system or control too roughly. Excessive miss approach altitude will cause serious problem. It is usually caused by wrong data input to FMC or wrong altitude setting on MCP. It is important to monitor the altitude at appropriate time in order to avoid ATC violation.

The final operational step 1.8 Follow M/A Procedure shows there were 50% of 'Task execution incomplete'; 25% of 'Task executed in wrong direction'; and 30% of 'Task executed too late' (Figure 1 and Table 1). There are including 13 questions (Q53 to Q65) related to errors occurred at this stage, each operational step over 40% either by 'ME' or 'OTHER' shown as Table 2. Missed Approach is an instrument flight rules procedure which is a standard segment of an instrument approach. Generally, if the pilot in command determines by the time the aircraft is at the decision height (for a precision approach) or missed approach point (for a non-precision approach), that the runway or its environment is not in sight, or that a safe landing cannot be accomplished for any reason, the landing approach must be discontinued and the missed approach procedure must be initiated immediately. The missed approach procedure normally includes an initial heading or track and altitude to climb to, typically followed by holding instructions at a nearby navigation fix. The pilot is expected to inform ATC by radio of the initiation of the missed approach as soon as possible. At this stage, PF controls the aircraft with published missed approach procedure, PM informs ATC by radio. Before pressing altitude control selector, PF should verify correct altitude selected on MCP. If aircraft maintains at the wrong altitude may cause ATC violation or air collision. Decision Height is the lowest altitude aircraft can fly to until runway insight in order to prevent aircraft fly into unsafe area. PF should decide to make go-around if runway not insight at the approach minimums, and PM should call Approaching Minimums to remind PF to make judgment. Not prepared for go around when approaching Minimums is a serious mistake for pilot. Miss the timing of making go-around decision may cause aircraft fly into terrain and it is very dangerous, on the other hand, pilots decide to go-around before reaching Minimums is a safe operation but the timing of making such decision too early will consume time and fuel. Pilots have high work load during go-around and is possible to fail monitoring ATC clearances and cause serious problem. Using auto-flight system can reduce pilots' workload. It's a good decision to use auto-flight system when available and is appropriated during go-around.

Conclusion

In terms of feasibility and precision, together with previous data of incidents/

accidents and the studies of human factor engineering, HET is the appropriate technique to conduct error prediction for flight safety. By the use of a scientific approach using HTA to evaluate current SOPs design together with error analysis, interface layout and procedure certification, the flight safety will be enhanced and a user-friendly task environment can be achieved. This research requires the identification of the errors that were being made on the flight deck of Aircraft B during go-around. There are two hardware designed induced human errors been identified by the method of Human Error Identification, the first issue is the design of TO/GA switches and Auto-thrust Disengage switches on Aircraft B are very close to one another; pilots may accidentally press the wrong switch. Auto-thrust Disengage switch will disengage auto-thrust system which means thrust system needs to be operated manually. When TO/GA switch is pushed, thrust system will provide thrust to lift the aircraft. If accidentally pushes the Auto-thrust Disengage switch instead, no thrust will be provided. Either way will cause irretrievable consequences. The second issue is HDG (Heading) knob and IAS (Indicator Air Speed) knob are located close to each other. Some pilots get mix up easily. Fortunately, when pilot mistakenly turns IAS knob to adjust heading, it will be easy to detect because the heading display would not change. On the other hand, if pilot mistakenly turns HDG knob to adjust airspeed, it is also easy to detect because of the change of heading.

It has to be mentioned that software design, hardware design, training design, and ecology design may have impact to pilots' performance. Although most types of human errors occurred in the cockpit were investigated that cannot explicitly be linked to incidents or accidents because of the paucity of the data in the investigation reports, and the errors also represent daily issues for pilots as they make these mistakes, which they then have to correct. This research finds that there are three types of errors with high likelihood committed by pilots during performing go-around, 'Fail to execute'; 'Task execution incomplete'; and 'Task executed too late'. Therefore, there is a raising need to investigate further impact to flight safety for such errors occurred. Many of the errors that were found were the types of errors that most pilots were aware of and have simply had to accept on the flight deck. It is hoped that human factors certification standards would help to ensure that many of these errors are not included on future aircraft.

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References

1. Annett, J. (2005). Hierarchical Task Analysis, in, N.A. Stanton, A. Hedge, E. Salas, H. Hendrick, and K. Brookhaus (Eds.) *Handbook of Human Factors and Ergonomics Methods*. London, Taylor & Francis.
2. Annett, J., Duncan, K.D., Stammers, R.B. and Gray, M. (1971). *Task Analysis*, London: HMSO.
3. Baber, C., and Stanton, N. A. (1996). A systems approach to human error identification. *Safety Science*, 22 pp 215-228.
4. Boeing Commercial Airplanes Group (2000). Statistical Summary of Commercial Jet Airplane Accidents: Worldwide Operations 1959-1999, Boeing, Seattle, WA.
5. Civil Aviation Authority (1998). Global Fatal Accident Review 1980-96 (CAP 681), Civil Aviation Authority, London.
6. Chapanis, A. (1999). The Chapanis Chronicles: 50 years of Human Factors Research, Education, and Design, Aegean Publishing Company, Santa Barbara, CA.
7. Dekker, S. (2001). The Re-invention of Human Error. *Human Factors and Aerospace Safety*, 1(3), p. 247-266.
8. Harris, D., Stanton, N.A., Marshall, A., Young, M.S., Demagalski, J. and Salmon, P.M (2005). Using SHERPA to Predict Design-Induced Error on the Flight Deck. *Aerospace Science and Technology*, 9, pp. 525-532.
9. Kirwan, B. (1994). *A Guide to Practical Human Reliability Assessment*, Taylor and Francis, London.
10. Kirwan, B. (1992) Human Error Identification in Human Reliability Assessment. Part 2: Detailed comparison of techniques. *Applied Ergonomics*, 23, p.371-381.
11. Li, W-C., Young, H.T., Wang, T., Harris, D. and Li, L-W. (2009). Approaches of Aviation Accident Investigation in Different Cultural Contexts from Human Factors Perspectives, *Journal of Aeronautics, Astronautics and Aviation*, Vol. 41(1), P.53-59.
12. Li, W-C., Harris, D., and Yu, C.S. (2008). Routes to failure: analysis of 41 civil aviation accidents from the Republic of China using the Human Factors Analysis and Classification System, *Accident Analysis and Prevention*, Vol. 40, p.426-434.
13. Li, W.C. & Harris, D. (2007). Eastern Minds in Western Cockpits: Meta-analysis of human factors in mishaps from three nations, *Aviation*

Space and Environmental Medicine, Vol. 78 (4), p.420-425.

14. Li, W.C. and Harris, D. (2006). Pilot error and its relationship with higher organizational levels: HFACS analysis of 523 accidents, *Aviation Space Environmental Medicine*, Vol. 77 (10), p.1056-1061.
15. Marshall, A., Stanton, N., Young, M., Salmon, P., Harris, D., Demagalski, J., Waldmann, T. and Dekker, S (2003). *Development of the Human Error Template – a new methodology for assessing design induced errors on aircraft flight decks. Final Report of the ERRORPRED Project 1970*, London: Department of Trade and Industry.
16. Nelson, W.R, Haney, L.N, Ostrom, L.T, Richards, R.E. (1998). *Structured methods for identifying and correcting potential human errors in space operations*, *Acta Astronautica*, vol. 43, p. 211-222.
17. Reason, J. (1990). *Human Error*. Cambridge University Press: Cambridge.
18. Shackel, B. (1990). Human factors and usability. In: Preece, J. & Keller, L. (eds), *Human-Computer Interaction*. Prentice-Hall: Hemel Hempstead.
19. Sherry, L., Feary, M., Polson, P., Mumaw, R., and Palmer, E. (2001). A Cognitive Engineering Analysis of the Flight Management System (FMS) Vertical Navigation (VNAV) Function. *Human Factors and Aerospace Safety*, 1(3): p. 223-246.
20. Shorrock, S., T., Kirwan, B. (2002). Development and application of a human error identification toll for air traffic control. *Applied Ergonomics*, 33, p. 319-336.
21. Stanton, N.A. and Baber, C. (2002). Error by design: methods for predicting device usability. *Design Studies*, 23, p. 363-384.



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