# Flight Deck Task Management

Barbara Holder, Alan Jacobsen, Mark Nikolic, Stephen Whitlow

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## **List of Abbreviations**

Abbreviation	Term
ACARS	Aircraft Communications Addressing and Reporting System
ADS-B	Automatic Dependent Surveillance - Broadcast
AOV	Areas of Vulnerability
ASRS	Aviation Safety Reporting System
ASAP	Aviation Safety Action Program
ATC	Air Traffic Control
ATIS	Automatic Terminal Information Service
CDTI	Cockpit Display of Traffic Information
CPDLC	Controller-Pilot Datalink Communications
CRM	Crew Resource Management
СТМ	Cockpit Task Management
EFB	Electronic Flight Bag
FDAWG	Flight Deck Automation Working Group
FMS	Flight Management System
FO	First Officer
GPS	Global Positioning System
LOE	Line Oriented Evaluation
LOFT	Line Oriented Flight Training
LOS	Line Operations Simulation
MCDU	Multi-function Control and Display Unit
NAS	National Airspace System
NextGen	Next Generation Air Transportation System
NOTAM	Notice to Airmen
NTSB	National Transportation Safety Board
PED	Personal Electronic Device
PF	Pilot Flying
PM	Pilot Monitoring
RNAV	Area Navigation
RNP	Required Navigation Performance
TBFM	Time Based Flow Management
ТВО	Trajectory-Based Operations
TEM	Threat and Error Management
ТМ	Task Management

## Foreword/Preface

"Flight deck task/workload management continues to be an important factor affecting flight path management. Managing tasks within the flight deck is complex and requires managing flight deck workload, distractions, and tasks generated by others outside the flight deck. Flightcrew members will continue to be required to manage increased complexity when they transition to new operations, as additional tasks may be added to the pilots' task loading. Therefore, the overall pilot task loading of the combination and integration of the systems needs to be examined for both normal and non-normal operations."<sup>1</sup>

This report seeks to expand on previous findings in the area flight deck task management as well as identify potential solution paths for issues that have been identified.

Flight Deck Automation Working Group report "Operational Use of Flight Path Management Systems: Final Report of the Performance-Based Operations Aviation Rulemaking Committee/Commercial Aviation Safety Team Flight Deck Automation Working Group" released by the Federal Aviation Administration (FAA) in 2013

## **Executive Summary**

The aviation industry has identified task management (TM) as an important factor in effective monitoring and flight path management by pilots. While this concept has been documented in reports and papers over the last twenty-plus years, the findings of the Flight Deck Automation Working Group's (FDAWG) report "Operational Use of Flight Path Management Systems: Final Report of the Performance-Based Operations Aviation Rulemaking Committee/Commercial Aviation Safety Team Flight Deck Automation Working Group", released by the Federal Aviation Administration (FAA) in 2013, highlighted its continuing importance.

One of the challenges in studying TM is to understand what it is and how pilots and the airlines address it in training and flight operations. This report uses the following definition of TM:

Task management is a dynamic process that involves both strategic and tactical organization of pilot tasks over the course of a flight. Strategic activities involve proactive planning, task prioritization, task allocation, task resource management, timing of tasks, and anticipating and assessing the flight situation. Tactical activities are to monitor and respond to real-time changes in the flight situation and include monitoring task performance, reprioritization, reallocation, making decisions, and managing emergent events and disruptions. The primary objective of task management is to support the "aviate" task while balancing other operational objectives.

As seen in this definition, TM encompasses several sub-activities that pilots must manage including: task planning, task prioritization, task loading, workload, task allocation, time management, and information management. The main goals of TM are to effectively manage resources and disruptions during the course of a flight. TM is a time-driven, contextually-defined meta-activity that allows pilots to expand and contract activities in accordance with available time and operational pressures and demands. Hence, it represents a complex activity that is required for the overall safe and effective execution of the flight.

### Literature Review

We conducted a literature search pertinent to TM under five topical areas and then summarized the significant literature and findings related to each. Many of the papers we reviewed use the terms "cockpit" and "flight deck" interchangeably, so for consistency we chose to use the word "flight deck" throughout this paper and should be considered synonymous with "cockpit". The five categories are:

- Allocation of tasks between pilot flying and pilot monitoring
- Management of information
- Management of attention, interruptions, and workload
- Task switching
- Flight deck task management errors

## **Review of Accident and ASRS data**

A high-level review of accidents since 2009 identified accidents in which TM errors were probable causes or contributing factors. Of the 133 accidents reviewed, 14 (10.5%) were identified as having TM factors. Within those 14 accidents, 76 TM errors were observed. In 11 of the 14 accidents (78.6%) TM issues impacted flight path monitoring.

To assess how TM issues may persist in Part 121 operations, we also analyzed Aviation Safety Reporting System (ASRS) reports on incidents occurring between January 2010 and July 2016. The focus of the review was on altitude deviations, which often result from human factor issues and represent a flight path monitoring issue as well. The search criteria used the following terms:

- Occurred between January 2010 and July 2016
- Was Part 121 Operation (Passenger and Air Carrier)
- Primary Problem was Human Factors
- Contributing Human Factors were Communication Breakdown, Distraction, Time Pressure or Workload

Using these parameters, the search returned 271 reports, of which 39 (14%) included TM as a contributing factor. Within these, 120 TM errors were identified. The same types of TM errors were seen in both the accident data and ASRS reports, although the percentages of each were somewhat different across the two. In both analyses however, Task Initiation was the most significant source of error. Other sources included Task Prioritization and Resource Allocation.

## **Current Practices of TM**

To explore and describe how TM is understood, trained, and practiced by operators, we conducted ethnographic research by observing pilots as they worked, interviewed pilots at multiple airline training and flight standards departments, and analyzed training and operational documents. Six airline operators participated in this study, four major and two regional. Interviews were conducted at each airline with instructor pilots, check airmen, and standards pilots, focusing on how task management, or its components, are understood, trained, and evaluated at the airline. We reviewed training materials provided by six airlines that describe their automation policy and procedures and policies that govern TM performance and then performed a comparative analysis on them.

We directly observed Crew Resource Management (CRM) and Threat and Error Management (TEM) ground training sessions and full-motion simulation sessions, during which operators described their TM training and how instructors teach and evaluate TM behaviors. We also observed simulator training at three major operators that included four Line Operations Simulation sessions, two Maneuvers Validation sessions, two Line Operations Evaluation sessions, two Line Oriented Flight Training sessions, and two Special Purpose Operations Training sessions. The research team also conducted jump seat observations at one major operator on 26 revenue flights to identify TM practices pilots currently use.

#### Summary of current practices

New technologies, the broader use of performance based navigation procedures, increasingly complex airspace, and the extensive use of flight management systems and automation to direct aircraft

trajectory are each shaping how pilots fly. We observed common strategies for TM across the six airlines. These included strategic TM techniques such as:

- Planning and anticipating how a flight will progress and creating a shared understanding of the mission and its possible impacts on piloting tasks.
- Including task priority in the briefings.
- Anticipating disruptions or threats and creating contingency plans.
- Using charts and information flow to stay organized.

Observed common techniques for tactical TM included:

- Interleaving steps of two or more tasks into one task.
- Deferring a task to a period of lower workload or suspending a task.
- Using the automated systems to reduce workload.
- Saying "unable" to Air Traffic Control or requesting an extended vector or hold.

## Emerging Issues Related to TM

Emerging issues for TM relate both to changes that are part of the NextGen National Airspace System implementation plan and those that occur in the way information is presented on the flight deck. Five areas of changes were identified:

- Increased use of data communications (data comm)
- More precise navigation requirements and more efficient routing
- Increased availability and use of surveillance displays on the flight deck
- Increased integration of various sources of information
- Mixed equipage across an airline's fleet

These different areas of change were seen to result in the following emerging vulnerabilities:

1) New procedures and tasks

The addition of new procedures introduces new tasks that will be added to those tasks that already need to be managed. It entails new responsibilities for planning and maintaining interval management. As well, for some period of time there will be issues of both mixed equipage and mixed use of procedures as the new air space evolves.

2) Airspace procedure complexity

The potential impact of this element on TM is the generation of instrument procedures that will require new or different pilot monitoring methods as well as new ways of communicating and sharing information between controllers and pilots. Also included here is the uncertainty of how specific approaches will be conducted especially when last minute approach procedures are initiated by air traffic controllers. And finally, more complex flight paths will lead to increased reliance on and use of automation that must be monitored.

3) Monitoring, understanding, and managing new information

The introduction of new sources of information such as uplinked weather and Automatic Dependent Surveillance - Broadcast, while valuable for planning, introduces new information management strategies that can impact TM. The use of electronic information such as that presented on portable electronic devices (PEDs) also requires different strategies for managing information as compared to paper versions of the same the information again impacting TM. PEDs can either help or hinder the pilots' understanding of how to integrate dissimilar information from different sources and hence can either help or hinder TM. With increased integration of "operationally approved" with "certified systems" information sources, pilots may need a better understanding of the differences between data sources in order to manage and interpret the information appropriately, especially where conflicts might arise.

### **Summary of Findings and Recommendations**

#### Finding 1. Crew dynamics create interaction patterns that can disrupt TM.

The interaction patterns between the two pilots can have a role in disrupting task management by not balancing task loading, interrupting or distracting each other, not communicating, or performing unexpected actions.

#### Recommendations:

- Training should foster a global understanding of TM concepts like crew and task interaction, timing, and dependencies.
- Procedures should be designed to organize the task flow such that tasks requiring a resource (information or attention) are done with focus and without concurrent tasks.

#### Finding 2. Communication patterns facilitate TM performance.

Well performing crews exhibited communication practices that fostered shared-awareness of aircraft status, task status, and flight path management status. These included both verbal statements and gestures.

#### **Recommendations:**

- The FAA in conjunction with a joint industry-government standard committee should develop a standard language for pilot communication that operators can adopt and train to support TM and crew coordination that goes beyond traditional in-flight call outs.
- Airlines should develop communication models similar to those we observed being used effectively among the pilots. Examples include the use colors to represent levels of task saturation or fatigue such as green for "I'm good" and red for "I need help.
- There is a need to train pilots to work as a team. In contrast to typical CRM training, this training should provide guidance on how to share task load, how to interact and communicate, and how to dynamically manage workload, disruptions, and tasks.

#### Finding 3. Anticipating tasks facilitates task flow.

The ability to anticipate tasks was observed as a means to effectively support the PF and to keep the task flow moving in well-performing crews. Anticipating tasks included proactively taking actions to reduce task loading, establishing accurate mental models, and keeping the pace or timing of tasks on track.

#### Recommendation:

• Include the concept of task anticipation and ways to achieve this in training programs.

## Finding 4. Procedures and policies influence TM by establishing what tasks to do, their priority, their allocation, and when to do them.

When procedures are developed in isolation from each other, they may overlap, not integrate into the operation, and over-task the pilots' cognitive resources at critical phases of the flight or during critical tasks.

#### Recommendations:

- Airlines should:
  - Review procedures for their fit into the operational task flow and ensure procedures do not conflict with other procedures or critical tasks.
  - Keep normal checklists short and design them using published human factors guidance.
  - Design operational procedures so that the task load between the PF and PM are balanced through all phases of flight.
- The FAA should verify that NextGen airspace and flightcrew procedures are implemented in a way that does not over task the pilots or the controllers.
- Air traffic controllers should have an appreciation for pilot workload on flights into and out of busy airports with complex procedures to understand how challenging flying these procedures can be.

#### Finding 5. Review and define non-technical skills.

The definition and training of non-technical skills is inconsistent across the operators we observed. CRM and TEM concepts are a basis for nontechnical skills training, but several operators have moved to focus on risk management, citing that it combines CRM/TEM and includes other concepts such as recognition-primed decision making, risk assessment, and so on.

#### Recommendations:

- The FAA should:
  - Assign a working group to modernize non-technical skills training.
  - Update their non-technical skills definitions so there is a standard from which operators can develop effective training to resolve the variation in definitions and uses of nontechnical terms and concepts.
- Airlines should train pilots in understanding how human vulnerabilities may impact their capability to effectively perform the TM activity. These include the narrowing of attention, monitoring, prospective memory, cost of task switching, biases, etc.

#### Finding 6. Pilots need a broad base of knowledge, skill, and strategies to effectively manage tasks.

TM is a cognitive activity where knowledge and expertise direct and manage action. A pilot needs extensive knowledge of operational tasks, the time needed to complete a task, the pace of the airline's operation, and what tools work when, to manage task load and allocation.

#### Recommendations:

Airlines should:

- Assess their training programs to ensure pilots can develop the meta-knowledge they need for effective TM in training. This includes knowledge of tasks, allocation, task interactions, resource needs, and timing.
- Define task priority so that it is clear to pilots which tasks have priority in which contexts.

## Finding 7. Effective flight path management depends on TM and operational understanding of automated systems.

The traditional "aviate" task is being increasingly thought of by industry in terms of flight path management and monitoring. Pilot knowledge of the flight management modes and how they control the aircraft may be incomplete or inaccurate, which may lead to surprise and confusion that could disrupt TM.

**Recommendations:** 

- Airline policies should recognize that automation is a tool and is not required to be used at all times.
- Managing the flight path should be the focus of training on automated systems that impact the flight path.
- Work to establish industry standards for automation terminology and behavior. Automation
  functionality and nomenclature vary across the avionics manufacturers and pilots have to know
  and remember the differences in capabilities between the different products. These differences
  can increase workload when a pilot is attempting to do a task in the way they were trained but
  the device on the aircraft is from a different manufacturer and functions differently.
- Research should be conducted to define and assess appropriate automation training for flight path management that includes strategies for effective TM.

#### Finding 8. Operational factors can make TM challenging.

Pressures of the operating environments contribute to TM challenges that are out of the pilots' control. Pilots are subjected to disruptions and are given policies or procedures that may not be conducive to effective task management.

Recommendations:

- Procedures, policies, and checklists should be designed to support TM.
- Controllers should understand the TM challenges they introduce into the flight deck when they issue late runway changes, complex clearances, or take pilots off an area navigation (RNAV) approach and do not let them fly as is.
- Pilot training should include:
  - How to be able to manage disruptions.
  - How to become skilled at dynamically rebuilding a mental model of the arrival once they are taken off of it.

- Airlines should:
  - Establish clear task priorities to support decision making and management of operational pressure.
  - When possible use Flight Operational Quality Assurance data and Aviation Safety Action Program (ASAP) reporting to understand the pressures, time management issues.
  - Develop ways to address them in operations and training.

## Finding 9. Each flight has periods of high and low task loading; pilots can use that structure to anticipate and plan tasks.

On every flight there are expected periods of high and low task loading. We observed effective task management by pilots who used this structure to allocate tasks and distribute workload and to manage dynamic task allocation. Successful organizations are thoughtful about specifying in procedures and policies who does what and when.

#### Recommendations:

- Develop a task loading map across flights using operational data and use this map in training to teach strategic task planning and allocation.
- Provide training for methods to deal with periods of low and high workload.

## Finding 10. Training does not adequately replicate the task management needed in the actual work environment.

Many training elements in simulator sessions are not experienced in realistic real-time, but are compressed; as a result of the simulator session time manipulations, pilots reported in debriefs after real operational events that they were surprised about how long it took to handle conversations and coordinate with other people.

#### Recommendations:

- Airlines should strive and regulators should recommend that pilot training be operationally representative and simulate the operational environments especially with regard to the timing of events or the time it takes to do a task (such as manual gear extension).
- Airlines should train how to manage the *timing* of different pieces of the time management process and define policies that specify what to do.

## Finding 11. Pilots need attention management training on monitoring time critical and mission critical tasks.

On any flight, pilots must divide attention between tasks and they need supporting tools and strategies to manage their attention. In order to achieve this, it is helpful to define the time-critical tasks and mission-critical tasks and tasks that require a pilot's focused attention for each phase of flight.

#### Recommendations:

• Pilots need to know how to monitor the automation to ensure it is doing what is expected and anticipate what it will do next. This could be an additional task scan pattern that should be developed and trained.

• Pilots should be trained to manage their attention and how to allocate their attention between tasks

## Finding 12. Task saturation occurs when a pilot has too many tasks to do, the task is too difficult, or there are other pressures on task performance leading to improper task prioritization.

Improper task prioritization occurs when pilots remain focused on a lower priority task even though a higher priority task is present.

#### Recommendations:

- Airlines should define tactical task priority for normal operations
- Training should include how to deal with emergent events.

#### Finding 13. Pilots need to know how to manage information and information flow.

The training we observed on information management, especially between tablet Electronic Flight Bags and the installed devices did not specifically address operational use and effective management strategies. In addition as part of NextGen more information pertinent to the flight will be available to the pilots. They need to know how to manage the flow of information, when and how to access and assimilate information for task performance, as well as understand the trustworthiness of the source of various information.

Recommendations:

- Airlines and regulators should ensure the "apps" used on personal electronic devices such as tablets meet stringent usability requirements and present information in a way that does not distract or confuse, e.g., information provided on personal electronic devices should be easy to find and interpret.
- Pilot training should include where information will come from at what times and how to access information and assimilate it into the operations. Part of this training should focus on the trustworthiness of various types of information.

#### Finding 14. Pilots need to know how to manage time and think of time as a resource.

The operators we interviewed and observed all had some kind of training on time management.

Recommendations:

- Train pilots to control the pace of the operation so they do not get rushed unnecessarily.
- In training, focus on the timing of different pieces of the operational process
- Airlines should instill a culture of discipline and professionalism to ensure that what pilots learn in training regarding TM is actually done in the field.

#### Finding 15. Instructors need training on how to train and evaluate task management.

Our observations concluded that, while all operators train various components of TM, none of them explicitly or comprehensively train it. We also observed many missed opportunities by instructors to illustrate both good and ineffective TM performance and behaviors during simulator sessions.

Recommendations:

- Trainers should be trained themselves in how both to train and evaluate TM during training sessions.
- In training and procedures a bias to complete long tasks before starting some emergent/interrupting task should be instilled.

#### Finding 16. Pilots need training on how to monitor.

Although the industry has identified effective monitoring skills as an issue, pilots are still left to develop their own strategies. Since monitoring is such an important task that must be managed, this is an area where further work is needed; how to effectively develop and maintain the skills to monitor.

Recommendation:

• Conduct further study to determine how to train pilots to do a better job of monitoring as a task rather than as a role.

### **Proposed Validation Methods**

The above recommendations are based on a review of literature and accident and ASRS data as well as interviews and observations at four airlines, jump seat observations at one airline and interviews only at two other airlines. The recommendations, however, are the result of an analysis of the vulnerabilities, and hence it would be beneficial to conduct a validation of the proposed solutions as well as how to evaluate the implementation of the recommendations. This report focuses on shorter term validations that could take place over a one to two year time frame. Several different validation methods are proposed. The first is structured interviews with subject matter experts such as flight instructors as well as pilots to understand the practicalities of implementing the proposed solutions as well as gaining their expert opinion as to how well the solutions would address gaps in their training or procedures. A second proposed validation method is conducting empirical studies to determine the impact of new training or procedures on task management in a simulated environment. A third proposed validation method would be to engage with one or more airlines willing to implement the proposed solutions and then determine the effectiveness of those solutions. As part of the airline interview activity to determine current practices, at least one of those airlines visited expressed interest in participating in follow-on validation studies.

## I. Introduction

## I.I Background

This report documents the work undertaken in support of Volpe Task Order No. T0026, "Flight Deck Task Management." The objectives of this work effort were to:

- 1) Develop a specific and standard definition of task management (TM).
- 2) Conduct a review of published literature, accident reports, and Aviation Safety Reporting System reports since 2009 that are related to TM.
- 3) Conduct observational studies to determine and document current airline practices around TM training and operations.
- 4) Define TM vulnerabilities related to the training and actual operational practices as well as identify any emerging vulnerabilities.
- 5) Generate a set of recommendations to address the findings and vulnerabilities related to TM.
- 6) Develop a plan for validation of the identified recommendations.

This work was motivated by the findings of the Flight Deck Automation Working Group (FDAWG) documented in their report "Operational Use of Flight Path Management Systems: Final Report of the Performance-Based Operations Aviation Rulemaking Committee/Commercial Aviation Safety Team Flight Deck Automation Working Group," released by the Federal Aviation Administration (FAA) in 2013. The FDAWG report identified deficiencies in TM, such as the "maintenance of vigilance and avoidance of distraction," as a contributing factor in aviation accidents. Prior work also specifically identified the significance of TM in the context of commercial aviation. These works include reports by Rogers, W. H. (1996), "Flight deck task management: A cognitive engineering analysis" and Funk, K., Suroteguh, C., Wilson, J., & Lyall, B. (1998), "Flight deck automation and task management." In addition, various components and topics related to TM such as attention allocation, workload, and interruption management, have been well-developed in the existing literature. This Flight Deck Task Management report attempts to synthesize this body of earlier work and, along with additional analysis of recent incidents and current practices, builds upon the TM construct in order to identify existing vulnerabilities and develop training and operational recommendations for current and future airspace operations.

## 1.2 The Challenge of Task Management

Although the commercial aviation transport system is the safest mode of global transportation, the industry continually strives to improve the safety and efficiency of the system. Pilot TM, including proper prioritization and allocation of tasks between crewmembers, remains a critical factor in flight safety. For example, in a review of National Transportation Safety Board (NTSB) and Aviation Safety Reporting System (ASRS) reports, Chou, Madhavan, & Funk (1996) found that TM errors occurred in 23% of the accidents (79/324) and 49% of the incidents (231/470) reviewed. In addition, as stated above, the FDAWG identified deficiencies in TM as contributing or causal factors in a number of accidents between 1996 and 2009 and cited the "maintenance of vigilance and avoidance of distraction" as particularly

challenging (Performance-based operations Aviation Rulemaking Committee/Commercial Aviation Safety Team, 2013). The FDAWG report specifically identified "TM is more difficult" as a contributing factor in five accidents and "New tasks and error introduced" as a factor in nine accidents. Furthermore, we have identified an additional 15 commercial air transport accidents since 2009 where TM was a contributing factor (see Section 4, Accident Analysis below). In general, these accidents all share common contributing factors related to TM performance, such as workload management, task prioritization, monitoring, task timing, and task allocation.

Accident and industry reports have linked TM performance to flight path management and monitoring effectiveness. A paper published by the UK CAA "Monitoring Matters, Guidance on the Development of Pilot Monitoring Skills" (CAA Paper 2013/02) to address in-flight loss of control events, cited effective TM as a critical enabler of effective monitoring:

"It is evident from nearly all of the case studies that carrying out tasks associated with landing checklist (Bournemouth, Buffalo, Schiphol), emergency drills (Everglades, Indonesia, Palmerston North), landing charts (Cali), and handling (AF447) took priority over monitoring tasks. Flight path monitoring/selective radial instrument scan must be a priority task that is not compromised by other priority tasks. Task scheduling (e.g., carrying out normal checklist), sharing (e.g., balancing the monitoring workload and being aware when the Pilot Monitoring has very limited capacity) and shedding (e.g., prioritizing tasks) must be considered as strategies to achieve a good monitoring practice."

Furthermore, the Flight Safety Foundation (FSF), in collaboration with the Air Line Pilots Association (ALPA) and the NTSB, published a report titled "A Practical Guide to Improving Flight Path Monitoring" (2014), which identifies elements of TM as contributing to ineffective monitoring and include: poor workload management, becoming engrossed in other tasks, and failing to interleave multiple concurrent tasks adequately (p. 10). A final recommendation of the report is for operators to:

"Instill the concept that there are predictable situations during each flight when the risk of a flight path deviation is increased, heightening the importance of proper task/workload management."

Most recently, the Flight Path Management working group of the Air Carrier Training Aviation Rulemaking Committee (2016) identified effective TM as critical for protecting the flight path and defined flight path management as "the planning, execution, and assurance of the guidance and control of aircraft trajectory and energy, inflight or on the ground".

While TM is not yet widely recognized in the aviation industry as a specific concept to consider and/or analyze, we believe that it effectively captures a core competency that is critical for safe and effective pilot performance.

This report focuses on TM (and its components) as a critically important pilot skill and a significant contributor to commercial aviation safety.

## **I.3 Structure of this Report**

Based on the objectives of the work effort defined in Section 1.1, this report is organized as follows:

#### • Task Management Definition and Framework (Section 2)

This section discusses the components of TM, a framework in which to understand and analyze TM as well as how TM relates to other concepts such as workload, crew resource management (CRM), and attention allocation.

• Literature Review Summary (Section 3) While a summary of TM-related literature is documented in this section, details of the literature reviewed are given in Appendix A.

#### • Accident Analysis (Section 4)

This section summarizes TM-related accidents from 2009 to 2016.

- Aviation Safety Reporting System Incidents (ASRS) (Section 5) ASRS incidents from 2009 to 2016 were queried to identify those related to TM and summarized in this section.
- Current Practices and Vulnerabilities (Section 6)

In order to identify current practices, the team conducted interviews, training observations at four airlines, jump seat observations at one airline and interviews only at two airlines. Note that not all airlines participated in all three types of information gathering.

#### • Emerging Issues in Task Management (Section 7)

Much of the emerging trends identified are from the perspective of emerging airspace operations as defined in the FAA NextGen development.

#### • Findings and Recommendations (Section 8)

The vulnerabilities related to TM in current and emerging operations are identified here as well as general findings on current practices. The most significant output of this report are the recommendations in Section 9 that are based on all of the work presented in Sections 3 through 8. They include recommendations on training, procedures, and design as well as good practices seen at some airlines that would be of value to replicate across the industry. The recommendations also highlight actions that the FAA can take to reduce the vulnerabilities related to TM.

#### • Proposed Validation Methods (Section 9)

The validation proposals in this report focus on validations that could take place over a one- to two-year time frame.

## 2.Task Management Definition and Framework

## 2.1 Task Management Definition

No standard operational definition for TM is currently in use in aviation. Previous definitions of TM include those offered by Funk (1991) and Rogers (1996) who both describe TM as a function of a dynamic system where system behavior is a discrete sequence or continuous series of system input, state, and output behaviors over a time interval. Funk (1991) defined TM as the "initiation, monitoring, prioritization, execution, and termination of multiple concurrent tasks" by pilots. This definition was later developed into a normative theory of TM that describes an on-going process involving creating an initial agenda and managing the agenda (Funk et al., 1998). He goes on to describe agenda management as a tactical activity that involves assessing the current situation, activating tasks, terminating tasks, assessing task resource requirements, prioritizing active tasks, allocating resources to tasks in priority order, and updating the agenda as appropriate. Rogers (1996) characterized TM as a time-driven activity that moves between tactical and strategic application in accordance with the particular demands of the situation. Both of these definitions share two important aspects of effective TM: the need for a mental model of how the flight will unfold that is based on planning and the recognition the plan will be adapted through hierarchical and iterative processes.

In addition, new research and new understandings of human cognition suggest that tasks are situated and performed based on the context of the activity and the interactions between the person, context, and activity. To account for the full range of TM activities it is necessary to view TM as an activity within a complex sociotechnical system. The sociotechnical system includes the flight deck environment (its tools, resources and constraints), the humans in the system (pilots, cabin crew, air traffic controllers, and airline operations personnel), procedures and policies that govern its operation, and the operational environment that sets the context. The complexity of operating a commercial aircraft involves performing multiple tasks in a real-time environment that is inherently dynamic and managing tasks involves planning and adapting to moment to moment changes in flight deck activity. Pilots manage tasks by applying their knowledge, skill, and abilities to take action that is appropriate for the current situation.

We offer the following definition of TM:

Task management is a dynamic process that involves both strategic and tactical organization of pilot tasks over the course of a flight. Strategic activities involve proactive planning, task prioritization, task allocation, task resource management, managing the timing of tasks, and anticipating and assessing the flight situation. Tactical activities are to monitor and respond to real-time changes in the flight situation and include monitoring task performance, reprioritization, reallocation, making decisions, and managing emergent events and disruptions. The primary objective of task management is to support the "aviate" task while balancing other operational objectives. This definition includes not only how pilots manage tasks on the flight deck but also how TM relates to flight path management and monitoring. TM can be considered as a meta-activity that helps a pilot to successfully handle issues of workload, monitoring, flight path management, and disruptions, as well as time, information, and attention management. Details of each of these sub-tasks is described below that includes the components of TM and a framework for understanding TM.

## 2.2 Task Management Components

Task management is a time-driven contextual cognitive activity in which pilots assess their situation and maintain continual awareness of the timing of the operation relative to ongoing and future task demands. It organizes activity to facilitate coordination between entities performing tasks internal and external to the flight deck. Several sub-components of TM are themselves meta-activities, adding to its complexity. Task management activity has both strategic and tactical elements which pilots move between during the flight depending on the demands of the context.

#### Task Planning

Task planning occurs strategically and tactically. Strategic planning involves prioritizing tasks, defining their allocation to the PF or the PM, defining the timing of tasks, managing the task resources needed to support the tasks, anticipating periods of high and low workload, and anticipating potential disruptions (i.e., threats) and developing contingency plans for managing them. Tactical planning occurs in real-time to adapt the plan to meet the changing demands of the situation and involves assessing the situation and restructuring the plan according to the situational needs.

#### Task Priority

Task priority defines which tasks have primacy at a given point in time and receive the bulk of the cognitive resources for their performance. Task priority may be specified in procedures or operational policies, but pilots may also define priority dynamically in the moment based on the circumstance. Emergent events such as a non-normal condition with the aircraft or the environment can force a dynamic reprioritization of tasks.

#### Task Load and Workload

In Advisory Circular (AC) 120-51E the FAA describes "Workload Management" and advises operators to stress the "importance of maintaining awareness of the operational environment and anticipating contingencies. Instruction may address practices (e.g., vigilance, planning and time management, prioritizing tasks, and avoiding distractions) that result in higher levels of situation awareness."

The circular also recommends operational practices that include: "monitoring and accomplishing required tasks, asking for and responding to new information, and preparing in advance for required activities...proper allocation of tasks to individuals, avoidance of work overloads in self and in others, prioritization of tasks during periods of high workload, and preventing nonessential factors from distracting attention from adherence to SOPs, particularly those relating to critical tasks. Many of these recommended practices are components of task management. One issue with this AC is it defines workload management by its components and does not give a definition of workload. Consequently operators define "workload" inconsistently and many use it interchangeably with "task load".

To address this issue, an explanation of the relationship between task load and workload is warranted to explain the dynamic relations between the concepts and their relations to task management. Operators use the term "task load" to define the number of tasks a pilot must perform in an allotted amount of time which characterizes task load objectively as tasks/time. Operators use the term "workload" to describe the difficulty or effort required to do those tasks. In this characterization workload is a subjective result, so when workload is high, the pilot will experience tasks as effortful or difficult. It is possible to have high task loading and be in a state of low workload, especially if the tasks are easy and there is plenty of time to do them. It is also possible to be in a state of low task load and be in a state of high workload, if the one task is particularly difficult, time consuming, or if the pilot is fatigued or stressed, the perception of workload will be high. Hence the term workload is to reduce the number of tasks or to reduce the stress associated with doing the tasks.

Managing the experience of high workload is what the AC 120-51E describes as operational practices and is essentially the activity of task management described here. The experience of high workload transitions the pilot into the activity of tactically managing their tasks with the specific purpose of reducing their workload. On every flight there are many tasks the pilots need to accomplish and the task load varies by the phase of flight. The workload the pilot experiences while doing those tasks will depend on many factors such as experience, operational pressure, operational factors, and cognitive resources required to perform the task, etc. If a pilot is skilled at strategic task management and the flight goes according to plan, the workload experienced should remain stable. However when something changes and increases the workload, then the task load will need to be reallocated, reprioritized, postponed, or shed and that is when the pilot engages in tactical task management.

#### **Task Allocation**

The allocation of tasks involves assigning a task to a person or an entity for both normal and emergency operations. Task allocation may shift dynamically because of a disruption, or it may morph to balance the workload between crew members. Nominal task allocation is frequently specified in operator procedures, but airline policy may permit (or require) dynamic task allocation under certain circumstances. Tasks may also be allocated to persons or entities external to the flight deck such as Air Traffic Control (ATC) or dispatch. For example, calling the Company to obtain weather updates is one resource pilots may use to obtain more information that can then be used as a resource for accomplishing a task.

#### Task Timing

To complete their tasks in the time available, pilots must plan and schedule tasks, decide when to initiate them, and plan the timing of concurrent or dependent tasks. Task timing includes both a tactical element—managing tasks in the present moment—and a strategic dimension—proactively scheduling tasks at low periods of activity so that more time is available for other tasks during periods of high activity. Managing time also involves managing time-limited tasks, such as on-board fire or low fuel situations.

#### Information Management

Information resources must be allocated and managed throughout the flight. Managing information

involves controlling the pace, flow, acquisition, construction, and assimilation of information needed for task performance. Pilots must ensure the information needed to perform their tasks is accurate, complete, reliable, and is integrated into the overall workflow in a timely manner. Also critical is knowing how and when to access information needed for the task, where it is located, and how and when to obtain (e.g., getting Automatic Terminal Information Service {ATIS} via Aircraft Communications Addressing and Reporting System {ACARS} through datalink) and assimilate it into the task.

#### Task Performance Monitoring

Monitoring task progress and evaluating task outcomes is a knowledge-driven process that focuses attention to observe and track task performance. It is essential for building expectations about tasks at risk for non-completion and understanding their potential effect on the flight deck workflow. Task monitoring is done by both pilots concurrently throughout the flight to identify bottlenecks and resource limitations that will affect task performance. On-going monitoring includes monitoring tasks delegated to the automated systems yet monitoring in general is a task all pilots are expected to perform throughout the flight and monitoring task performance is a subset of that activity. Pilot roles, such as pilot flying (PF) and pilot monitoring (PM), nominally specify which tasks are allocated to each role. The role of pilot monitoring should not be confused with task performance monitoring. Both the PF and the PM will do task performance monitoring in their respective roles.

#### **Disruption Management**

On every flight, emergent events can interrupt or distract pilots from current tasks and the flight timeline that must be managed. Emergent events may be time-critical, requiring immediate attention (such as on-board fire) that places additional cognitive demand on the pilots to manage it. Or, a disruption might be a distraction (such as an unnoticed mode transition) or an interruption (such as a call from ATC). Disruptions occur on every flight, and although they may be anticipated, they cannot be predicted.

#### Communication

Task management organizes flight deck activity to function and facilitate communication between entities performing tasks. Communication patterns develop shared mental models, enable error detection and correction, share status, and direct action.

## 2.3 Task Management Framework

A framework for TM provides an organizing structure to describe and understand the activity. We recommend operators use this framework as a resource to describe the complexity of TM the activity of task management in context.

#### A complex-sociotechnical system

Over the past 20 years, contemporary theories of human cognition have emerged from new findings in cognitive neuroscience research and from the understanding that cognition occurs when the body interacts with an environment for action and not just in the individual's brain. The concept of cognition has moved from one of information processing to one that couples perception, action, and decision to the social and physical environment—"situated cognition" (Hutchins, 1995; Noe, 2004; Clark, 2008) and because cognition is co-constructed by the context, an important part of expertise involves creative

manipulation of the setting to make cognitive work manageable and efficient. Pilot action, attention, and perception are tightly coupled to the task and the task context so we should not look at task performance in isolation. Successful performance depends on appropriate interactions between the pilots and other human agents, the flight deck and its tools and resources, the aircraft, and the operating environments. This perspective has important consequences for how we might train and evaluate TM.

Sociotechnical systems involve people and technology interacting to accomplish objectives in a complex environment. The flight deck of a commercial aircraft is a sociotechnical system where human pilots interact with technology to meet mission objectives that cannot be attained by pilots or technology alone. In sociotechnical systems, the humans and their organizations work jointly to reach organizational objectives, which cannot be met by the individual technical and social aspects of the system (Trist & Bamforth, 1951). The study of modern complex systems requires an understanding of the interactions and interrelationships between the technical, human, and social aspects of systems. These interactions and interrelationships are complex and non-linear.

TM is accomplished in the interactions between subcomponents of the system that include: the pilots, technologies, procedures, and policies across environments (Figure 2-1).



Figure 2-1. The Overall Sociotechnical System

#### The Pilots in the System

In today's operating environment, tasks are not linear and pilots do not always control when a task can be initiated or terminated. The knowledge and skills pilots bring to the situation, their adaptability, and their capability to manage change are central to effective TM. Pilots apply their knowledge to develop expectations or "mental models" that may be used as templates for guiding their activity. These are not rigid action plans, but are expectations about how things are likely to be and the expected activity required to achieve them. Pilots use their knowledge of daily operations in coordination with the actual environment to guide their activity and adjust the task flow and pace to meet the actual operational demands of the specific context. Pilots also bring to the interaction cognitive capabilities (such as attention and memory), social capabilities (such as communication and coordination), and physical/perceptual capabilities (such as body, hands, eyes, and ears). Each capability has strengths and vulnerabilities that can influence the interaction. For example, crew factors such as fatigue or inadequate knowledge and skill can interfere with task performance

#### **Procedures and Policies**

Operating procedures are designed to facilitate activity coordination between the pilot and the technologies and systems on the airplane. Procedures are resources to support task sequence and allocation, communication patterns, and task coordination. Operational policies provide strategies and techniques to manage flight deck activity and flight operations. Procedures and policies that are rigid or do not fit into the operational workflow may make TM more challenging.

#### Flight Deck

The flight deck environment provides technology, information, and tools for pilots to conduct their work and fly the airplane. The flight deck is where task performance and its management occurs; its design influences TM efficiency by facilitating or constraining how tasks are performed. The design of the flight deck also defines how resources for tasks, such as information, are represented to pilots and the means for receiving and accessing information. Thus, the flight deck can make tasks easy or complex depending on memory or monitoring demands due to the design of controls and feedback. TM involves choosing tools and resources to support task performance while also complying with the airline's procedures and policies on how to use these tools.

#### **Operational Environments**

Aircraft operate in dynamic real-time environments that influence the operation. Operational environments contribute factors that add complexity and workload to the functioning of the system and those factors are external to the aircraft. For example, dynamic hazards, such as weather, birds, icing, poor airport infrastructure, terrain, and operational complexity, such as complex arrivals, are all contributing factors. Flying is always conducted within a context so pilots need to manage operational factors and their potential impact on task performance. The flight and pilot activities have a basic structure, but it's the variability of contextual factors that arise during the flight that require pilots to adapt to changing activities.

## 3. Literature Review Summary

The pertinent literature related to TM was categorized under five topical areas. We include a summary of the significant literature as well as findings related to each. The five categories are:

- Allocation of Tasks between Pilot Flying and Pilot Monitoring
- Management of Information
- Management of Attention, Interruptions and Workload
- Task Management: Switching between Tasks
- Cockpit Task Management Errors

### 3.1 Allocation and Understanding of Tasks

#### Findings from the review:

- Crew task allocation must consider a number of factors pertaining to the crewmember, including role, resources and time available, workload, experience and acceptance.
- In addition to understanding aircraft state and status, proper CRM should ensure that pilots understand task state and status, status of queued tasks and the prioritization strategy.
- Efforts should be focused on evolving pilot training to include proper flight deck TM and error avoidance, as well as developing formal task management Standard Operating Procedures.
- Computational tools may be effective for aiding crew task allocation. Future research should focus on developing algorithms and sensors to measure system state and assess crew workload.
- The most effective strategies for personal task management include "Perceived Severity" (placing priority on the highest perceived threat) and "Event/Interruption Driven" (placing priority on interrupting tasks based on an event). The "Aviate-Communicate-Navigate-Manage Systems" strategy works best for monitoring task status and progress.
- Flight task initiation times and prioritization errors are significantly impacted by crew workload resources as well as the combination of task saturation and complexity.
- Flight deck TM should also be evaluated in the broader context of the distributed "operational team".
- Single Pilot Operations (SPO) will require fast, predictable and efficient allocation of tasks between the pilot, automation and distributed crew. Existing automation will need to adapt to SPO, and could potentially result in loss of pilot situation awareness as well as skill degradation.

- Cahill, J., McDonald, N., & Losa, C. G. (2014). A sociotechnical model of the flight crew task.
- Chou, C. C., Madhavan, D., & Funk, K. (1996). Studies of cockpit task management errors.
- Damos, D. L., & Tabachnick, B. G. (2001). Cockpit task prioritization: Jump seat observations.
- Funk, K., & Braune, R. (1999). The Agenda Manager: A knowledge-based system to facilitate the management of flight deck activities.

- Johnson, A., Oman, C., Sheridan, T., & Duda, K. (2014). Dynamic task allocation in operational systems: Issues, gaps, and recommendations.
- Johnson, W., Lachter, J., Feary, M., Comerford, D., Battiste, V., & Mogford, R. (2012). Task allocation for single pilot operations: A role for the ground.
- Schutte, P. C., & Trujillo, A. C. (1996). Flight crew task management in non-normal situations.

### 3.2 Management of Information

#### Findings from the review:

- It is important to understand how the transition from paper to digital data in the flight deck affects pilots' planning and flight performance. Some advantages of paper include ease of manipulation, flexibility of spatial layout, direct marking, quick glance, and physicality.
- Concurrent tasking and off-nominal events during preflight preparation and taxi out are important factors in many incidents and accidents. Care should be taken to align airline SOPs with the capabilities and workflows of the monitoring pilot.
- Typical pilot workflows can differ across pilots based on their training, expertise, SOPs and other factors. Workflow-driven assistance tools can help by consolidating supplemental information and providing situational awareness of workflow to support task management.
- Information flow for flight operations is dynamic and time-critical, where current events are affected by past and present events and in turn affect subsequent events. Flight information is dynamic, constantly changing and dependent on the evolution of events.
- The design of information displays in the Next Generation Air Transportation System (NextGen) flight deck should support the structures and strategies pilots actually use, instead of inventing new ways of presenting information.
- Navigation chart designs, particularly those for complex procedures such as Required Navigation Performance (RNP) and area navigation RNAV, should be evaluated in terms of information content and style of presentation.
- Charts must take into account all types of pilots (general, business, commercial), aircraft capabilities (flight management systems and levels of automation), and presentation materials (paper charts, tablet Electronic Flight Bags, flight deck avionics).
- Complex charts must present information in an efficient, organized, clear and unambiguous manner. Unnecessary information should be removed and clutter reduced by splitting information across multiple charts.

- Barhydt, R. and Adams, C. (2006). Human factors considerations for area navigation departure and arrival procedures.
- Butchibabu, A., Midkiff, A., Kendra, A., Hansman, R.J., & Chandra, D. (2010). Analysis of safety reports involving area navigation and required navigation performance procedures.
- Chandra, D. and Grayhem, R. (2012). Human factors research on performance-based navigation

instrument procedures for NextGen.

- Chandra, D., Grayhem, R., and Butchibabu, A. (2012). Area navigation and required navigation performance procedures and depictions.
- Hankers, T., Hecker, P., Barraci, N., & Schiefele, J. (2013). Identification of present-day transport pilot workflow and derivation of mobile aids.
- Hartmann, S. (2013). Information analysis for a future flight deck design in the context of 4D trajectory based operation.
- Hutchins, S., Nomura, E., & Holder, B. (2006) A multi-cultural study of paper use in the flight deck.
- Loukopoulos, L. D., Dismukes, R. K., & Barshi, I. (2003). Concurrent task demands in the cockpit: Challenges and vulnerabilities in routine flight operations.
- Poage, J. L., Donohoe, C., & Lee, J. T. (2011). Soft system analysis to integrate technology & human in controller workstation.
- Solodilova-Whiteley, I., & Johnson, P. (2006). Uncovering the information needs in complex aerospace systems.

### 3.3 Management of Attention, Interruptions and Workload

#### Findings from the review:

- Attention and workload are closely related concepts.
- There are a number of variables that can cause workload to fluctuate and thereby affect the pilot's ability to attend to their tasks. These include:
  - o Number of tasks
  - o Time pressures
  - Predictability of task variables
  - Pilot expectations
- The Aviate-Navigate-Communicate-Systems Management hierarchy and aviation checklists are good tools for reinforcing pilot training.
- Pilot experience level is important for dealing with higher workloads; more experienced pilots practice strategies that are successful in high demand situations.
- Unexpected or low prevalence events pose the largest problems for attention management.
- Automation is a double edged sword that helps pilots with high workload situations but can cause confusion during abnormal events.

- Burian, B. K., Pruchnicki, S., Rogers, J., Bonny, C., Williams, K., Silverman, E., Runnels, B. (2013). Single-pilot workload management in entry-level jets.
- Cristina, I., & Wickens, C. D. (2007). Factors affecting task management in aviation.
- Dismukes, R., Loukopoulos, L. D., & Jobe, K. K. (2001). The challenges of managing concurrent and deferred tasks.

- Minotra, D. (2012). The effect of a workload-preview on task-prioritization and task-performance.
- Wickens, C. D. (2002). Situation awareness and workload in aviation.
- Wickens, C. D. (2008). Multiple resources and mental workload.
- Wickens, C. D., & Alexander, A. L. (2009). Attentional tunneling and task management in synthetic vision displays.

## 3.4 Task Management: Switching between Tasks

#### Findings from the review:

- Entirely removing the cost of switching tasks is not (currently) possible.
- Task switching leads to costs in performance in at least two ways: Response time and accuracy.
- Task switching can lead to (prospective) memory errors.
- The cost of task switching is increased by interference from one task's information to another's.
- People are differently willing and able to task-switch.
- People's reports of their confidence in their task switching ability do not correspond to actual performance.

- Allport, A., Styles, E. A., & Hsieh, S. (1994). Shifting intentional set: Exploring the dynamic control of tasks.
- Cellier, J. M., & Eyrolle, H. (1992). Interference between switched tasks.
- Department Of Transportation National Highway Traffic Safety Administration Docket No. NHTSA-2010-0053 (2012). Visual-Manual NHTSA Driver Distraction Guidelines for In-Vehicle Electronic Devices.
- Dismukes, R. K. (2010) Remembrance of things future: Prospective memory in laboratory, workplace, and everyday settings.
- Horrey, W. J., Lesch, M. F., & Garabet, A. (2009). Dissociation between driving performance and drivers' subjective estimates of performance and workload in dual-task conditions.
- Loukopoulos, L. D., Dismukes, R. K., & Barshi, I. (2003). Concurrent task demands in the cockpit: Challenges and vulnerabilities in routine flight operations.
- Loukopoulos, L. D., Dismukes, R. K., & Barshi, I. (2009). Analysis of concurrent task demands and crew responses.
- McClurkin, D.A. (2009). Aviate, navigate, communicate.
- Meuter, R. F. I. & Allport, A. (1999). Bilingual language switching in naming: Asymmetrical costs of language selection.
- Ranney, T. A. (2008). Driver distraction: A review of the current state-of-knowledge.
- Rogers, R. & Monsell, S. (1995). Costs of a predictable switch between simple cognitive tasks.
- Rubinstein, J. S., Meyer, D. E. & Evans, J. E. (2001). Executive control of cognitive processes in task switching.

- Yeung, N. & Monsell, S. (2003). Switching between tasks of unequal familiarity: The role of stimulus-attribute and response-set selection.
- Wickens, C. D., Dixon, S. R., & Ambinder, M. S. (2006). Workload and automation reliability in unmanned air vehicles.
- Wickens, C. D., & Alexander, A. L. (2009). Attentional tunneling and task management in synthetic vision displays.

### 3.5 Flight Deck Task Management Errors

Note that much of the industry refers to flight deck TM as Cockpit TM. Flight deck TM is currently considered to be the preferred terminology by the FAA.

#### Findings from the review:

- The most likely threats to flight path monitoring are task prioritization errors where flightcrews attend to lower priority tasks at the expense of monitoring the flight path.
- Another threat is Late Task Initiation errors.
- As the flightcrew's cognitive resources are stressed, flight path monitoring is increasingly under the threat of being under-attended due to competing demands from pop-up and interrupting tasks.
- Effective management of interruptions could mitigate flight deck TM error impacts.

- Flight Safety Foundation. (2014). A practical guide to flight path monitoring.
- Chou, C.D., & Funk, K. (1990). Management of multiple tasks: Cockpit task management errors.
- Chou, C.D., and Funk, K. (1993). Cockpit task management errors in a simulated flight operation.
- Funk, K. (1990). Cockpit task management.
- Latorella, K. A. (1999). Investigating interruptions: Implications for flight deck performance.
- Madhavan, D. (1993). Cockpit task management errors: An ASRS incident report study.
- Sasou, K., & Reason, J. (1999). Team errors: definition and taxonomy.

## 4. Accident Analysis

The team conducted an initial, high-level review of accidents since 2009 to identify cases where TM errors were probable causes or contributing factors for subsequent detailed analysis. Specific TM errors are identified and categorized by error type based on the error taxonomy for crew TM (Chou and Funk, 1990) as well as overall workload:

- Task Initiation (Early, Late, Incorrect, Lack)
- Task Monitoring (Excessive, Lack)
- Task Prioritization (High, Low)
- Resource Allocation (High, Low)
- Task Termination (Early, Late, Lack, Incorrect)
- Task Interruption (Incorrect)
- Task Resumption (Lack)
- Workload (High, Low)

Of the 133 accidents since 2009, 14 (10.5%) were identified with TM errors. Appendix B contains the full list and synopses of accidents reviewed. Detailed analysis investigated the nature of TM errors and identified impacts, if any, on flight path monitoring. Our assessment was prepared with the intent of informing future training and operational standards for flightcrew TM.

This accident analysis triaged all major aircraft accidents between 2009 and the present and analyzed those with an emphasis on TM errors. The 14 accidents in this category are summarized below with TM issue and impact on flight path monitoring.

- The 2009 Colgan Air Flight 3407 crash was the result of a number of human factors issues, of which the most relevant were the crew's improper response to the stall, driven by the overallocation of (PF) resources to (PM) tasks, failure to adhere to emergency procedures and failure to properly monitor tasks to their completion. As a result, the flightcrew was unaware of the degradation of airspeed.
- 2. The 2009 Turkish Airlines Flight 1951 accident occurred due to mechanical failures coupled with a number of TM errors, leading to a late response to the emergency condition and failure to properly monitor the instruments, specifically airspeed and altitude.
- 3. The 2009 Air France Flight 447 accident was an example of a high workload situation in which a small sensor fault (brought about by icing) spiraled into a serious situation due to the crew's attention tunneling and their failure to jointly establish a plan of action, share responsibilities, and maintain shared situation awareness. As a result, the crew was late in identifying and correcting deviation from the flight path.
- 4. In the case of the 2010 Air India Express Flight 812 accident, poor situation awareness on the part of the recently awakened pilot exacerbated an already perilous situation. It compressed the task schedule and increased crew workload, which ultimately led to improper task prioritization and decision making. The crew failed to monitor altitude, resulting in the flight being twice the target altitude on finals.

- The 2011 Manx2 Flight 7100 analysis revealed that among other CRM issues, roles and task allocation were not properly defined, which led to poor situation awareness and confusion in the high workload environment. There were no substantial issues with flight path monitoring identified.
- 6. In the 2011 Georgian Airways United Nations Flight accident, poor self-monitoring and temporal concerns led to improper task prioritization and excessive task monitoring (attention tunneling) under high-stress/ high-workload conditions. There were no substantial issues with flight path monitoring identified.
- The 2011 Noar Linhas Aéreas Flight 4896 accident exemplified poor CRM, poor resource management, failure to execute proper procedures and failure to monitor roles/progress on tasks. The PF, task saturated by emergency, failed to manage airspeed as it decayed below Vmca.
- 8. In the case of 2011 First Air Flight 6560 accident, failure to prioritize instrument monitoring and localizer navigation early on in the approach led to a compressed task schedule, late initiation of checklist procedures, and divergence between the crew's mental models of the situation. As a result, the flightcrew was 600 feet above glideslope when turning onto final approach.
- 9. While the 2011 Airlines PNG Flight 1600 accident was initiated by a mechanical issue, the flightcrew failed to initiate proper procedures and to monitor instruments (which might have helped them land safely); additionally there was a breakdown in communication and shared SA when a radio call was prioritized over the flying task. There were no substantial issues with flight path monitoring identified.
- 10. The 2012 Bhoja Air Flight 213 analysis revealed a lack of attention to emergency alerts, failure to respond to alerts, and a poorly defined task allocation. The flightcrew exhibited ineffective management of the key flight parameters of airspeed, altitude, descent rate, and thrust.
- 11. In the case of the 2012 Sukhoi Superjet 100 Exhibition Flight accident, the crew prioritized communication with a potential buyer above their flying and navigation tasks, thus failing to monitor instruments, ignoring alerts, and creating delays in communication and planning. A distracted PF failed to monitor heading that resulted in exiting the orbit.
- 12. The 2013 Asiana Airlines Flight 214 accident was caused primarily by the crew's insufficient monitoring of instruments and late task initiation, driven by high workload, overreliance on automation and poor CRM. The crew failed to manage vertical profile, resulting in aircraft being well above glideslope at 5 nm point.
- 13. The 2014 TransAsia Airways Flight 222 accident stemmed from poor CRM as well as failure to monitor instruments while conducting visual search (attention tunneling), poor allocation of resources, and the late response to reaching MDA without visual contact. The aircraft's hazardous flight path was not detected and corrected by the crew in time to avoid the collision with the terrain.
- 14. 2014 Indonesia AirAsia Flight 8501 accident began with a system failure, though the primary cause was failure to follow emergency procedure, introducing an improper task in the procedure (getting up to pull circuit breakers), prioritizing the alert and manual error diagnosis over the flying task, and failing to monitor instruments (prioritization/over-allocation of

resources to the system task). The flightcrew distracted by multiple failures and the aircraft reverting to Alternate Control Laws, failed to manage airspeed and angle of attack, eventually resulting in stall.

Within these 14 events, 76 TM errors were identified. Table 4-1 categorizes the observed TM errors.

Error Category	Error Type	Number of Occurrences	Percent of Total
Task Initiation	Early	0	0.0%
Task Initiation	Late	10	13.2%
Task Initiation	Incorrect	3	3.9%
Task Initiation	Lack	7	9.2%
Task Monitoring	Excessive	5	6.6%
Task Monitoring	Lack	10	13.2%
Task Prioritization	High	2	2.6%
Task Prioritization	Low	2	2.6%
Task Prioritization	Incorrect	7	9.2%
Resource Allocation	High	7	9.2%
Resource Allocation	Low	5	6.6%
Task Termination	Early	2	2.6%
Task Termination	Late	0	0.0%
Task Termination	Lack	1	1.3%
Task Termination	Incorrect	0	0.0%
Task Interruption	Incorrect	3	3.9%
Task Resumption	Lack	1	1.3%
Workload	High	11	14.5%
Workload	Low	0	0.0%

Table 4-1. TM errors observed in the 14 accidents with TM as causal or contributing

The rate of occurrences within each error category for the 76 TM errors is summarized in Figure 4-1 below. Note that the four largest TM error categories account for 77% of the errors: Task Initiation, Task Monitoring, Task Prioritization, and Resource Allocation.


Figure 4-1. Observed Task Management Errors by Category in 14 Accidents

## Conclusions

TM is the pilots' capability to strategically orchestrate and tactically adapt task performance over the course of the flight; it functions to protect aircraft flight path and trajectory as its primary goal. Throughout all of the cases studied, TM errors played an integral role in the sequence of events leading to the catastrophic outcome. Detailed analyses indicated that in 11 of 14 (78.6%) accidents TM issues impacted flight path monitoring.

# 5. ASRS Analysis

To assess persistent TM issues in Part 121 operations, we conducted an ASRS analysis of incidents between January 2010 and July 2016. We narrowed the ASRS search more so than that done by the FDAWG in order to focus our resources on a common event, altitude deviation, which often results from human factors issues and represents a flight path monitoring issue as well. The ASRS search criteria were as follows:

- Date of Incident was between January-2010 and July-2016
- and Federal Aviation Regulations (14 CFR) Part was Part 121
- and Human Factors (since 6/09) were Communication Breakdown or Distraction or Time Pressure or Workload
- and Event Type was (Deviation-Altitude) Crossing Restriction Not Met or Excursion From Assigned Altitude or Overshoot or Undershoot
- and Contributing Factors were Human Factors
- and Primary Problem was Human Factors
- and Mission was Passenger
- and Reporter Organization was Air Carrier

This search resulted in 271 reports. We reviewed all reports to assess whether they included TM errors. As stated in Section 4 Accident Analysis, the TM errors included:

- Task Initiation (Early, Late, Incorrect, Lack)
- Task Monitoring (Excessive, Lack)
- Task Prioritization (High, Low)
- Resource Allocation (High, Low)
- Task Termination (Early, Late, Lack, Incorrect)
- Task Interruption (Incorrect)
- Task Resumption (Lack)
- Workload (High, Low)

If the narrative implicated any of these TM errors, the report was flagged that TM was a contributing factor. In addition, other contributing factors, such as ATC requested changes and pilot fatigue, were identified. Of the 271 reports, 39 (14%) included TM as a contributing factor. Within the 39 TM-related incidents, 120 TM errors were identified. The breakdown of TM errors by type is shown in Table 5-1.

Error Category	Error Type	Occurrences	Percent of Total	
Task Initiation	Early	3	2.46%	
Task Initiation	Late	10	8.20%	
Task Initiation	Incorrect	4	3.28%	
Task Initiation	Lack	8	6.56%	
Task Monitoring	Excessive	6	4.92%	
Task Monitoring	Lack	10	8.20%	
Task Prioritization	High	10	8.20%	
Task Prioritization	Low	16	13.11%	
Resource Allocation	High	6	4.92%	
Resource Allocation	Low	14	11.48%	
Task Termination	Early	2	1.64%	
Task Termination	Late	1	0.82%	
Task Termination	Lack	0	0.00%	
Task Termination	Incorrect	0	0.00%	
Task Interruption	Incorrect	4	3.28%	
Task Resumption	Lack	2	1.64%	
Workload	High	23	18.85%	
Workload	Low	3	2.46%	

#### Table 5-1. ASRS Error Breakdowns

The rate of occurrence in each error classification across selected events is summarized in Figure 5-1, below. The four TM error categories that accounted for the largest percentage of the errors were Task Initiation, Task Prioritization, Resource Allocation, and Workload, accounting for 79% of the errors.



Figure 5-1. Observed TM Errors from ASRS Reports

Synopses and error categorization of all TM-related ASRS reports found are shown in Appendix C. Following are three examples:

## Report 1: Failure to reset altimeter results in erroneous altitude indication

In the first example, a DHC-8-400 (Q400) crew distracted by weather, turbulence, Electronic Flight Bag (EFB) usage and passenger safety, forgot to reset a low altimeter (29.11 to 29.92) while climbing to FL230 and were subsequently advised by ATC of an altitude deviation.

The aircraft had been delayed for maintenance before departure and had the passengers on board for an hour, so there was a temporal demand factor. Multiple lines of thunderstorms and high winds were present on departure, distracting the PF. The PM was having some problems with a frequency change (the reception was poor and they were given a wrong frequency) which took some time to resolve. Both pilots were distracted and failed to reset either altimeter, which resulted in a large indication error. As they checked on to the new frequency, the Controller asked what their altitude was, which is when they spotted and corrected the problem. The main factor in this event was attention tunneling; the PF was focusing on the EFB to find clear weather and the PM focused on frequency change.

Four TM errors observed in this case included (1) task prioritization (Low) of the instrument monitoring task (failure to follow SOP on departure), which should have been a priority ("aviate") task; (2) task monitoring (Excessive) of the weather (PF) and radio (PM); (3) resource allocation (Low) to the aviate and monitoring tasks; and (4) workload (High). Contributing factors included the temporal demands imposed by the ground delay, severe weather, and stress (expressed by the PF in his report).

# Report 2: Confused and distracted by control mode and procedures, crew descends below minimum altitude on RNAV approach

In this case, B737-700 flight crew experienced difficulties attempting to practice a RNAV approach into JAX in visual meteorological conditions (VMC). Control wheel steering mode was inadvertently selected and the aircraft descended prematurely, triggering a low altitude alert from ATC and an Enhanced Ground Proximity Warning System warning. A visual approach ensued.

It was the Captain's (the PF) first attempt at practicing an RNAV approach and the first officer (the PM) had only flown one before. The crew was on approach into JAX, and requested the RNAV (GPS) 31. ATC cleared them direct to NIBLE (IAF); however, they were past NIBLE when starting the turn, which resulted in a larger turn than expected (virtually entering a downwind). When cleared for the RNAV approach, due to the close proximity to NIBLE, the autopilot was turning right towards the fix and shortly thereafter started a left turn towards POTME (close timing was a factor). At some point, the PF unknowingly disengaged LNAV and went into control wheel steering mode. PM alerted him to the mode change, but he did not respond. The crew became disoriented; they were off course, confused with what the airplane was doing, and descending. The PF disengaged the autopilot and continued descending while flying away from the field. PM instructed him several times to stop descending, climb, and return to the glidepath. The PF, fixated with the new RNAV procedures, was unresponsive to the PM's verbal alerts. The AC had descended below the charted altitude at POTME (2,600 ft., 9 miles from TDZ) to about 1,700 ft. MSL. ATC alerted the crew, who responded with 'correcting,' requested and were subsequently cleared for the visual approach. The main factors in this event were poor CRM, and attention tunneling on RNAV approach exacerbated by unfamiliarity with RNAV procedures, and failure to terminate the procedure. The PM noted in his report that they should have prioritized flying the airplane above all else, and should have discontinued the RNAV approach earlier when they became disoriented. The PM felt he was assertive but nonetheless, the PF failed to heed his guidance. PF fixation on the procedure and mode confusion caused him to ignore (or perhaps fail to hear) the warnings of his crewmate.

Four TM errors observed included: (1) high prioritization of the RNAV procedure, (2) excessive task monitoring (procedural as well as confusion about the AC control response), (3) failure to initiate the climb and redirect to course, and (4) failure to terminate the RNAV procedure and request the familiar visual flight rules (VFR) approach as soon as they became disoriented. Other contributing factors included inadequate training, poor CRM and spatial disorientation.

## Report 3: Distracted by mode confusion and mental calculations of the speed setting, the pilot flying failed to work collaboratively with the PM and adhere to procedure.

In the third example, an A320 Captain on the LAS TYSSN THREE RNAV calculated his descent constraint compliance incorrectly and failed to meet one of the constraints before realizing his error, even though his First Officer (FO) was cautioning about the error.

Enroute to LAS, ATC cleared the crew to descend to FL260 at 280 KIAs. The crew leveled off at FL260 and set cruise mode for a managed descent speed of 282 KIAS; however, the PF erroneously selected 280 on the FCU instead of 280 KIAs. ATC cleared them to descend via the RNAV arrival for a visual approach to Runway 25L. The PF dialed in 8,000 to meet the altitude restriction at PRINO. Both crewmembers had

triple checked all the altitude constraints on the arrival, and both had the constraints button pushed. The first waypoint had an 'at or above FL200' constraint and the subsequent waypoint had an 'at or below FL190' constraint. They engaged managed descent and calculated that they needed 21 miles to get below FL190 over the second waypoint (19 nm away from the first). The aircraft started a 900 FPM descent, still in selected speed of 280. The Multi-function Control and Display Units (MCDU) showed approximately 2,400 FT low on the path but slowly decreasing deviation. The PM noticed and informed the PF about the navigation errors, but due to attention tunneling (focusing on the altitude and descent rate calculations), he failed to adhere to proper procedure to correct the descent.

Three main TM errors were observed, including low prioritization of the aviate task, late initiation of the corrective measure, and low/poor resource allocation in not prescribing the troubleshooting to the PM. Contributing factors included distraction, PF fixation on calculation task, and inadequate CRM.

#### Conclusions

The three cases presented above illustrate the impact of TM errors on the pilots' ability to properly navigate, adhere to published procedures and maintain stability on the flight path. Procedural compliance and flight path management are directly impacted by crew TM errors.

# 6. Current Practices and Vulnerabilities

# "If you are managing error, you are managing the past. If you manage threats, you are behind the airplane. If you manage risk, you are managing your future." $^2$

To explore and describe how TM is understood, trained and practiced by operators, we conducted ethnographic research by observing pilots as they work. We interviewed pilots at multiple airline training and flight standards departments and analyzed training and operational documents. Six airline operators participated in this study, four major and two regional. Interviews were conducted at each airline with instructor pilots, check airmen, and standards pilots, focusing on how task management, or its components, are understood, trained, and evaluated at the airline. Interviews were also used to discern periods that require TM tools. We reviewed training materials provided by six airlines describing their automation policy and procedures, as well as policies that govern TM performance, and then performed a comparative analysis on these policies across airlines.

We directly observed CRM and Threat and Error Management (TEM) ground training sessions and fullmotion simulation sessions, during which operators described their TM training and how instructors teach and evaluate TM behaviors. We also observed simulator training at three major operators, which included four Line Operations Simulation (LOS) sessions, two Maneuvers Validations sessions, two Line Oriented Evaluation (LOE) sessions, two Line Operations Flight Training (LOFT) sessions, and two Special Purpose Operations Training sessions. The research team also conducted jump seat observations at one major operator on 26 revenue flights to identify TM practices pilots currently use in operations. We also identified a number of TM vulnerabilities that are addressed with training and procedure recommendations in Section 8.

While we sought to obtain a representative sample of operators and materials, our data collection was limited to the access to training and policy materials that could be provided by the operators and by the jump seat and training observations we were able to complete. Only two of the major operators were permitted to release all their training and operations manuals, while the remaining operators were able to release some of their training materials. Our analysis identifies how operators describe and characterize TM for their operations, how they train TM, and the procedures and policies that support it.

## 6.1 Task Management Description

All six operators have training, procedures, and policies that address TM components. They all describe TM generically as a set of non-technical skills, knowledge, and strategies that support effective flight management and monitoring. All six operators train to known tasks and threats, based on their understanding of how they fit nominally into the overall workflow of a flight in their operation. TM per se is not trained or discussed comprehensively at any operator, but several of its subcomponents are trained with supporting procedures or policies specifying how they are to be conducted (see Table 6-1 for summary).

Policies and procedures are published in training materials, flight operations manuals, and other materials distributed to pilots such as posters, cards, or pamphlets. Each operator trains TM components in flight simulation sessions, such as LOE, LOS, or in the LOFT sessions. These gate-to-gate sessions are scripted scenarios that morph with the decisions the pilots make during the event and are intended to develop critical thinking skills and proper task allocation skills within the context of realistic and recognizable flight operations. The current practices of the six operators is described for each of the TM subcomponents in the following sections.

TM Subcomponents	Major 1	Major 2	Major 3	Major 4	Regional 1	Regional 2
Planning	training / policy	training / policy	training / policy	training / policy	training	training / policy
Priority	training / procedure					
Task load	training	training	training	training	training	training
Allocation	training / procedure					
Time management	training / policy	training		training / policy	training / policy	training / policy
Information management	policy	training		training		
Monitoring tasks		training	training	training		
Task resources	training	training		training		
Disruption management		training				training / policy
Task characteristics			training			
Communication	training / policy	training	training	training		
Automation to reduce WL	training / procedure	training / policy	training	training / procedure	training	training / procedure
FPM areas of vulnerability (AOV)		training	training			training

 Table 6-1. Summary of task management subcomponents specified in training, procedure, or policy at six

 U.S. operators. Blank boxes represent areas where operator has no training, procedures, or policies.

## Task Planning

Strategic planning involves prioritizing tasks, defining their allocation to the PF/PM, defining the timing of tasks, and managing the resources needed to support the tasks. All six operators train pilots to proactively anticipate problems, to develop a plan of action, to plan tasks, and to include these in their briefings. The intended function of the briefing is to "set the stage for the operation and task priority." The plan anticipates "threats," "disruptions," and "changing conditions," and describes how they will be

managed. Plans are shared between pilots so they can construct a shared understanding of the plan. A shared understanding is intended to help the pilots maintain coordination with each other and organize their activities accordingly.

## **Task Prioritization**

Task prioritization is trained at all six operators along with procedures that define managing and monitoring the flight path as the highest priority. Operators characterize this priority in general policies such as: "stabilize aircraft and maintain control" or "safety, comfort, efficiency" or prioritization falls to crew to "clearly prioritize operational tasks." Pilots are given general guidance such as "determine the best course of action," but specific guidance on how to determine the best course of action is not provided. In interviews, pilots reported that prioritizing tasks in a real-time environment was challenging and often resulted in task saturation. One major operator's policy advises pilots to brief the operational priority of tasks for each flight phase to facilitate the dynamic reprioritization of tasks as needed.

### Task Load and Workload

Four of the operators we interviews train "workload management" as part of their CRM/TEM training and includes several TM subcomponents under it. These operators also place "disruption management" and "time management" under the category of workload management as part of their TEM training. They provide procedures and policies to support workload management that includes "distributing tasks," "balancing tasks," "and prioritizing tasks," "allocation of tasks between PF/PM," "disruption management," and "time awareness." Two operators train "risk management," which they describe as the next step beyond CRM/TEM. While these operators do not have a workload management distinction in their training, they do address each of the same components with training and procedures. Disruption or event management at these two operators is trained in separate modules that includes time management.

In training, pilots are given strategies as resources to balance tasks with time. For example the following summary of one operator's policy describes their strategies for managing task load:

When task loading is high, the pilot may choose to reduce the number of tasks or increase the time available to complete the tasks, if time is not limited. A reduction in task load may be achieved by performing tasks at some other time, delegating tasks to another person or entity, or dropping tasks. To increase time available the pilot may slow or stop the aircraft or slow the pace of the operation. When time is limited, such as a low fuel or fire condition, tasks must be reprioritized. Task loading changes with context and circumstance so pilots need to continually assess the situation to make smart decisions about structuring the task load.

Two operators touch on decision making for workload management in training modules and in their policies. In this context, decision making is portrayed as a tactical process for deciding which tasks to drop, defer, or suspend. Training and policies at all six operators encourage pilots to schedule task performance during periods of low workload and to set up for periods of high workload in advance (for example, "briefings are accomplished during periods of low workload such as prior to departure.") To reduce task loading, the pilot is instructed to reduce the number of tasks or increase the available time to do them. However, reducing the number of tasks (i.e., task shedding) must be done thoughtfully so that important tasks are preserved and non-essential tasks are deferred. This decision process will also

depend on the specific circumstances of the flight, but none of the training or policies specify how this is to be done. Monitoring of task performance is trained at three operators, but all three focus this on monitoring the other pilot for task saturation.

### Task Allocation

Strategic task allocation is specified in procedures and operational policies that assign known tasks to a pilot's role (PM/PF) or rank (Captain/First Officer), such as the preflight configuration of the aircraft. However, tactical task allocation is left up to the pilots to redistribute the workload, so it remains balanced during the flight preventing either pilot from task saturation. None of the six operators provide specific training on how to keep the task load balanced in real-time or how to determine when one or the other pilot is over tasked. Pilots are encouraged to use "personnel resources to complete tasks efficiently and those resources may be internal to the flight deck (e.g., automation or other pilot/observer) or external to the flight deck (e.g., cabin crew) or the aircraft (e.g., company dispatchers, air traffic controllers, etc.). One instructor offered, "Crews that perform best tend to have a better sense of the big picture of what everyone else is doing, but training this is not straightforward."

#### Time Management

Time management is trained at five of the operators we observed. The concept of time management involves using time as a resource and making good use of time. Making good use of time involves planning the timing of tasks, such as doing tasks early or during periods of low task loading such as the cruise phase of flight. Using time as a resource involves the notion of "creating time" by slowing or stopping the aircraft on the ground, requesting an extended vector, saying "unable" to an ATC request, or entering a hold if the crew needs more time to complete tasks. If time is limited by circumstance and the aircraft's trajectory cannot be changed, operator time management policies suggest flightcrews focus on flying the aircraft, maintaining safety, and dropping non-essential tasks. Time management also suggests controlling the pace of the operation so there is sufficient time to complete the required operational tasks. Training on these strategies is conducted in ground training and in flight simulation events that are line oriented. All operators agreed pilots need training on how to focus on the *timing* of different elements of the time management process and define policies that specify what to do.

#### Information Management

All operators recognized information management as an important component of task and flight path management; however, because of its complexity, they are struggling to develop policies and training to define operational performance standards for information management. What is trained are "rules of thumb" for managing information. Memory joggers are trained, such as using piece of paper, coffee cup, tape, or timer on a cell phone, to remind the pilot that information is coming or is not yet complete. Operators are also beginning to consider training for how to manage information between installed avionics and a carry-on portable electronic device (PED). An instructor reported there is a need for training on PEDs because "the iPad is a liability that has to be managed," and pilots do not receive instruction on how to use it or its applications and features.

Because information is a resource for task performance, pilots must actively manage this information flow. Pilots need to know where information is located and when it will arrive (or need to be sent); information can arrive in the flight deck at unscheduled times, its arrival can also result in interruptions.

Therefore, when able, information flow needs to be managed to make sure the timing of information does not disrupt the pilots and helps rather than hinders TM. The three operators that train or have policies for information management focus on managing information on their tablet EFB; however, information management is a much larger issue than the EFB. Information flows to and from the flight deck through a variety of sources (ATC, dispatch, cabin, ground crew, other aircraft, etc.) and media (radio, ACARS, paper, EFB, or in-person). With respect to TM, information is associated with tasks: pilots must acquire it in a timely manner, ensure its accuracy, completeness, and reliability, apply it, and sometimes communicate it.

Operators are seeing an increase in information automation, which could be a data uplink to the flight management system (FMS), or information about the flight path as depicted on the navigation display or the flight management system or as a depiction of turbulence that comes into the flight deck from an EFB application. This information requires careful management and pilots need to know how and when to access or send, in the case of controller-pilot datalink communications (CPDLC), information for a particular task. Another challenge is that pilots may not control the timeliness of such information coming into the flight deck or its readiness, for example an ACARS chime during takeoff roll. Information prioritization and awareness of task loading need to account for the fact that the flow of information may not coincide with the crew's ability to deal with it at that time. This is an evolving challenge that warrants future research to inform guidance on effective information management that supports task management.

#### **Disruption Management**

Disruptions are events that are not planned and emerge from the complexity of the operational environment and introduce a new suite of tasks for the pilot to manage. Disruptions range from a simple verbal request, to a change in arrival clearance or runway, to an emergency situation. Disruptions may occur at any time during the flight and are potential "threats" or "risks" to the operation that must be managed. The policies governing the management of disruptions are explained in CRM and TEM policies and non-normal procedures; they provide pilots a process for reliably managing emergent events. When a disruption occurs, policies emphasize that the focus of the operation is on flying the airplane, assessing the situation, and deciding on action. For nominal disruptions the pilot is to decide how to address it: whether to ignore the disruption, stop the current task and address it, go back to the previous task, or to perform a new task based on the disruption. The issue with disruptions and task management is that emergent events may drive task reprioritization, reallocation, and task shedding. Remembering to return to an interrupted task.

In non-normal or emergency situations, all six operators have procedures and policies that allocate tasks to the pilots, either by role or by rank, and that define task priorities. For example, one operator's procedure requires the FO to assume the PF role regardless of his current role and the Captain manages the emergency situation. All operators have policies for emergency situations that state the first task priority is to "fly the aircraft," then "assess the situation." Once the aircraft is stable, the Captain can designate PM/PF roles. If the event is time-critical, the policies dictate that pilots take action and communicate. If there is time, the crew may plan action, communicate, and prioritize tasks. Non-normal

procedures for a specific failure are carried out by the crew according to assigned roles, but any further task allocation occurs at the discretion of the Captain. Operator policies note that the PM/PF roles may change during the management of the event.

### Automation as a Resource to Reduce Workload

All six operators have automation policies that encourage pilots to use automation as a resource to reduce workload. These policies instruct pilots to use "the appropriate level of automation for the situation" and to "use automation as a resource to reduce workload," but none of the operators explicitly described a process for doing so—possibly because appropriate use of automation depends on the specific context or circumstance. Another concern is that the act of delegating a task to the automated systems itself creates a new monitoring task for the pilot. There is a risk that pilots may neglect or forget to monitor the automation's performance, so there has been a renewed focus on training pilots to "actively monitor" the automated systems and the flight path. Instructors at one airline encourage trainees to "trust the automation but verify it" and if one pilot steps out of the flight deck or is focused on another task, the other pilot should update or say "no changes" so both pilots are aware of the current state of the automation. In interviews, pilots revealed that unexpected automation behaviors were a "major distraction" that could redirect the pilots' attention away from other tasks. The most common example cited was the way the automation ignores programmed altitude constraints when it transitions from VNAV PTH to VNAV SPD mode, which can result in a flight path deviation as well as confusion that increases workload.

### Flight Path Monitoring Areas of Vulnerability

Three operators (2 majors and 1 regional) use the "areas of vulnerability (AOV)" concept from the Flight Safety Foundation Guide on Flight Path Monitoring (2014) to support task planning and task priority. For planning, they use the AOVs to identify periods of the flight where there is high risk of a serious outcome such as being on or near a runway or in close spaces at the gate, close to ground, changing the flight path trajectory (lateral, vertical, speed), or approaching 1000 ft. in descent. During these periods, pilots are instructed to avoid all non-essential tasks. Medium threat areas are defined as periods in the flight where the operations may degrade quickly such as when the airplane is in motion on the ground, climbing or descending, and flying below 10,000 ft. All non-essential tasks are to be avoided or performed by the pilot monitoring (PM) while in medium threat areas. Low threat periods are when the airplane is stable and time is available such as when the airplane is stopped or flying straight and level in cruise. During these periods, the pilot's focus is on monitoring.

The three operators that do not use the AOV concept have policies for pilots to identify periods of high and low workload and to plan the tasking accordingly, with the task priority on protecting the flight path. The operators not using the AOV concept expressed in interviews that it is not sufficient for TM planning and task prioritization but can be a useful tool for focusing pilot attention to the flight path at high risk periods of the flight. Because the AOV concept has not yet been formally validated, there was some reluctance within the operators' flight operations and training departments to adopt it.

## 6.2 Task Management in Action: Observations from the Jump Seat

Twenty-six flight segments were observed at a major US airline from the jump seat during revenue service. Our objective was to describe what TM challenges pilots face and what crews do when they perform well. We did not focus on errors, which are well documented elsewhere (see Loukopoulos et al., 2009). We set out to identify TM strategies that crews employ effectively and ones that fall short. We observed patterns of crew interaction in "good" strategies that created stability in the timeline and coordination of activity. The pilots we observed had a good sense of their airline's operational pace and knew when they were getting behind the aircraft or the task flow. This sense of pace is not trained, but it seems to be acquired by pilots over time. As one Captain put it, it takes "35 years of flying." This section summarizes TM as observed during flight operations at one major US airline. Specific jump seat observations and incidents are described in italics below.

Pilots plan and organize their flight by applying knowledge in coordination with the context. They identify which tasks to do and when to do them based on their knowledge, anticipation of high and low workload periods in the flight, high risk tasks or situations in the flight, and expected changes to the plan. Pilots share strategic plans with each other in the form of briefings and their tactical plans via communication patterns. As tasks are carried out, pilots move between strategic plans and their tactical application, adapting as needed to meet the specific demands of the context.

In the planning process, crews assess the situation, identify resources needed for tasks, and notionally prioritize and allocate tasks. Strategic task prioritization and allocation is defined by procedures and policies but as the plan is enacted it becomes more tactical in response to the real-time demands of the flight. Some examples of strategic planning we observed included:

- While the Captain was doing a generator check, the FO protected the flight's timeline by proactively planning for two futures by doing the performance calculations for both takeoff runways (taking off on runway 08 and runway 03) in case there was a last minute change. This is a strategy to enable fast tactical performance if needed.
- The FO briefed "hot spots" on the airport surface, turns, and departure altitudes prior to taxi. This briefing enabled the crew to anticipate areas where focused attention would be needed and to plan other tasks around those high risk areas.
- *"I'm thinking we'll get RNP15 but I'll back it up with the instrument landing system (ILS)."* The PM was expecting one approach but also worked a plan for the other approach as a contingency to keep workload stable in the event of a change.
- On arrival, the pilots discussed takeoff stopping margin and the new airline policy in place that reduced the margins from 5000' to 2000' to plan ahead for the next leg. The crews were already planning for the next takeoff on their arrival and discussing the new policy to assure they could comply.

Tasks to be performed are defined by procedures, policies, and the operation and vary by situation and phase of flight. Tasks are allocated on the flight deck to pilots based on their role (PM/PF) or their rank

(Captain/FO) and to the automated systems. Tasks can also be allocated to personnel external to the flight deck such as flight attendants, maintenance personnel, company dispatch, fleet manager, ATC, etc. At any given moment, pilots need to manage resource availability as well as capability and allocate them to tasks.

Resources for TM include:

- Information that pilots need to acquire, analyze, interpret, create, assimilate
- Pilot cognitive resources including knowledge, attention, memory, and perception

Following are several examples of pilots acquiring or trying to acquire information that we observed:

- *The PM requested ride reports upon entering light turbulence.* The context triggered the information gathering from ATC for turbulence along their route of flight.
- The crew tried multiple times to find ATIS and gate information via ACARS, but it wasn't working. This situation actually increased crew workload as they kept trying and eventually gave up and resorted to communication frequencies. This unreliability added workload and prolonged the task. If an information resource is unreliable, the pilots are required to use an alternative information source that may add time and create additional tasks and frustration.

Pilots reported that information management before the use of EFBs was easier because pilots could have multiple pieces of paper, such as two charts on approach, laid out spatially for quick reference. Today, pilots can only have one page on a PED such as the iPad open at a time, which adds to information bottlenecks and workload as pilots now have to switch between pages. It is especially challenging in the approach flight phase. Pilots believe this aspect of the operation introduces considerable risk and liability. We observed some general information management tasks that added workload:

- Correlating the position of the airplane with weather data.
- Pilots reported finding information in a PED such as the iPad is difficult, which could be caused by poorly designed applications.
- Software updates are pushed to the PED daily, and pilots have to keep up with what's new. For example, an update could be automatically initiated at the beginning of a flight that would require over 50 pages of reading. While it is not realistic to expect the crew to read it thoroughly, they are responsible for knowing the information and this introduces an unexpected task during a high workload period.

In particular, monitoring task performance relies on pilot knowledge to direct attention and to anticipate changes in the environments that may affect flight path management. Keeping the operation on pace requires pilots to monitor task performance and anticipate upcoming tasks and their needed resources. Transitions between tasks occurred with a familiar cadence, and when it differed this was a cue for crews to monitor more closely.

• There was a cadence between the crew and they seemed to transition between tasks and to prioritize events naturally. When one member of the crew was off doing something, the other

pilot would catch them up on events when they were complete. None of the flights were unusually high tasking, but energy management was always an issue.

- It was common for the PM to hold the checklist card waiting for the PF to call for it. Holding the card shows the PF that the PM is ready and it serves as a reminder that a checklist task is pending.
- At one point, the FO thought a check-in was not acknowledged by ATC, and the Captain recommended he try again only to discover that the crew had never checked in. This illustrates how easy it is to get distracted and how pilots can misremember doing something so routine. Good communication and coordination between the crew is essential to avoid, capture, and recover from TM errors.
- During single engine taxi, the PM monitored the engine warm up time and announced "5 minutes recommended" the recommended warm up period while physically guarding the engine to protect the timing of the engine warm up.
- The pilots monitor altitude and speed entries by repeating aloud the clearance. A PM Captain caught an altitude entry error when the FO entered 120 instead of 210. ATC had said climb and maintain Flight Level 210, and while he was entering the new altitude he said 120, which prompted the Captain to correct.
- Cross feed monitoring fuel balance with focused attention. PF proactively stopped the task.

The task load, or the number of tasks the crew needs to perform, is defined by the operational policies and procedures but the context will most likely drive the pilots' perception of workload. Pilots need to tactically prioritize tasks based on their criticality and decide to either suspend the current task, defer the emergent task, interleave them into one task or perform them concurrently. Interruptions, distractions, and emergent tasks are a part of normal flight operations and pilots have developed their own strategies for managing them.

- On one flight the seat armrest in the first class passenger cabin would not stow. The Captain had to complete a form which interrupted the preflight tasking and resulted in an incorrect fuel load being entered. The Captain decided to defer the task of addressing the seat issue and instead focused on the preflight tasks during which the captain was able to correct the error.
- A ground crewmember's hat was sucked into the airplane and the Captain was taken out of the normal flow of events to resolve the problem. He went outside to assess the situation and to talk with the ground crew and get everyone focused on solving the problem. The FO informed the passengers of exactly what had happened. The Captain, after consulting with maintenance and dispatch determined that the plane was flyable if they MEL'd the left pack and remained below 24000 feet enroute to destination. The alternative would have been to remove several fasteners on the panel resulting in a significant delay. Because he had been distracted for a considerable amount of time, he ran through all checklists again to ensure everything was ready and dispatch had to ready new forms that included the new MEL.

There are many factors inherent in commercial aircraft operations that induce workload. Aside from

something happening to the airplane, crew fatigue, interaction dynamics, or crew qualifications can also disrupt and impede task performance. Too many tasks to complete in a short period of time or tasks that are difficult and complex may require more time to complete and create additional workload. An unbalanced allocation of tasks between pilots may result in task saturation along with multiple concurrent tasks that divide attention and demand additional cognitive resources.

- Flying through FL180 doing the approach checklist, ATC interrupted the FO from completing the checklist with a frequency change. The FO completed the read back and then returned to the checklist and started from the beginning.
- The crew was interrupted by the ground crew right as they started their before push checks, and the Captain said in a friendly voice "Hey we'll be with you in just a moment." The interruption was managed by preserving the current task and placing the interrupting party on hold until they were done. This is a great example of protecting and focusing attention for a critical task.
- The crew was starting an engine during pushback and was interrupted by ATC with a runway change to 17. This became a distraction that led the PM and PF to divide attention and tasks so the PM could re-calculate takeoff performance.

ATC is one of the main factors in adding workload especially for flight path management tasks.

- ATC cleared them direct, which was good, but the Captain said "so what he did is made us high, which gives us more to do." When asked what tools they use, Captain says "I'm using the VNAV glide path deviation and mental math."
- "You just never know coming into here." When cleared to land, ATC issued a late runway change, from 7R to 7L which prompted PM to do a new task of setting 078 degrees for 7L ILS on final approach.

ATC can either facilitate TM or add considerable workload to the operation and complicate TM. ATC centers that maintain high consistency in their requests and clearances with relaxed controllers are very helpful because they help the pilot establish a plan and expectations for how the arrival will progress. They also work with the pilots to adapt their flight path as needed.

ATC gave a reduced speed clearance and the crew responded by selecting VNAV SPD to reduce speed prior to descent, and also asked ATC for relief on making the altitude constraint due to ATC asking for the lower speed. This shows the crew anticipates the VNAV mode not honoring the altitude constraint and work to mitigate their risk with a new task of requesting relief from ATC.

Centers that frequently change the aircraft's airspeed, are inconsistent, with unaccommodating controllers add to the crew's overall workload. Speed changes in complex arrivals require more active management and increases workload and complicates TM. Because controllers cannot see activity inside the flight deck, they may issue requests that interrupt critical tasks like aircraft configuration changes. One pilot confessed to landing once without clearance due to task saturation. On numerous occasions ATC calls interrupted checklist performance, aircraft configuration, and callouts.

Pilots need to maintain coordination with the other pilot and the flight path. Rigorous communication patterns can be especially effective for re-engaging after an interruption or concurrent task.

- If one pilot temporarily redirects attention to another task (e.g., PAX PA), that pilot reports "I'm back" and the other pilot responds "no changes" to indicate the flight path status and situation are the same. When there is a change, the pilots respond with "we're cleared to 210" and if there are no changes to the flight path but there is a change in airplane state the response is "no changes, EAI is on."
- During the approach briefing from the FMC the PM reported 6800 (feet) at one waypoint and the PF said "I see 8600," crew confirmed and corrected the error.

Pilots use heuristics to monitor and manage the flight path, typically developed from operational experience and expectations of automation behavior. Although pilots expect the automation to perform as programmed, it frequently does not result in the desired aircraft performance. One pilot offered "the autothrottle can vary up to 15kts and it takes effort to monitor vertical path and speeds." Monitoring the automated systems requires sustained attention and demands cognitive resources.

- VNAV PTH transitioned to VNAV SPD, and would not have honored the 17000 altitude constraint if the pilot had not corrected with V/S. The PM pointed out that there is no alert, so "both of us are sitting here monitoring because it will just do stuff, one green light changes to another green light."
- VNAV within the airplane was not performing consistently and no Vertical Situation Display was installed, so that when the FMS was programmed to fly through an altitude gate the crew never knew exactly where they would be. The system sometimes allowed 10 to 20 knots of deviation as the auto throttles were set to idle and armed during VNAV descents and didn't rearm to consistently maintain the speed. Thus the PF continually adjusted the throttle.

Some of the techniques and heuristics we observed pilots using to manage the flight path were:

- A Captain reported "It's easy to get high because of a tailwind. I back myself up with some mental math for a 3 degree glide slope descent I cross check both."
- A Captain advised FO "if they leave you hanging like this, 150kt, 30 degrees flaps works."
- A Captain flew a large turn south of runway centerline to lose energy.
- "I use the descent page and the legs page and I do math for each waypoint restriction because sometimes you wonder if the software was purchased at Dollar General."
- To keep the plan while simultaneously not committing to it the crew kept the DISCONTINUITY in the flight plan to keep the arrival and the approach, "Once cleared then I put CLIFF up there," which removes the DISCONTINUITY.
- While operating speed brakes in a descent from FL380 the PF noted he has to intervene in speed to keep from over speeding and changed speed in PERF to .80

• The crew relied much more on standard aviation rules of thumb for descent and energy planning. One heuristic was to descend at 1000 FPM at 210 knots and 1500 FPM at 250 knots, allowing for a constant angle descent.

## 6.3 Summary of Findings

## Challenges

New technologies, the broader use of performance based navigation procedures, increasingly complex airspace, and the extensive use of flight management systems and automation to direct aircraft trajectory are each shaping how pilots fly. Operators are expanding routes, hiring new pilots, integrating new aircraft and technology into their fleets, and strategically merge with other operators. All of these changes create new challenges, especially with mergers, as they entail combining safety cultures and standard operating procedures from different airlines. New technologies and new flight procedures encourage the full use of the automated flight management systems, but this makes managing aircraft trajectory more challenging due to the additional cognitive workload required to monitor and understand system behavior. All these factors influence TM at the flight crew level.

## **Common Strategies for TM**

Across the operators, we observed a convergence of strategies and tactics pilots use for TM; although these may be effective in many cases, they do not cover all aspects of TM. Common techniques for *strategic* task management included:

- Plan and anticipate how the flight will progress, create a shared mental model and share it in the briefing.
- As part of the briefing include task priorities for the upcoming phase of flight.
- Anticipate disruptions or "threats" and create a contingency plan for their mitigation.
- Plan and schedule tasks to perform at high and low workload periods of the flight. Schedule as many tasks as practical at low workload flight phases to "buy yourself some time".
- Stay organized with charts and information flow, so to not become distracted.

Common techniques for tactical task management included:

- Interleave steps of two or more tasks into one task.
- Defer a task to a period of lower workload.
- Suspend a task, switch to another task, and then resume primary task.
- Dynamically reprioritize tasks based on the context.
- Drop a task and do not resume it.
- Use the automated systems to reduce workload.
- Say unable to ATC or request an extended vector, or hold.

## Standardize TM/CRM/TEM/Risk concepts.

Although each operator had similar understandings of workload management, no operator had a documented definition of workload management. Rather, workload management was defined by its components such as planning, allocating, time management, and deciding on action. Definitions

included a mix of objective workload (task demands and available resources) with subjective workload (what the pilot feels) constructs which contributed to its lack of clear definition. For the operators that trained CRM and TEM, there was agreement that "situation awareness" should be removed as a training construct because it is a result of other activities rather than an activity itself. All six operators reported "situation awareness" was a challenge to train effectively. Two of the operators did not even use the terms CRM/TEM to describe non-technical skills. <u>Recommendation</u>: Given the variation in definitions and use of non-technical terms and concepts, we recommend the FAA update their non-technical skills definitions so there is a standard from which operators can develop effective training.

## Knowledge matters for TM.

Pilots need a broad base of knowledge, skill, and strategies to effectively manage tasks. TM is a cognitive activity where knowledge and expertise direct and manage action. A pilot needs extensive knowledge of operational tasks, the time needed to complete a task, the pace of the airline's operation, and proficiency in knowing what approaches are effective in managing task load and allocation. For example, TM is facilitated by operational understanding in terms of high workload periods of the flight and what happens locally at the airport and ATC as well as knowledge of how to use task resources, especially the automated systems. While several pilots we interviewed referred to TM as "airmanship," this needs to be unpacked to support TM training. <u>Recommendation</u>: Assess training programs to ensure pilots can develop the knowledge they need for effective task management during training.

## *Effective flight path management depends on TM and operational understanding of automated systems.*

Within the industry, the traditional "aviate" task is increasingly thought of in terms of flight path management and monitoring. As such, airlines should begin training pilots in the operational use of the automation for managing the flight path. The operators we interviewed expressed concern about their pilots' apparent lack of understanding of operational use of the flight management modes and how they fly the airplane. In particular, their collective data point to issues with flight management automation understanding in the vertical modes and with energy management. When a pilot is confused or surprised by the aircraft's behavior it may disrupt task flow, task prioritization, and task management. In particular, pilots need knowledge and understanding of vertical and lateral trajectories and energy states, and how the automated systems fly them. During interviews and jump seat discussions, pilots reported the knowledge requirements to operate the automation are high and believe it would be helpful to establish industry standards for automation terminology and behavior. Automation functionality and nomenclature vary across the avionics manufacturers and pilots have to know and remember the differences in capabilities between the different products.

<u>Recommendation</u>: Conduct research to define and assess appropriate automation terminology and training for flight path management that includes strategies for effective TM.

## Contextual factors make TM challenging

Several contextual factors in the operating environments contribute to TM challenges that are out of the pilots' control. Pilots are subjected to disruptions and are given procedures that may not be conducive to effective TM. For example, long checklists, complex procedures, procedures that require concurrent tasks, and ATC practices all impact TM. <u>*Recommendation*</u>: Human cognitive vulnerabilities as well as

contextual variability must be factored into airspace procedure design to minimize disruptive effects and to ensure the procedures fit into the operator's flight operations. Procedures, policies, and checklists need to be designed to better support TM by being more resistant to interruptions and have flexibility so procedures can fit into workflow as needed.

## There are periods of high and low workload during each flight.

As Advanced Qualification Program operators, all six operators have a data-driven understanding of their operations and the periods of high and low workload that occur during their operations. In general, the highest task loading is at the gate through initial climb after gear and flaps are retracted and in the descent and approach, particularly below 10,000 ft. One operator shared from a recent LOSA that "65% of their errors are on ground." While the workload profile can vary somewhat across operations, the general structure of flight operations is fairly stable and predictable.

## TM Gaps in Training Observed

Although all six operators train some components of TM (see Table 6-1), none of them train it comprehensively, resulting in knowledge and skill gaps that could leave them vulnerable to lapses in TM performance. The general component categories where operators should consider providing or improving training for TM include: disruption management, information management, task monitoring, task resource management, task characteristics and contextual factors that influence TM, communication patterns, automation use for flight path management, and managing the timing of tasks and the pace of operations. The following list identifies training gaps we observed:

- Training does not adequately replicate the actual work environment, so pilots do not have the opportunity to develop practiced skill other than on the line. All operators agreed that pilots need training on how to focus on the *timing* of different elements of the time management process, and they need to define policies that specify what to do.
- Training in the simulator needs to match the actual environment to the extent possible, especially with regard to the timing of events or the time it takes to do a task (such as manual gear extension). Pilots need to understand they control the pace of the operation and that rushing due to an incorrect perception of the required tasks and the time it takes to perform them can result in errors. Simulator sessions should preserve time so that pilots obtain an accurate understanding of how long a maneuver will take in the operating environment and how long it will take to coordinate activity with others.
- Current training on how to manage information, especially with PEDs and the installed devices, leaves pilots struggling to find their own solutions. Pilots need to know how to manage the flow of information but also when and how to access and assimilate information for task performance.
- Pilots need to develop structured patterns of attention. Pilots need to be skilled at managing their attention and be instructed on how to divide their attention between tasks while still checking the status of concurrent tasks.
- Procedures and operational policies may add workload or confuse the task priorities if they are not clear and understood by the pilots.
- Pilots need to be proficient in the operation and behavior of automated systems and know how to monitor the automation to ensure it is doing, and will continue to do, what is expected.

- When pilots become task saturated, they may focus on lower priority tasks. Even though pilots know that flying the aircraft is the top priority, they have to be diligent about continuously checking to ensure someone or the automated system is flying.
- Pilots need to be able to recognize when they are becoming task saturated and respond appropriately.
- Pilots need to understand there are human cognitive vulnerabilities and biases. Training should introduce these concepts and provide tools for their mitigation. For example, once distracted, humans have a bias against returning to the previous task. Stress is often a consequence of high cognitive workload, particularly if it is sustained. Stress changes cognitive functioning and degrades performance. There is a cost for switching between tasks, humans tend to continue performance on lower priority tasks, resulting in TM failures in timely switching from low priority tasks to high priority tasks.
- Educate pilots on task characteristics that make TM challenging due to high cognitive demand, such as task difficulty or complexity.
- Pilots need to be trained on scan patterns that support task monitoring for important tasks and aircraft states throughout the flight. Humans are poorly equipped for vigilance tasks like checking for rare, unexpected events.
- With experience, pilots may develop an intuition for what tasks need protecting, but it might be worth identifying them for less experienced pilots.

### TM Performance Vulnerabilities

- Defining tactical task priority for normal operations is a gap in pilot training. The lack of dynamic task prioritization strategies leads pilots to develop their own techniques, which may not be effective. Pilots need to know which tasks are important and when, which are time-critical and mission-critical, and how to prioritize them for the current situation. This training should be based on the airline's operational contexts.
- Pilots need to understand how the automation will control the aircraft so they are not confused or surprised by its behavior. To effectively use the automation to reduce workload, the pilots need to understand how to use it operationally, so training for automation should be conducted in the context of flight path management. Create policies about when to use the automation and when to fly manually. Proper automation use requires thorough understanding of which automation tool to use for which task; otherwise, using the automation could actually increase the workload by adding tasks and requiring extra monitoring. This highlights the importance of training automation knowledge to support effective use to facilitate TM without degrading it.
- Getting pilots to articulate the level of task load or saturation they are experiencing and the factors that increase or decrease it remains a challenge. Several operators requested recommendations on identifying task loading between crew members. Being able to recognize attentional tunneling, in oneself and in others, is a difficult skill to train.
- Many training elements in simulator sessions are not experienced in realistic real-time, but are compressed. As a result of the simulator session time manipulations, pilots reported in debriefs after real operational events that they were surprised at how long it took to handle

conversations and coordinate with other people.

• Operators' use the terms task load and workload interchangeably and define workload simply as tasks to accomplish in the available time. Numerous studies have shown that workload is complex and should also consider the impact of other factors such as task difficulty, stress, and fatigue, in the overall metric of workload. Operator definition of tasks over time is too simplistic, and therefore the strategies they train pilots to use to mitigate workload may not be effective across circumstances.

# 7. Emerging Issues in Task Management

While it is important to understand how TM is trained and practiced in the current operational environment, we must also look ahead to the implications of the ongoing transition to new air traffic management tools and procedures, as envisioned by NextGen initiatives, for task management in the flight deck. Emerging TM issues will also be driven by other evolving factors in aviation such as the move towards paperless operations and increased availability and use of new types of electronic displays for surveillance and information.

In the context of this document, NextGen refers to the modernization of procedures and operations in the National Airspace (NAS) as set forth by the FAA NextGen Implementation Plan (2016). While many documents dealing with NextGen call for significant and fundamental changes in the role of pilots (e.g., Lyall, et. al., 2011 and Letsu-Dake, et. al., 2012), it is increasingly understood that the actual tasks performed by pilots and controllers in NextGen are not likely to change in dramatic ways. Rather, what is likely to change are the methods by which those tasks are carried out, the amount and presentation of information that is available, as well as the introduction of more precise and time-based navigation procedures. There is also a high likelihood of a fairly long transition phase during which pilots will experience a mix of current and NextGen operations across the NAS. All of these changes represent potential challenges for TM as different ways to accomplish aviating and navigating will probably generate new strategies for focusing on new or different types of information and modes of communication.

## 7.1 Key Emerging Elements

Several key emerging elements of NextGen could impact TM:

- Increased use of data communications (data comm) between ATC and pilots.
- More precise navigation requirements and more efficient routing resulting from reduced separations and increased timing requirements (e.g., 4-D trajectory management and increased speed interventions). Such changes result in an increased need to monitor the automation used to manage these more precise flight paths.
- Increased availability and use of surveillance displays on the flight deck.
- Increased integration of various sources of information, e.g., on-board weather radar and offboard weather broadcast from the ground; System-Wide Information Management.
- Mixed equipage across an airline's fleet.

As can be concluded by the above items, the most significant emerging vulnerability is the addition of new tasks for pilots to manage. In addition, new approach procedures require different pilot procedures and hence represent different tasks. Yet, the previous and current approach procedures remain in the system. In fact, one of the vulnerabilities identified by pilots we interviewed is that ATC will sometimes clear the aircraft for one of the new types of precision approaches and then revert to the traditional method of vectoring the aircraft late in the approach, adding pressure to the pilots to manage the

approach. This pressure is exacerbated when the air traffic controller is unfamiliar with the performance characteristics of the aircraft and requests the aircraft to fly profiles that are either difficult or impossible for the aircraft to follow due to performance constraints. Hence, the variability as well as uncertainty in instructions from ATC during approach can add TM vulnerabilities for the pilots.

New tasks almost certainly mean that pilots will also need to learn and manage more information. For example, Lyall et al. (2011) reported that the depth of information provided to pilots may need to be increased in NextGen. They also reported that since NextGen will incorporate new automated systems, mode awareness of the automation will be even more important in NextGen, again impacting TM.

Each of the bulleted emerging elements above and their relationship to TM are discussed in more detail below. The details contain examples as well as potential gaps and/or issues.

## 7.2 Specific Emerging Elements

## 7.2.1 Increased Use of Data Communication

Data comm has been shown to be a benefit for many aspects of both current and NextGen communications (e.g., Lozito, et al., 1993 and Shelton, et al., 2009). Communication during transoceanic operations has become easier with the introduction of data comm via CPDLC and has been used successfully for years in that environment. The caveat for this success however, is that CPDLC is being used in transoceanic operations predominantly in low-workload phases of flight. While numerous benefits are associated with the use of data comm messages, their increased usage also places potential pressure on TM. The use of CPDLC is envisioned to increase in domestic operations (EUROCONTROL, 2005), which may result in new vulnerabilities.

## Summary of Issues and Gaps:

- Potential vulnerabilities around mixed use of voice and data comm
- Timing delays and characteristics associated with data comm messages as compared to voice
- Potential risk of increased head-down time with use of data comm messages

## Examples:

In an early study on the use of CPDLC run at the FAA Technical Center in 1996 (DOT/FAA/CT-96-3), pilots found the mixed use of CPDLC and voice communications caused confusion or doubt in forty-four percent of the flights tested. While these findings may have resulted from an inadequate division and/or understanding of when CPDLC versus voice communication should be used, the pilots found that it was more difficult to listen to their call sign in a mixed data comm and voice environment than in a voice-only environment. In another study Lozito, et al. (2003) found that during periods of high workload or time pressure, a mix of data comm and voice communications did not achieve optimum results. The researchers concluded that procedures for managing mixed media communications are necessary. Hence, using two communication methods together will require different TM strategies. Both pilots and controllers will need to understand how the two communication methods should be utilized and prioritized.

Another issue with CPDLC related to TM is the delays that can be associated with data comm messages.

With voice communications, it is normally assumed that the most recent communication is the most upto-date. With data comm, there may be a delay in the arrival of certain messages. This situation will place additional importance on how to determine the communications timing, especially where two messages may be in conflict. It could add to the task of appropriately prioritizing messages.

The timing characteristics of voice versus data comm also points to the issue of characterizing and understanding the urgency of communications. Anything of significant urgency, especially in the terminal area, will most likely need to utilize voice, while lower urgency communications will use data comm. While this categorization of urgent versus non-urgent communications may be intuitive and actually help pilots understand the urgency of communications, it is another way in which TM may be impacted in NextGen.

The first implementations of CPDLC in US domestic airspace have been at airports where departure clearances can now be issued by CPDLC. One of the benefits is that it is possible to request and/or to receive late updates to departure clearances to take advantage of changes or to accommodate ATC needs. This represents an additional challenge for TM, especially if during taxi operations under low visibility conditions the pilot needs to be head-down loading a new route and checking that it makes sense. Here, the risk is in over-utilizing a feature that adds to workload and TM for the pilot if there isn't more automation involved in loading the new routes.

According to at least one airline representative, prior to the introduction of CPDLC, voice communications were never trained at his airline. Items like how to deal with all of the background clutter of voice communication was learned in on-the-job training. With the implementation of CPDLC, data comm is at least being trained at some airlines. For example, since early CPDLC was often implemented via Multi-function Control and Display Units (MCDUs) and the interface was not always intuitive, training had to be performed in the use of the messages. However, pilots may now need more training in the domestic environment for the combined use of data comm and voice communications.

## 7.2.2 More Precise Navigation Requirements and Higher Efficiency Routing

As more complex and reduced-separation paths are being implemented, the pilot task of monitoring airplane navigation performance may take on an increased amount of focus. Much of this monitoring will be done using displays rather than just out-of-the-window monitoring. In addition, NextGen precision approaches will require increased use of automation in order to achieve timing and separation requirements. Both additional monitoring of displays and the increased use of automation will have an impact on TM.

## Summary of Issues and Gaps:

- Increased use of displays for monitoring other aircraft during visual approaches
- Increased monitoring of automation used to fly more precise flight paths
- Increased emphasis on 4-D trajectory introduces additional pressure on TM with more precise monitoring of more parameters.
- Redistribution of workload across different phases of flight means TM may change over

different phases of flight as compared to today.

• Overall increased workload in some emerging procedures will impact the crew's ability to manage tasks.

## Examples:

For some procedures like Simultaneous Offset Instrument Approaches (SOIA), which is in use at San Francisco airport, there is an increased need for pilots to monitor the path of other aircraft to ensure that any "blunders" are identified in a timely manner. While these approaches are done visually today, in NextGen pilots may need to rely more on displayed information to supplement or replace out-thewindow views. This situation will add pressure to TM in trying to integrate both an out-the-window view and the information portrayed on visual displays on the flight deck.

While NextGen promises to eliminate the complexity of step-down approaches, some of the constant descent approaches are being made more complex in terms of lateral navigation and decreased separation with other aircraft. More complicated paths impact TM by requiring additional monitoring during these types of approaches and monitoring to ensure adherence to tighter path accuracy requirements as well as monitoring other aircraft with greater accuracy. Complications increase when pilots using Global Positioning System (GPS) navigation also need to pay attention to items like Required Navigation Performance (RNP). While employed today, monitoring of RNP is another task that needs to be included in the pilot's ability to navigate in emerging airspaces.

The potential increased use of automation in NextGen is not in and of itself a risk; however, the way pilots monitor the status of the automation as well as the intent of the automation does become another challenge to TM. How will the pilots learn to filter and prioritize information such that they can take-over when appropriate? The pilot role may become increasingly one of a flight deck manager in NextGen; so, how will this new role be trained? Will training provide the required proficiency and knowledge to use (and effectively monitor) the automation for this role? Lyall, et al. (2011) specifically investigated the training vulnerabilities that are expected with NextGen. One of the findings from this report was that the increased use of automation in NextGen is one of the primary gaps in training cited by the experts interviewed. They also stated that there will be more opportunities for automated system failures and increased interactions of systems. Both of these represent TM vulnerabilities within NextGen.

In addition to more complex paths that allow for increased arrival capacity, NextGen is also predicted to see the increase of 4-D trajectory requirements with an increased importance on achieving time constraints. This adds more items to monitor and prioritize for aviating and navigating tasks, and how required time of arrival constraints are managed impacts TM.

While certain flight deck displays may add significant situation awareness for speed and altitude, these same displays offer yet another source of information that pilots must now manage in their overall scan and information management flow. In addition, according to Sheridan (2009) the use of these 4-D trajectory clearances are more formalized than existing "readback-hearback" style communication techniques and will be less flexible near assigned deadlines close to airports, thus increasing workload and requiring good situation awareness between multiple roles (crew and controllers).

Another potential challenge area is the use of concepts such as dynamic airborne reroute procedures in higher workload situations. With this concept the operator's dispatcher can identify a more beneficial route for an aircraft while in-flight by making use of real-time wind and temperature data. The dispatcher then uplinks the new route to the aircraft's FMS via company data comm. The pilots load the new route and make sure it appears sensible. Then however, to meet regulatory requirements, the dispatcher uplinks a new version of the flight plan that the pilots received prior to departure. The pilots print this flight plan and check through it for new notices to airmen (NOTAMs) and significant meteorological information, alternate airports, extended operations data, equal time points, etc., then compare the route, point by point, inter-point distance by inter-point distance, with the values in the FMS legs pages. Assuming the two received flight plans are consistent, the crew then sends an acceptance downlink to the dispatcher, and then downlinks the new route to ATC as a route request using CPDLC. If ATC approves the route, the pilots load the cleared route into the FMS as a modification of the original route and check point by point that it is consistent with the requested route. If the clearance agrees with the request, the pilots send an acceptance downlink, and finally send a company data comm message to the dispatcher indicating ATC approval. Clearly, this sequence of activity represents significant potential for increased workload for the pilots. Where it has been implemented in trans-oceanic flights, it has not been an issue; however, when implemented in domestic operations, the additional workload may negatively impact TM in a higher workload domestic airspace environment. With the introduction of 4-D trajectory-based operations (TBO), it is likely that such reroutes for weather, traffic congestion, or operator benefit may become common, and would likely represent a new challenge for TM.

## 7.2.3 Increased Availability and Use of Surveillance Displays on the Flight Deck

Many of the concepts emerging in NextGen entail the use of new types of surveillance displays such as electronic airport map displays and various forms of cockpit display of traffic information (CDTI) displays for depicting Automatic Dependent Surveillance - Broadcast (ADS-B) equipped airplanes. Time based flow management (TBFM) is a key component of NextGen to increase the efficiency of the NAS. The pilot's ability to perform interval management is key to expanding the benefits of TBFM. While TBFM will achieve NAS efficiencies, it also requires additional pilot tasking for planning and executing interval management procedures. For example, the use of ADS-B applications for interval management represents new and different pilot tasking requirements. While these new ways to achieve interval management may actually reduce pilot workload as route clearances can be given earlier and with more consistency, there is a redistribution of workload likely to occur with more communications and more navigation data entry occurring early. Hence this redistribution of the timing of these tasks needs to be accounted for in concepts of operations.

New types and applications of surveillance displays using ADS-B In data represent a significant step forward in presenting pilots with visual information that gives them more awareness of the overall airspace situation. These new displays can be considered analogous to the moving map/navigation displays implemented in the first generation of glass flight decks. However, while these displays may present information more intuitively, pilots now have new emergent and (sometimes) unintended capabilities that may impact TM. Depending on how intuitive these displays are, the risk to TM is likely to be minimal yet as the amount of information increases on surveillance displays, the impact on information management rises with a corresponding effect on TM. Regardless of how intuitive the presentation of ADS-B In data is, it still represents new tasks that pilots must manage. In some cases, tasks that were solely relegated to ATC are now becoming part of pilot tasking.

### Summary of Issues and Gaps:

- New surveillance displays increase pressure on information management and hence TM
- The introduction of new tasks will impact TM
- The increased use of displays for monitoring other aircraft during visual approaches will impact TM

#### Examples:

In oceanic operations, in-trail procedures are a tool pilots use to plan and receive approval for an altitude change during the cruise phase of flight that would not be permissible without ADS-B equipped aircraft. Initial revenue flight tests in the Pacific have shown the value of this capability from an efficiency perspective. While it is an example of a new task that pilots take on during a very low workload phase of flight, it also represents another task that pilots must now learn and manage.

A recent study on in-trail procedures (Cardosi and Lennertz, 2016) related that pilots using the ADS-B traffic display in trans-oceanic operations found several new and novel uses for these displays. New uses include being able to identify and call other aircraft ahead of them for turbulence reports, help for routing around convective weather, and examining the traffic situation ahead of them to strategically manage their airspeed to avoid holding as they approached a busy airport. While these unintended uses of ADS-B traffic displays in and of themselves can be perceived as advantageous, they represent an increased vulnerability in terms of TM. Without guidance or procedures about how and when to use or not use this information, pilots risk getting distracted with this new source of information.

Another potential ADS-B CDTI application related to interval management includes CDTI assisted visual separation. The operational concept of CDTI assisted visual separation is to assist pilots to acquire and maintain visual contact with a leading aircraft while performing a visual separation on approach procedure in VMC. If visual contact is lost, the CDTI is used to maintain separation and alert pilots when spacing is less than minimum safe spacing. With this new way of monitoring traffic, the pilot's task of visual spacing when delegated by ATC as "traffic to follow" remains the same; however, the way "visual" separation is achieved changes. This operational concept requires new information sources for the pilot to monitor and integrate, adding to the tasks the pilot needs to manage during a high workload phase of flight. Consequently, this example highlights an opportunity for additional TM training in order to maintain safe operations.

Another type of display format with a potential impact on TM is the use of synthetic vision systems and synthetic vision guidance systems (SVGS) for low-visibility operations. The potential impact on TM for this element includes new ways to portray data as well as new methods for integrating data. Also expected will be new requirements and procedures for the use of SVGS.

## 7.2.4 Increased Integration of Various Sources of Information

Even today, with the advent of portable electronic displays (PEDs) for airlines and pilots, more off-board information is becoming available to pilots. While the provision of more information is a step forward in giving pilots a heightened awareness of the overall mission situation, it brings additional challenges for TM. Additional information must be managed. The move from paper to electronic representation of information brings about the need for new techniques to interface with the information; the use of sticky-notes, bookmarking, and highlighting in the paper medium is not necessarily available in electronic presentation methods. As new information is brought onto the flight deck, how and where that data should be treated and trusted may become more complex. Pilots need to know how to manage information and information flow (this is elaborated on in Finding 13 in chapter 8). In today's operations pilots need to understand the trustworthiness of the various sources of information. However with increased integration of "operationally approved" with "certified systems" information sources, pilots may need a better understanding of the differences between data sources in order to manage and interpret the information appropriately, especially where there might be conflicts.

### Summary of Issues and Gaps:

- The ability to adequately manage as well as understand the trustworthiness of new and different sources of information represents a potential vulnerability to TM.
- The ability to adequately manage information across multiple display types represents another vulnerability to TM.

#### Examples:

In NextGen especially, pilots have access to both on-board weather radar as well as weather data broadcast from the ground and other meteorological information. How does the pilot manage these different sources of information? For example with on-board weather radar, the timeliness of the data is well understood. For off-board weather, the timeliness of the information is less clear. How do pilots manage understanding the meaning of off-board weather information in terms of its timeliness and hence pertinence to the mission? And how do pilots integrate this new source of information with on-board weather radar information?

In NextGen, the System-Wide Information Management concept will make "unlimited" information available for dispatchers and pilots to determine better courses of action during normal, rare-normal, and non-normal conditions. This adds a layer of decision-making and situation awareness achievement to the pilots' tasks in what may already be a trying situation. Again, these sources of information may enhance overall situation awareness, but they are a further challenge to managing and prioritizing information. In addition, pilots may be required to understand the integrity and/or source of the information, especially where two or more sources are in conflict. As Lyall et al. (2011) report, "Management of multiple sources of information that are similar will become more important as well. The pilots will need to be able to know how to compare the information from different sources and how to manage it and act upon it appropriately." Multiple sources of information require the pilot to shift attention among the different sources and allocate heads down attention to review the information, and they impose an additional comparison task. New types and sources of information will clearly impact TM because pilots will need to manage the tasks of attending to, processing, and integrating this information.

As the propensity for not just allowing but requiring PEDs and other forms of electronic display of information increases, there will need to be a change in how pilots manage information because of how it is presented on these new devices. On a positive note, the ability to move this information to electronic presentation represents an opportunity to better integrate information as well as update it in real-time. The introduction of more electronic display and interactivity with the information also represents an opportunity to help pilots manage the information flow and tasks performed when there are disruptions or multiple tasks must be accomplished with asynchronous inputs. A good example is during pre-flight where a number of asynchronous tasks and disruptions must be managed and executed successfully prior to airplane push-back.

At the same time, the strategies used for managing paper-based information are not the same as for electronic based information. For instance, today pilots make many notes on paper and add bookmarks such as paperclips and sticky notes to paper information to facilitate retrieval. These techniques are not necessarily available for electronic versions of the same information and can be a challenge in managing electronic information. In addition, paper information from various sources is often spread out in different locations across the flight deck to help manage and integrate the information needed to execute the mission. With the move towards electronic displays, that same information is often time-shared on the same multi-function electronic display, potentially representing an increase in both workload and information management. Consequently, along with the benefits of moving from paper to electronic display and interactivity, vulnerabilities may also be introduced.

The integrity and accuracy of information on a PED may be different than that presented elsewhere on the flight deck. However, this difference in information integrity and accuracy is already present on the flight deck today; pilots need to understand the accuracy, timeliness, and accuracy of paper information such as charts, NOTAMs and weather forecasts. In almost all cases, information expected to be presented on PEDs merely represents moving the display of supplemental information from one medium (paper) to another (electronic).

The vulnerability to TM is not the introduction and proliferation of PEDs, but rather the increase in types of information presented to pilots. The use of PEDs may increase how many differing data sources pilots will need to handle however the fundamental task of dealing with dissimilar information already exists. Pilots deal with dissimilar sources and conflicting information today but additional vulnerabilities may emerge with the potential increased amount of integration of this information.

## 7.2.5 Mixed Equipage and Air Space Operations across an Airline's Fleet

The move to NextGen will not be a discrete shift but rather a gradual transition. Current operations will exist in parallel for a long period of time, which will complicate many types of procedures pilots need to contend with. The complex arrivals and departures, runway changes, direct-to-marker clearances, etc. envisioned for NextGen have the potential to add workload to pilots that will impact TM.

### Summary of Issues and Gaps:

- New airspace categories and arrival procedures may put pressure on TM as pilots learn these new procedures and how to use the required information to execute them.
- Pilots will likely operate under different procedures and tasks as they operate in different air spaces, putting pressure on how to manage changing operations.

### Examples:

The plan for NextGen is to incrementally apply changes across the NAS. Such changes mean that airplanes flying in different regions of the airspace will be flying under multiple procedures and operations. From a TM perspective, the new procedures and/or tasks that may require new information management and information scanning strategies may be utilized one day and then not seen again for some period of time. In the interim, the previously learned procedures and tasks will again be employed. The vulnerability of this scenario is that the TM strategies will need to account for the intermixing of these different procedures and tactics for executing the procedures. The vulnerability is not so much on TM itself, but rather on the components of TM such as workload and information management.

The introduction of new airspace categories (e.g., performance-based airspace) has the potential to confuse pilots who must deal with different operating rules at different times. In addition, international differences in ATC equipage and airspace procedures will introduce another set of challenges and require en route transitions from one set of pilot responsibilities to another. Again, this represents a challenge as different TM strategies may need to be employed within each operating environment—one more item that pilots must remember and manage.

The other aspect of mixed equipage/operations that may have an impact on TM is the fact that differences in airplane equipage will probably lead to airplanes being handled differently by ATC, thus requiring different TM strategies. Not all aircraft of the same type in an airline's fleet will have the same level of equipage; pilots who fly airplanes with different levels of equipage for NextGen operations, therefore, will need to employ different TM strategies depending on the equipage of the airplane.

Of course, both of these aspects occur today as pilots fly around the globe in different air traffic management environments and airplanes of the same type sometimes have different capabilities as new functionality is retro-fitted across an airline's fleet. However, to the degree that NextGen represents significant change, these differences will be exacerbated during the transition phase of NextGen.

## 7.3 Summary of Emerging Vulnerabilities

## 1. New Procedures -

The addition of new procedures introduces new tasks that will be added to those tasks that already need to be managed. This includes new responsibilities for planning and maintaining interval management. As well, for some period of time, pilots will face issues of both mixed equipage and mixed use of procedures as the new airspace evolves.

## 2. Airspace Procedure Complexity -

The potential impact to TM for this element is the generation of instrument procedures that will require new or different pilot monitoring methods as well as new ways of communicating and sharing information between controllers and pilots. Also included here is the uncertainty of how specific approaches will be conducted, especially when last-minute approach procedures are initiated by air traffic controllers. And finally, these more complex flight paths will lead to the increased reliance on and use of automation that must be monitored.

## 3. Monitoring, Understanding and Managing New Information -

The introduction of new sources of information such as uplinked weather and ADS-B In information while valuable for planning, introduces new information management strategies that can impact TM. The use of electronic information such as that presented on PEDs also requires different strategies for managing information as compared to paper versions of the same the information again impacting TM. PEDs can either help or hinder the pilots' understanding of how to integrate dissimilar information from different sources and hence can either help or hinder TM. With increased integration of "operationally approved" with "certified systems" information sources, pilots may need a better understanding of the differences in characteristics among various data sources in order to manage and interpret the information appropriately, especially where conflicts might arise.

In general, these vulnerabilities related to TM already exist today, but they are exacerbated by some of the concepts expected in NextGen operations. Hence, in the findings and recommendations section there are few, if any, recommendations identified that are specific to these emerging issues. Rather, by implementing many of the recommendations, the above vulnerabilities will be mitigated.

# 8. Findings and Recommendations

## Finding 1. Crew dynamics create interaction patterns that can disrupt TM.

The interaction patterns between the two pilots can have a role in disrupting TM by not balancing task loading, interrupting or distracting each other, not communicating, or doing unexpected actions. This finding is evidenced by the following observations.

- Pilots need to establish a clear plan for the division of workload for the flight in their initial briefing. Pilots who had difficulty working together especially suffered with coordination and keeping the workload balanced when the workload was increased.
- One pilot interrupting the other pilot's tasking occurred when one pilot asked for confirmation of something he or she is doing or asked the other pilot for information to support his or her task, without being sensitive to the other pilot's attentional focus.
- When a pilot was confused or something did not seem right, the pilot did not engage the other pilot in helping to rectify his or her understanding.
- TM is disrupted when one pilot's task is not complete and the other pilot pushes forward with another dependent task. One example involved the PF still reviewing the arrival, and the PM started doing the checklist. This divided the PF's attention between two mission critical tasks.
- The actions of one pilot have TM consequences for the other pilot's tasks. For example, an FO edited the flight plan and deleted the arrival which dropped the performance targets from the FMS. This resulted in an over speed condition that surprised both pilots. The pilots need to understand about task dependencies and interactions.
- Doing a task the other pilot does not expect or doing tasks out of sequence without discussing it can result in a disconnect between pilots leading to confusion and impact on the other pilot's task performance.

## Recommendations:

- Training should foster a global understanding of TM concepts like crew and task interaction, timing, and dependencies.
- Pilots should be trained:
  - About the negative effects of interruptions, and should learn techniques to either delay interruptions when possible, or to get another crew member's attention in more subtle or nonintrusive ways (e.g. "I have a question when you're ready...")
  - To know how to perform their assigned tasks individually as well as jointly to maintain safe and efficient operations.
  - How to coordinate their actions with that of the other crew member and communicate with each other about current and predicted status.
- Procedures should be designed to organize the task flow such that tasks requiring a resource (information or attention) are done with focus and without concurrent tasks.

### Finding 2. Communication patterns facilitate TM performance.

We identified communication practices that fostered shared-awareness of aircraft status, task status, and flight path management status. These included both verbal statements and gestures. However, operators generally did not train these kinds of communication practices. Defining communication practices to support TM could be useful for coordinating action. Direct speech was a specific technique that pilots reported was effective for bringing a pilot back into the loop when they became fixated or task saturated. Some phrases that pilots used effectively include the following:

- "See it, say it," was a common technique used to check important information. It was used to correct errors when one pilot read an altitude restriction off a chart at 6800 ft. the other pilot said "I see 8600."
- "No changes" was used to communicate there was no change to flight path or clearances after one pilot went offline to do another task or went to the lavatory.
- "All set" was used as a way to indicate the aircraft configuration tasks or flight path management tasks were completed and set as expected.
- "I'm done" was used to inform the other pilot they had concluded a task the other pilot was waiting for them to complete and was a way to indicate to not interrupt the pilot until so stated.
- "No MELs" was used to share there were no MELs for that flight segment.
- "Top of page" followed by the page number, was used to indicate which page a change was being made to the flight plan. A common error observed was to edit the flight plan with a directto clearance that was entered on the wrong page of the flight plan. By giving the page number the PF and the PM could check to ensure that the direct-to clearance is entered on the correct page and hence at the correct point in the route.
- When checking the current task and to ensure someone is managing the flight path pilots would announce their understanding of what the other crew member was doing and what they themselves were doing and asked for confirmation, "You're still flying the jet and I'm on the arrival." The PF responded "I'm flying."
- "You good?" or "Are you green?" were interrogations to the other pilot about their status, either task loading or task progression or fatigue, etc. It was used as a quick way to ask them if they needed help.
- "On speed" was used by the PM to support the PF and assure energy state of the aircraft is being monitored.
- The PM would read the clearance while the PF confirmed it on the MCP with a gesture of pointing to the window where the targets were entered.

All operators expressed the need for PM training because each operator experienced regular weekly or monthly events that would have been prevented if the PM had intervened. These events included low airspeed, stick shaker, landing on a taxiway, and low altitude vertical deviations. To facilitate awareness of the other pilot's workload and fatigue status, two operators had developed their own internal models to support pilot-to-pilot communication of their status. They use colors to represent levels of task saturation or fatigue such as green for "I'm good" and red for "I need help." These models had become part of the airlines' operating cultures and were used effectively among the pilots we observed.

## Recommendations:

- The FAA in conjunction with a joint industry-government standard committee should develop a standard language for pilot communication that operators can adopt and train to support TM and crew coordination that goes beyond traditional in-flight call outs. This would standardize operations and facilitate a meaningful interaction independent of personalities or cultures.
- Airlines should develop communication models similar to those we observed being used effectively among the pilots. Examples include the use colors to represent levels of task saturation or fatigue such as green for "I'm good" and red for "I need help.
- There is a need to train pilots to work as a team. In contrast to typical CRM training, this training should provide guidance on how to share task load, how to interact and communicate, and how to dynamically manage workload, disruptions, and tasks. Training should take a holistic approach that treats the flight deck as a system with pilots as subcomponents in that system who team to manage the flight. Each pilot would be performing their role as PF or PM to jointly reach the objectives of the operations. This perspective shift from pilots as individual contributors to pilots as a team within a system may facilitate PM intervention if the operation does not progress as planned. This training should:
  - Specifically identify areas where explicit task coordination is required such as verifying and understanding the flight path.
  - Train pilots to prepare for high task loading phases of flight with teamwork, task allocation, and time management.
- Conduct a follow-on study to develop and evaluate effective communication models for pilot coordination that was observed at two operators.

## Finding 3. Anticipating tasks facilitates task flow.

The ability to anticipate tasks was observed as a means to effectively support the PF and to keep the task flow moving in well-performing crews. Anticipating tasks included proactively taking actions to reduce task loading, establishing accurate mental models, and keeping the pace or timing of tasks on track. The anticipation of tasks, the context, and thinking through upcoming tasks and events is helpful for creating an accurate mental model of the upcoming flight segment and anticipating how it is going to progress. The creation of a mental model enables the crew to build expectations about the flight and how to plan for it. New information is assimilated into that understanding and the plan is continuously updated.

• Examples included the PM holding the checklist or announcing upcoming tasks needed to get the airplane down after being held high by ATC.

• Pilots we interviewed reported thinking about their upcoming flights at least a day in advance. They monitor the weather at the airports in the regions where they will be flying and they apply their local knowledge of how the flight typically progresses along those routes. For example, the pilots all knew at which airports ATC would typically issue a runway change, last minute vectors to final, or keep them high, speed them up or slow them down. By the time the flight crew arrives at the airport they have developed a nominal plan for how the flight will progress.

## Recommendation:

• Include the concept of task anticipation and ways to achieve this in training programs.

## Finding 4. Procedures and policies influence TM by establishing what tasks to do, their priority, their allocation, and when to do them.

When procedures are developed in isolation of each other, they may overlap, not integrate into the operation, and over-task pilots' cognitive resources at critical phases of the flight or during critical tasks. Some examples of problematic procedures and policies that affected TM include:

- Policies that require pilots to perform checklists while the aircraft is in motion on the ground add to cognitive workload by dividing attention between navigating and guiding the aircraft on the surface and performing the checklist. A good example of this is single-engine-taxi-out policies that require starting an engine while taxiing out and then doing the before takeoff checklist while the airplane is in motion. We understand that single-engine taxi out serves company economics however procedures and policies should be designed to support these policies and place all safety critical items on a checklist prior to moving the aircraft (such as the Before Taxi Checklist). We observed no issues with single-engine-taxi-in procedures.
- Normal Checklists are subject to "item creep." It is easy and tempting to solve operational issues by adding an item to a normal checklist. There are human performance issues associated with long normal checklists, or broken checklists, and operators should strive to keep normal checklists short with only safety critical items.
- NextGen airspace procedures add complexity and workload to pilot tasks. Common issues
  included the procedures being partially implemented so that pilots would be on the arrival
  procedure for part of it then taken off or slowed down, then receiving vectors or being asked to
  rejoin.
- Arrivals with unclear intercept points can result in extensive time and effort dedicated to setting up an otherwise simple arrival.

## Recommendations:

- Airlines should:
  - Review procedures for their fit into the operational task flow and ensure procedures do not conflict with other procedures or critical tasks.
  - Keep normal checklists short and design them using published human factors guidance.
  - Design operational procedures so that the task loads between the PF and PM are balanced through all phases of flight.
- The FAA should verify that NextGen airspace and flightcrew procedures are implemented in a way that does not over task the pilots or the controllers.
- Air traffic controllers should have an appreciation for pilot workload on flights into and out of busy airports with complex procedures to understand how challenging flying these procedures can be for pilots.
- Procedures and policies need to be designed to support pilot attention, memory, tasking, and
  information flow, with inherent flexibility so that tasks may be dynamically reallocated or shifted
  in time and so the procedures support the pilots' actions across all flight contexts. For example,
  one operator we interviewed has a single-engine-taxi policy that disproportionately burdens the
  PM and impacts TM performance during taxi.

### Finding 5. Review and define non-technical skills.

The definition and training of non-technical skills is inconsistent across operators. CRM and TEM concepts serve as a basis for nontechnical skills training but several operators have moved the focus to risk management because it combines CRM and TEM and includes other concepts such as recognition-primed decision making and risk assessment. The CRM and TEM guidance should be modernized and to include advances in cognitive science and expertise research. While risk management is a beneficial concept to include in training and can facilitate TM performance, in the training we observed it neither addressed TM explicitly nor included discussion of cognitive vulnerabilities that impact TM.

### Recommendations:

- The FAA should:
  - Assign a working group to modernize non-technical skills training. This effort could also be included in follow-on work to this study.
  - Update their non-technical skills definitions so there is a standard from which operators can develop effective training to resolve the variation in definitions and uses of non-technical terms and concepts.
- Airlines should train pilots in understanding how human vulnerabilities may impact their capability to effectively perform the TM activity. These include the narrowing of attention, monitoring, prospective memory, cost of task switching, biases, etc.

#### Finding 6. Pilots need a broad base of knowledge, skill, and strategies to effectively manage tasks.

TM is a cognitive activity that relies on knowledge and expertise. A pilot needs extensive knowledge of operational tasks, the time needed to complete a task, the pace of the airline's operation, and what tools are effective to manage task load and allocation in different contexts. Understanding operations in terms of high workload periods of the flight, local variations and idiosyncrasies at particular airports and terminal areas as well as knowledge of how to use task resources especially the automated systems (see Finding 7) is extremely beneficial for aiding TM performance. Effective TM requires pilots to have a meta-understanding of the tasks themselves, their characteristics, required resources to complete them, time needed to complete them, and interdependencies.

#### Recommendations:

- Airlines should:
  - Assess their training programs to ensure pilots can develop the meta-knowledge they need for effective TM in training. This includes knowledge of tasks, allocation, task interactions, resource needs, and timing.
  - Define task priority so that it is clear to pilots which tasks have priority in which contexts.
- A follow on task could define TM knowledge requirements.

# Finding 7. Effective flight path management depends on TM and operational understanding of automated systems.

The traditional "aviate" task is being increasingly thought of by the industry in terms of flight path management and monitoring. Pilot knowledge of the flight management modes and how they control the aircraft may be incomplete or inaccurate, which may lead to surprise and confusion that could disrupt TM. In particular, pilots need knowledge and understanding of vertical and lateral trajectories, energy states and how the automated systems fly them. Pilots need to have a comprehensive understanding of the auto flight modes, what they do and how they control the airplane across the flight regime. Inadequate knowledge of the systems leaves the pilots vulnerable to surprise or confusion that can disrupt the timeline and flow of tasks and can lead to flight path deviations.

### Recommendations:

- Airline policies should recognize that automation is a tool and is not required to be used at all times. Pilots may need to use less automation when they become confused by it or if it adds workload.
- Managing the flight path needs to be the focus of automation training. Pilots need to recognize there is always a flight path, whether it is flown by the pilot or the automation and that managing and monitoring it is the highest priority task. Operators should develop flight path management training that focuses on the operational use of both automation and manual flying for managing the flight path including vertical and lateral trajectories, as well as energy management.
- Specific scenarios should be defined by the training and flight operations departments to allow crews to practice flight path management skills in simulator sessions to engage in deliberate and exploratory practice of the flight management modes and how they control the aircraft across operational situations when they are in training so they are less likely to be surprised in a way that could disrupt task flow and priority.
- Training should also focus on enabling pilots to develop manual flying skills and be comfortable in disengaging the flight management automation or in reducing the level of the automation being used. Flying an aircraft manually can be a demanding task requiring significant cognitive resources to perform and may increase the pilot flying's workload to the point where the

distribution of workload and task allocation may become unbalanced and result in inappropriate task priority or shedding.

- Establish industry standards for automation terminology and behavior. Automation functionality and nomenclature vary across the avionics manufacturers and pilots have to know and remember the differences in capabilities between the different products. These differences can increase workload when a pilot is attempting to do a task in the way they were trained but the device on the aircraft is from a different manufacturer and functions differently.
- Research should be conducted to define and assess appropriate automation training for flight path management that includes strategies for effective TM.

#### Finding 8. Operational factors can make TM challenging.

Pressures of the operating environments contribute to TM challenges and many are out of the control of the pilots. The operational environment can lead to disruptions that interfere with effective TM. For example, long checklists, complex procedures, procedures that require concurrent tasks, and complex ATC clearances all impact TM.

#### Recommendations:

- Human cognitive vulnerabilities should be factored into procedure design as well as an
  operational factors that might disrupt their completion to ensure the procedures fit into the
  operator's flight operations. For example during high stress situations a pilot may experience
  the narrowing of attention, a reduction in working memory capacity, or may miss important
  cues. Procedures should be designed to be resilient to these kinds of vulnerabilities by
  presenting appropriate content that is understandable and by formatting the content to be
  usable under stressful situations.
- Procedures, policies, and checklists need to be designed to support TM and be evaluated to ensure they do so.
- The FAA should ensure the controllers understand the TM challenges they introduce into the flight deck when they issue late runway changes, complex clearances, or take pilots off an RNAV approach and do not let them fly as is.
- Pilot training should include:
  - How to be able to manage disruptions and keep the global perspective in mind balancing the local with the global operation.
  - How to become skilled at dynamically rebuilding a mental model of the arrival once they are taken off of it.
- Airlines should:
  - Establish clear task priorities to support decision making and management of operational pressure. When possible use Flight Operational Quality Assurance data and ASAP reporting to understand the pressures, time management issues, and develop ways to address them in operations and training.

 Provide guidance on task priority and train pilots to effectively switch between tasks and monitoring the flight path so that flight path status is always checked after they do a different task. Include information and TM strategies that enable pilot to engage in other actions (such as using charts, EFBs, ACARS, etc.) while also effectively monitoring the flight path and airplane energy state.

# Finding 9. Each flight has periods of high and low task loading and pilots can use that structure to anticipate and plan tasks.

On every flight there are expected periods of high and low task loading. We observed effective task management by pilots who used this structure of expected high and low task loading to allocate tasks and distribute workload and to manage dynamic task allocation. Successful organizations are thoughtful about specifying in procedures and policies who does what and when.

Recommendations:

- Develop a task loading map across flights using operational data and use this map in training to teach strategic task planning and allocation. For example provide pilots with a representative set of the flights they will be flying and identify where predictable periods of high, medium, and low workload appear in the flight. Identify tasks that are critical and require dedicated attention.
- Provide training for methods to deal with periods of low and high workload. Examples of what pilots need to know as part of this training includes:
  - What risks and tasks are important and why in order to help prioritize them.
  - What tasks may be dropped or deferred when task loading is high.
  - What tools to use for which task and information needed for specific tasks.

# Finding 10. Training does not adequately replicate the task management needed in the actual work environment.

Many training elements in simulator sessions are not experienced in realistic real-time, but are compressed. As a result of the simulator session time manipulations, pilots reported in debriefs after real operational events that they were surprised about how long it took to handle conversations and coordinate with other people. All operators agreed that pilots need training on how to focus on the timing of different pieces of the time management process, and they need to define policies that specify what to do. For example pilots need to understand how to control the pace of the operation and that rushing due to an incorrect perception of the time required to perform tasks can result in errors.

#### Recommendations:

Airlines should strive and regulators should recommend that pilot training be operationally
representative and simulate the operational environments especially with regard to the timing
of events or the time it takes to do a task (such as manual gear extension). Simulator sessions
should preserve real-time scenarios so that pilots obtain an accurate understanding of how long
a maneuver will take in the operating environment and how long it will take to coordinate
activity with others.

- Airlines should train how to manage the *timing* of different pieces of the time management process, and they need to define policies that specify what to do.
- Training should provide pilots with an opportunity to develop practiced skill in a non-jeopardy training setting.

# Finding 11. Pilots need attention management training on monitoring time critical and mission critical tasks.

On any flight, pilots have to divide attention between tasks and they need supporting tools and strategies to manage their attention. In order to achieve this it is helpful to define the time-critical tasks and mission-critical tasks and tasks that require a pilot's focused attention for each phase of flight. In addition, parameters that need to be monitored to simultaneously control and monitor the flight path and to do required concurrent tasks should be identified. This creates a "task-based scan" in which a pilot integrates information for the task in meaningful chunks that can be done. This allows the pilot to then switch to another concurrent task, perform the scan for it and then move back to the primary task starting with the scan for that task. For example, if the primary task is to monitor the flight path, before moving to a separate task the pilot does a scan of altitude, airspeed, flight mode annunciations, pitch, and power. The task-based scan can be used for those tasks that are dynamic so that when the pilot returns to the task after switching from another task or after being interrupted he or she has a scan pattern to apply that may also provide resilience to change blindness, i.e., the pilot's not being able to detect changes that had occurred since the last scan.

#### Recommendations:

- Pilots need to know how to monitor the automation to ensure it is doing what is expected and anticipate what it will do next. This could be an additional task scan pattern that should be developed and trained.
- Pilots should be trained to:
  - Manage their attention and how to allocate their attention between tasks. This should include effective scan patterns for modern flight decks specific to time and mission critical tasks.
  - Sample information at a rate that creates an internal clock so that if their attention is diverted from a critical flight path management task an unease develops in the pilot that serves as a cue to focus attention back to the defined "task scan" parameters. Operators should define sampling rates between time- and mission-critical tasks for cases where attention is divided. The purpose is to create an internal clock for the pilot to trigger awareness of long periods of lapsed attention to mission and time critical tasks.
- Know how to dedicate attention and regular sampling to the management and monitoring of the flight path. Pilots need to know which tasks require full focused attention at what times. This could be when in high threat environments (e.g., crossing a runway) or during high threat situations (e.g., windshear on final) or while executing tasks themselves (e.g., performance data entry).

# Finding 12. Task saturation occurs when a pilot has too many tasks to do, the task is too difficult, or there are other pressures on task performance leading to improper task prioritization.

Improper task prioritization occurs when pilots remain focused on a lower priority task even through a higher priority task is present. When pilots attempt to complete the task they are doing before moving to the higher priority task it can result in less time available for the higher priority task and errors. Pilots need to understand how crew interactions affect task load and priority, how to recognize when they or the other crew member are becoming task saturated, and respond appropriately. The lack of training in dynamic task prioritization strategies leads pilots to develop their own techniques which may not be effective.

#### Recommendations:

- Airlines should define tactical task priority for normal operations.
- Training should address effective management of emergent events. When these events occur, pilots should have the knowledge and skills to assess and prioritize emergent events among their current tasks and decide to either respond to them or to delay addressing the disruption. Real-time decision making is an important part of the process that also warrants further investigation.
- Further study is needed in this area.

#### Finding 13. Pilots need to know how to manage information and information flow.

The training we observed on information management, especially between tablet EFBs and the installed devices did not specifically address operational use and effective management strategies. In addition as part of NextGen more information pertinent to the flight will be available to the pilots. They need to know how to manage the flow of information but also when and how to access and assimilate information for task performance, as well as understand the trustworthiness of the source of various information.

#### **Recommendations:**

- Airlines and regulators should ensure the "apps" used on personal electronic devices such as tablets meet stringent usability requirements and present information in a way that does not distract or confuse, e.g., information provided on PEDs should be easy to find and interpret.
- Pilot training should include where information will come from at what times and how to access information and assimilate it into the operations. Part of this training should focus on the characteristics, including the trustworthiness, of various types of information.

#### Finding 14. Pilots need to know how to manage time and think of time as a resource.

The operators we interviewed and observed all had some kind of training on time management. Most of these were informal modules on what operators refer to as "creating time" or "good use of time." and are strategies for using time as a resource. "Creating time" involves changing the aircraft speed or trajectory to enable pilots to complete required tasks. Strategies to "create time" included: slowing or stopping the aircraft, entering a hold, requesting vectors, etc. "Making good use of time" involves doing tasks during low periods of task loading so more tasks are accomplished ahead of their planned

#### schedule.

These creating or good use of time strategies are used to essentially develop a strategic vision for accomplishing upcoming flight tasks and organizing the timing of those tasks so they can be accomplished without over tasking either pilot. Doing this requires the pilots to know the periods of high and low workload for their operation so they can plan tasks during low workload periods (see Finding 9).

#### Recommendations:

- Train pilots to control the pace of the operation so they do not get rushed unnecessarily.
- In training focus on the timing of different pieces of the operational process. Airlines should give pilots structure to know what to focus on when so that they can complete the airline prioritized tasks and know which tasks may be shed when time is limited.
- During training sessions (especially LOE/LOFT sessions) operators should preserve the timing of tasks, non-normal events, and coordination with people (external to flight deck or aircraft) so that pilots have an accurate understanding of the time it will take in the operational environment to do tasks and coordinate resources. (See Finding # 10.) Items in this training should include the following:
  - $\circ$  ~ Use time as a resource to manage tasks so you do not get overloaded.
  - How to manage events: focus on how to time activities, how to fit events into time, and set priorities.
  - How to manage change in plans and situation.
- Airlines should instill a culture of discipline and professionalism to ensure that what pilots learn in training regarding TM is actually done in the field.

#### Finding 15. Instructors need training on how to train and evaluate TM.

Our observations concluded that while all operators train various components of TM, none of them explicitly or comprehensively train it. We also observed many missed opportunities by instructors to illustrate both good and ineffective TM performance and behaviors during simulator sessions..

Recommendations:

- Since TM is an important overall piloting task, trainers should be trained themselves in how both to train and evaluate TM during training sessions.
- As part of "training the trainer", the following items should be considered:
  - o Introduce TM during initial training to instill the expectation to develop this skill.
  - TM evaluation should be done in context of LOE/LOFT where scenarios unfold in real-time and pilots are required to manage time without the benefit of freezing the sim or accelerating time.
  - TM training scenarios should include disruptions to assess how pilots manage them (defer/ignore/switch to emergent task; how well they resume interrupted task).

- Instructors should time disruptions to assess prioritization during flight path monitoring periods of vulnerabilities.
- TM constructs need to be simplified so instructors can readily identify good/bad TM practices during LOE/LOFT and immediately provide feedback.
  - E.g. periods when neither pilot is monitoring flight path
  - Not managing disruptions at the cost of flight path monitoring
- Training/Procedure: instill bias to complete long tasks before starting some emergent/interrupting task; longer tasks are particularly susceptible to flight path monitoring failures.

### Finding 16. Pilots need training on how to monitor.

Although the industry has identified effective monitoring skills as an issue, pilots are still left to develop their own strategies. Since monitoring is such an important task that must be managed, this is an area where further work is needed; how to effectively develop and maintain the skills to monitor. Because knowledge and attention are closely linked, building a strong foundation of knowledge in training is critical to effective monitoring.

Recommendation:

• Conduct further study to determine how to train pilots to do a better job of monitoring as a task rather than as a role.

# 9. Proposed Validation Methods

The findings of this report are based on a review of literature and accident and ASRS data as well as interviews, observations, and jump seat observations at a limited number of airlines. The recommendations, however, are the result of an analysis of the vulnerabilities based on the findings. It would be beneficial to conduct a validation of the proposed solutions as well as how to evaluate the implementation of the recommendations. The validation proposals in this report focus on shorter term validations (one- to two-year time frame). Longer term validations will not be addressed in this report.

There are several techniques for conducting shorter term validations. One method is to conduct structured interviews with subject matter experts (e.g., flight crew instructors) to obtain their inputs on the practicality of implementing the training and/or procedure solutions into their operations. In addition the structured interviews could also seek their input as to how effective they think the proposed solutions might be and if they perceive the solutions as addressing some the gaps their current training and/or procedures have related to task management. This is the lowest cost but also lowest fidelity type of validation. But it could be done in the shortest period of time.

A second type of methodology is to conduct empirical studies in simulators. This would entail soliciting line pilots to participate in a study that would employ the new training or procedure solutions. The pilots would first be evaluated on a number of performance tasks in a simulated environment. Then they would be given the new training or procedures after which they would be again evaluated on a number of performance tasks employed would all look to stress task management performance and different scenarios would need to be utilized in the pre- versus post-solution sessions as this study assumes a within-subjects design. Which scenarios to use pre- and post-solution sessions would be counter-balanced across pilots. This would be a higher cost study due to the use of simulators and the time required for line pilots to participate.

A third type of validation would involve working with one or more specific airlines who are willing to implement some or all of the proposed solutions at their airline. Two possible means of measuring the effectiveness of the proposed solutions are possible. The first would entail structured interviews with the line pilots and training instructors after the solutions have been implemented to obtain their inputs on how effective the solutions are perceived to be in handling task management. Specific task management scenarios would be used to elicit their inputs on the effectiveness of the solution. The positive of this technique is that it attempts to evaluate the effectiveness of the solutions after they are actually employed. Another means of assessing the effectiveness would be to conduct jump seat observations both before and after the solutions are implemented to determine if the solutions resulted in any differences in how pilots perform. Both of these validation techniques (structured interviews or jump seat observations) are the most costly methods but would give the highest degree of validation. This method would also take the longest period of time to execute as an airline would need to implement the solution before any evaluations could be done.

A variation on the above would be to combine one of more of the above methods. That would give the best validation results as a wider variety and number of participants could be included.

# **10. References**

Cardosi, K. and Lennertz, T. (2016). "Progression of Human Factors Considerations for the In-Trail Procedure". Prepared for: US Department of Transportation, Federal Aviation Administration, Human Factors Division (ANG-C1), 800 Independence Avenue SW, Washington, D.C. 20591

Chou, C. C. & Funk, K. (1990). Management of multiple tasks: Cockpit task management errors. In: Proceedings of the 1990 IEEE International Conference on Systems, Man, and Cybernetics, pp 470 – 474. Piscataway, NJ: The Institute of Electrical and Electronics Engineers.

Chou, C. C., Madhavan, D., & Funk, K. (1996). Studies of cockpit task management errors. The International Journal of Aviation Psychology, 6(4), 307-320.

Clark, A. (2008). Supersizing the Mind: Embodiment, Action, and Cognitive Extension. New York, NY: Oxford University Press.

Eurocontrol (2005): Initial Communications Operating Concepts And Requirements For The Future Radio System. Eurocontrol/FAA Future Communications Study Operational Concepts and Requirements, January 2005.

Flight Safety Foundation (2014). A Practical Guide to Improving Flight Path Monitoring. Final Report of the Active Pilot Monitoring Working Group, November 2014.

Funk, K. (1991). Cockpit task management: Preliminary definitions, normative theory, error taxonomy, and design recommendations. The International Journal of Aviation Psychology, 1(4), 271–285.

Funk, K., Suroteguh, C., Wilson, J., & Lyall, B. (1998). Flight deck automation and task management. In Systems, Man, and Cybernetics, 1998. 1998 IEEE International Conference on (Vol. 1, pp. 863–868).

Hutchins, E. (1995). Cognition in the Wild, Cambridge, MA: MIT Press.

Letsu-Dake, E., Rogers, W., Dorneich, M.C., & De Mers, R. (2012). "Innovative Flight Deck Function Allocation Concepts for NextGen", Advances in Human Aspects of Aviation (S.J. Landry, Ed.). Boca Raton, FL: CRC Press, pp. 301-310.

Lozito, S., Verma, S., Martin, L., Dunbar, M., and McGann, A. (2003). The Impact of Voice, Data Link, and Mixed Air Traffic Control Environments on Flight Deck Procedures. 5th USA-Europe ATM Seminar, Budapest, Hungary. Retrieved from http://www.atmseminar.org/papers.cfm?seminar\_ID=5

Lozito, S. A., McGann, S. A. and Corker, K. (1993): Data link air traffic control and flight deck environments: Experiments in flight crew performance. In R. E. Jensen and D. Neumeister (Eds.), Proceedings of the 7th International Symposium on Aviation Psychology. Columbus, OH: The Ohio State University, 1993, pp. 1009-1015.

Lyall, B., England, R., Harron, G., Hoffa, B., Jones, E., Lyall, M., Taylor, S., & Wilson, J. (2011). "Flight Crew Training for NextGen Automation Final Report" Research Integrations Incorporated report prepared for: Federal Aviation Administration, Office of the Chief Scientific and Technical Advisor for Human Factors.

Noe, A. (2004). Action in Perception, Cambridge, MA: MIT Press

Performance-based operations Aviation Rulemaking Committee/Commercial Aviation Safety Team Flight Deck Automation Working Group. "Operational Use of Flight Path Management Systems: Final Report of the Performance-Based Operations Aviation Rulemaking Committee/Commercial Aviation Safety Team Flight Deck Automation Working Group." Performance-based operations Aviation Rulemaking Committee/Commercial Aviation Safety Team Flight Deck Automation Working Group, September 9, 2013.

Rogers, W.H. (1996). Flight deck task management: A cognitive engineering analysis. Proceedings of the Human Factors and Ergonomics Society, Philadelphia, PA.

Shelton, K., Prinzel III, L., Arthur III, J., Jones, D., Allamandola, A., and Bailey, R. (2009). "Data-Link and Surface Map Traffic Intent Displays for NextGen 4DTand Equivalent Visual Surface Operations." NASA Research Report, NASA Langley Research Center, Hampton, VA, USA 23681.

Sheridan, T.B. (2009). Human-automation interaction in NextGen. Paper presented at the 80th Annual Scientific Meeting of the Aerospace Medical Association, Los Angeles.

Trist, E.L. & Bamforth, K.W. (1951) "Some Social and Psychological Consequences of the Longwall Method of Coal-Getting: An Examination of the Psychological Situation and Defences of a Work Group in Relation to the Social Structure and Technological Content of the Work System." In: Human Relations, 4, pp 3 – 38.

UK CAA (2013). Monitoring Matters - Guidance on the Development of Pilot Monitoring Skills: CAA Paper 2013/02. Paper produced by the UK CAA Loss of Control Action Group.

U.S. Department of Transportation (1996). Benefits of Controller-Pilot Data Link ATC Communications in Terminal Airspace. Report Number: DOT/FAA/CT-96/3, U.S. Department of Transportation, Federal Aviation Administration, William J. Hughes Technical Center, Atlantic City International Airport, NJ 08405

# **Appendix A: Full Literature Review**

In this appendix the literature related to TM is categorized under five topical areas:

- Allocation of Tasks between Pilot Flying and Pilot Monitoring
- Management of Information
- Management of Attention, Interruptions and Workload
- Task Management: Switching between Tasks
- Cockpit Task Management Errors

Each topical area contains a description of the relevant literature, a summary of the findings related to that literature, and the specific references. Note that the references in this appendix do not necessarily appear in Section 11 "References" of the main document.

# A.1 Allocation of Tasks between Pilot Flying and Pilot Monitoring

### A.1.1 Description of Relevant Literature

Crew task management, including proper prioritization and allocation of tasks between crewmembers remains a critical factor in flight safety. In a review of NTSB and ASRS reports (Chou, 1996), task management errors occurred in 23% of the accidents (79/324) and 49% of the incidents (231/470) reviewed.

The commercial flight crew is typically comprised of two ranks: (1) the Captain, who is ultimately responsible for the aircraft and is "in command" throughout the flight; and (2) the FO, who is subordinate to the Captain. Traditionally, pilot tasks are grouped into three prioritized categories— "aviate" (flight control), "navigate" (awareness of where the aircraft is and where it should be) and "communicate" (coordination with air Traffic Control (ATC)). A lower priority function, "manage systems" is also described by some authors as the fourth level in the hierarchy of tasks, involving interaction with engine, hydraulics and fuel systems. At any given time, both Captain and FO may perform many of the sub-functions within these categories (Damos, 2001; Cahill, 2014). However, the crewmember with the primary responsibility for the "aviate" task is known as the Pilot Flying (PF), and the other crew member, whose responsibilities include radio communications, display interaction, managing systems, and verbalizing checklists, is known as the Pilot Monitoring (PM). The PF and PM roles are often swapped between the Captain and FO, particularly on multi-leg or long-haul flights.

Because "aviate" tasks are the highest-priority tasks in the flight deck, the understanding of who is performing which role is the most crucial aspect of CRM for supporting task management. Pilots will commonly transfer authority for the PF role by announcing, "I've got the aircraft", at which time the non-flying pilot assumes the tasks typically associated with the PM. But when one of the pilots becomes workload-saturated, lacks the necessary expertise to perform a task, or does not have the time to complete a task, there is a need to delegate tasks in the safest and most efficient manner. Implicit in the assignment of individual flight tasks are several key factors pertaining to the crewmembers themselves (Funk, 1999; Johnson, 2012; Cahill, 2014):

• Current role (PF or PM);

- Visual, auditory, physical and cognitive workload resources required/available;
- Temporal constraints;
- Proper knowledge and expertise; and
- Acceptance of responsibility/willingness to perform the task.

Often, airline operational procedures and workflow descriptions prescribe a working method of task allocation between crewmembers which fails to consider each of the factors above (Cahill, 2014). For example, if SOP requires the PM to perform a systems checklist, but the FO acting as PM has little to no experience with the aircraft platform, it might make sense to swap roles and free up the Captain to verbalize the checklist, assisting the FO in completing checklist tasks. In addition, frequent interruptions often prevent the pilots from completing a task fully in the order in which it is prescribed (Damos, 2001). Finally, pilots may be unable to execute a procedural step at the point at which it occurs in the written procedures, either because the larger situation makes it inappropriate to execute at that moment, or because the necessary information is not yet available. An interesting note from a CRM perspective is that the PF is required to annunciate his intentions and actions to the PM at all times; as a result the PM is often interrupted from the critical task by responding to and supporting aviate tasks (Shutte, 1996).

To learn how pilots manage task allocation and interruptions in real-world scenarios, Damos (2001) collected data from turboprop and jet aircraft over a 9-month period on 4 different airlines. 788 "events" (categorized as ATC, flight attendants, and TCAS/automatic warnings) were recorded over 33 flights. Only unanticipated events were recorded (an expected response from ATC after a routine call, for example, was not recorded). The main goal of the task interruption analysis was to determine "if specific events differentially interrupted certain activities". Also examined was the impact of cockpit automation, FAR type, and crew size on the frequency of interruption. Seven major categories of cockpit activities were: briefing, performing a checklist, activities related to personal comfort (eating/drinking), cockpit communication, monitoring, programming and "housekeeping" (which encompassed a variety of activities including adjusting displays, reading and writing). Table A-1 shows frequencies of occurrence and interruption of activities by event type.

Activity	Categories of Events							
	ATC		Flight		TCAS		Automatic	
			Attendant				Warning	
	Freq <sup>1</sup>	Int <sup>2</sup>	Freq	Int	Freq	Int	Freq	Int
Briefing	2	2	1	1	0	0	0	0
Checklist	21	21	0	0	1	1	4	1
Personal	7	7	2	2	0	0	0	0
Housekeeping	120	62	4	0	1	0	11	2
Communication	53 <sup>3</sup>	30	1	1	1	0	8	2
	(51) <sup>4</sup>	na	(10)	na	0	na	(5)	na
Monitor	371	na	9	na	2	na	43	na
Program	3	2	1	1	0	0	0	0
Total	628	124	28	5	5	1	71	5

#### Table A-1 Frequency and Interruptions of Activities by Type of Event

<sup>1</sup>The number of observations

<sup>2</sup>The number of observations that were interrupted

'The number of observations in which the pilot not flying was talking or making an

announcement to the cabin

<sup>4</sup>The number of observations in which the pilot not flying was listening.

The only significant difference in the analysis of interruption probabilities was between ATC communications and checklists, where ATC was given a higher priority over checklists. Interestingly, there was no significant difference in the probability of task interruptions between ATC and housekeeping, ATC and TCAS/warnings, or TCAS/warnings and "housekeeping" tasks. The authors suggest this could be an issue of statistical power, however the data suggest that TCAS/warnings were prioritized below "housekeeping" tasks. On several occasions, although the PF was not evaluated, the author noted that the PF would perform activities which were not part of his/her assigned duties because the PM was otherwise engaged.

To optimize their own task assignments, flight crews may use a number of strategies. Schutte & Trujillo (1996) observed pilot performance to identify and analyze their strategies for personal task management as well as monitoring (as defined by Funk's Cockpit TM procedure: "assess current situation", "assess progress and status of active tasks"). Several task management strategies were observed:

- Aviate-Navigate-Communicate-Manage Systems (ANCS): Attention prioritized in sequential order with little regard for the context of the situation
- Perceived Severity: Highest priority placed on greatest perceived threat
- Procedure Based: Prioritize tasks with more well-defined procedures
- Event/Interrupt (E/I) Driven: Priority/attention given to a task based on an event or interruption

Results showed the "Perceived Severity" or "E/I Driven" strategies were most effective for personal task management, combined with the "ACNS" strategy for monitoring. This combination of strategies resulted in fewer errors and faster response times.

Automation in the flight deck changes physical work into cognitive work, and plays an important role in the type of tasks presented to the crew. Dynamic task allocation allows changing the allocation of tasks between crew and automation in response to the state of the operators, system or environment. Researchers (Johnson, et al., 2014) have evaluated nominal and off-nominal written procedures and suggested how to optimally implement dynamic task allocation to human or automation agents.

Several researchers (Chou, et al., 1996; Funk & Braune, 1999) have advocated for the introduction of computational aids to passively assist the pilots' awareness of pending tasks and prioritization. These applications employ algorithms and sensors to measure system state and assess crew task load. Chou specifically introduces a computational aid called the Cockpit Task Management System (CTMS), which is a passive engagement system that would perform the following functions:

- Maintain a model of aircraft state and cockpit tasks
- Monitor task state and status
- Compute task priority
- Remind the pilots of tasks in progress
- Bring attention to tasks that are being neglected

Funk takes this research a step further, introducing a construct known as "Agenda Management", which is defined as a superset of task management, managing the higher level functions involving both humans and machines to accomplish goals and missions on the flight deck. Funk proposes a distributed, multi-agent system, also referred to as Distributed Artificial Intelligence (DAI), which uses functional analysis and object oriented design principles to model the functional processes on the flight deck, and to facilitate proper task allocation and real-time task management monitoring. Future research should be aimed at the dynamic assessment of crew workload to inform and support the computational aids.

Process mapping workshops, interviews, and observations were conducted with both pilots and flight operations personnel from five airlines, as part of the Human Integration into the Lifecycle of Aviation Systems (HILAS) project, sponsored by the European Commission (Cahill, et al., 2014). Flights are characterized by different levels of operational and environmental complexity. The different operational and environmental problems experienced by crew impacts, specifically, (a) task workflows, (b) time on task, (c) task complexity, and (d) task workload.

Researchers broke down the hierarchy of piloting tasks into processes, sub-processes, and associated flight phases, and conducted a task analysis to understand the management of information and task workflows in the context of the flight crew as well as the broader context of the "operational team" (including the cabin crew, ground operations, ATC, etc.) (Figure A-1).



Figure A-1. Flight Crew Task - Active Flight Operations Process

The authors' proposed sociotechnical model represents a shift from a local explanation of Flight Crew task activity to a broader process-centric explanation.

Few, if any, researchers have addressed the use of agents to aid in the process of dynamic task allocation specifically between the two human (crew) agents. This may be due to the fact that the factors described above are constantly changing and need to be subjectively assessed by the pilots themselves in order for decision-making to be effective. In addition, due to the nature and importance of the "aviate" tasks, the FAA requires verbal acknowledgement of the PF role between pilots, so there is no misunderstanding regarding who is responsible for flying the aircraft at any given time. Future research should aim to create SOPs for safely implementing dynamic task allocation between pilots.

In a part-task simulator study (Chou, et al., 1996), scenarios were created to evaluate 3 IVs: Resource requirements (visual, manual and mental workload) based on the W/INDEX model, maximum number of concurrent tasks, and flight path complexity. They evaluated task management performance as defined by task initiation (average response time), number of late task initiations, a binary assessment of prioritization, and RMS navigation errors (deviation from flight path). The results found task initiation times and prioritization errors were significantly impacted by the pilots' resource requirements. They also found prioritization errors significantly impacted by the combination of task saturation and complexity.

An important topic to consider in the discussion of task management between crewmembers is the drive toward the goal of Single Pilot Operations (SPO). Johnson, et al. (2012) summarized findings of a NASA Technical Interchange Meeting (TIM) addressing issues related to SPO and the introduction of a ground-based crewmember performing many of the PM tasks. The authors described the need for moving to SPO and briefly discuss the findings of a cross-industry research project attempting to address task management issues. Three options were discussed: one was a simple single-pilot operation with no outside assistance, another was a single-pilot assisted by a dispatcher or member of the cabin crew, and

the third was the air-ground flight crew concept.

Several potential task management issues related to SPO were addressed:

- Automation will need to adapt to SPO, and could potentially result in loss of pilot SA as well as skill degradation,
- TBO in which ATC assigns a precise, synchronized route, 4D trajectory to the pilot, may impose greater workload on the single pilot (whereas in the current system, weather-based deviations are relatively simple, less stringent, and typically involve only heading and/or altitude changes),
- Pilot incapacitation in relation to improving medical examinations, tightening certification requirements, and introducing real-time physical monitoring devices, and
- Potential for boredom from the lack of social interaction with another crew member in the flight deck

The researchers suggested the best option for SPO would be air-ground distributed teaming. There may also be options for introducing a third party crewmember. For example, the Airline Operations Center can accept Aircraft Communications Addressing and Reporting System (ACARS) information and handle strategic weather re-routes thus alleviating some of the peak workload of the single pilot. Additionally, a distributed human crewmember may be better and faster than the flight deck systems in assessing pilot incapacitation. The optimal allocation of tasks as well as CRM and the loss of visual presence of the distributed crewmember (body language, facial expressions) should be assessed.

### A.1.2 Summary of Findings

- 1. Crew task allocation must consider a number of factors pertaining to the crewmember, including role, resources and time available, workload, experience and acceptance.
- 2. Proper CRM should ensure that pilots understand aircraft state and status, task state and status, status of queued tasks and the prioritization strategy.
- 3. Efforts should be focused on evolving pilot training to include proper CRM and error avoidance, as well as developing formal task management SOPs.
- 4. Computational tools may be effective for aiding crew task allocation. Future research should focus on developing algorithms and sensors to measure system state and assess crew workload.
- 5. The most effective strategies for personal task management include "Perceived Severity" (placing priority on the highest perceived threat) and "Event/Interruption Driven" (placing priority on interrupting tasks based on an event). The "Aviate-Communicate-Navigate-Manage Systems" strategy works best for monitoring task status and progress.
- 6. Flight task initiation times and prioritization errors are significantly impacted by crew workload resources as well as the combination of task saturation and complexity.
- 7. Flight deck task management should also be evaluated in the broader context of the distributed "operational team".
- 8. SPO will require fast, predictable and efficient allocation of tasks between the pilot, automation

and distributed crew. Existing automation will need to adapt to SPO, and could potentially result in loss of pilot SA as well as skill degradation.

## A.1.3 References

Cahill, J., McDonald, N., & Losa, C. G. (2014). A sociotechnical model of the flight crew task. Human Factors: The Journal of the Human Factors and Ergonomics Society, 56(8), 1337-1363.

Chou, C. C., Madhavan, D., & Funk, K. (1996). Studies of cockpit task management errors. The International Journal of Aviation Psychology, 6(4), 307-320.

Damos, D. L., & Tabachnick, B. G. (2001). Cockpit task prioritization: Jumpseat observations. Los Angeles: Damos Research Associates.

Funk, K., & Braune, R. (1999). The Agenda Manager: A knowledge-based system to facilitate the management of flight deck activities (No. 1999-01-5536). SAE Technical Paper.

Johnson, A., Oman, C., Sheridan, T., & Duda, K. (2014, March). Dynamic task allocation in operational systems: Issues, gaps, and recommendations. In Aerospace Conference, 2014 IEEE (pp. 1-15). IEEE.

Johnson, W., Lachter, J., Feary, M., Comerford, D., Battiste, V., & Mogford, R. (2012). Task allocation for single pilot operations: A role for the ground. HCI-Aero 2012.

Schutte, P. C., & Trujillo, A. C. (1996, October). Flight crew task management in non-normal situations. In Proceedings of the Human Factors and Ergonomics Society Annual Meeting (Vol. 40, No. 4, pp. 244-248). SAGE Publications.

# A.2 Management of Information

# A.2.1 Description of Relevant Literature

For the purposes of this literature review, we are defining "information management" as the flight crew's understanding and usage of existing information presented via communications, displays and aeronautical charts. We do not address flight deck automation nor the accessibility of information using highly automated systems.

Electronic technologies such as EFBs, interactive navigation, and e-checklists have recently pervaded and replaced paper documents in many commercial flight decks. In the flight deck, display space is limited, but a key advantage to displays is the elimination of paper weight. It is important to understand how the transition affects pilots in planning and flight operations. Some advantages of paper include ease of manipulation, flexibility of spatial layout, direct marking, quick glance, and physicality. Hutchins, et al., (2006) conducted an observational analysis of pilots' interaction with paper information. Jump seat observations, interviews and video were collected from select commercial carrier revenue flights (777, 747, 737) and simulators (777) across three different airlines. The authors analyzed pilot behavior well prior to the preflight operation, observing paper charts, operations manuals, printouts and notes being carried by crew through the airport and/or given to the crew by dispatchers and maintenance personnel. Paper supplements were used to support weight and balance calculations and preflight checklists, even when e-checklists were used. During flight, the ACARS generates small paper

printouts with pertinent real-time information. Scratch pads were used to take notes from verbal information given to the pilots by dispatchers, maintenance personnel, ATC, etc. Pilots used paper and pencil to write down ATC clearance information in shorthand, allowing for timely recording and read back.

Pilots reorganized the paper layout dynamically throughout the flight based upon task context (i.e., charts relevant to the current phase of flight are most easily accessible) but the basic layout appears in Figure A-2.



Figure A-2. Spatial Layout - Paper Use in the Commercial Flight Deck

Throughout the flight, paper plays important roles in the following areas:

- Communications from dispatch, tower and ATC,
- Supporting preflight briefings,
- Manual entry of data from various sources into the Flight Management System (FMS),
- Confirmation of verbal messages
- Note-taking for read back and/or personal use
- Personalization of relevant information
- Translations of critical information to native language

According to the authors, from a sociotechnical perspective, "current practices involving paper documents help to establish and maintain social relations and personal identities." The key performance benefits of using paper in the flight deck are:

- **Tangibility** The physical aspect of paper supports the reliability of information flow, awareness of task flow and promotes an understanding of who has responsibility for tasks
- **Customizability** Allowing the pilot to personalize paper documents improves situation awareness, enhances comfort, allows for efficient read back of controller communications, supports native language and provides a clearer understanding of the critical elements of each

document

• **Portability** – Because they are portable, paper documents support a continuous availability of information and allow pilots to work and study their flight plans in the terminal, on the jetway, and even at home so they are better prepared for flight.

Loukopoulos, et al., (2003) challenge current workflow descriptions proposed in many airline SOPs, specifically during taxi-out operations. Observing multiple flights from the jump seats of two major airlines, the authors evaluated their task performance with respect to the airlines' written guidance and training materials. Pilots often perform concurrent tasking and are frequently interrupted, forcing them to interweave, suspend, and defer task components. The most pervasive forms of concurrent tasking for the PM involve monitoring systems concurrently with the activities of the PF.

They also analyzed ASRS incident reports and identified several specific cases related to concurrent tasking. Some examples of incidents related to task/workflow interruptions are described below:

#### Summary of ASRS incident report #289346:

A FO executing the pre-takeoff checklist during taxi was interrupted by an unexpected warning signal (a thrust reverser light). Troubleshooting and resolving the problem took a few moments, during which time the ground controller continued to issue traffic sequencing instructions. The FO monitored the taxi progress and switched radio frequencies to the tower frequency. When the captain **prompted him to resume the checklist**, he did so but **inadvertently omitted an item** (setting the flaps to the take-off position.). When the crew attempted to takeoff the configuration warning horn sounded, and the crewhad to abort the takeoff.

#### Summary of ASRS incident report #263589:

A crew neglected to set the flaps for takeoff after having deliberately deferred that action due to snow accumulation on the taxiways. Once in line for takeoff they became busy discussing a problem they had encountered earlier with the APU. A sudden and unexpected instruction from Tower placing them next for takeoff triggered the crew to rush to complete a wing contamination inspection and the below-the-line part of the checklist, inadvertently omitting the above-the-line items and, thus, not setting the flaps.

#### Summary of ASRS incident report #414686:

During taxi a FO discovered that his earlier calculations of performance data for the planned takeoff runway had been based on the wrong flap setting. In the course of **rechecking** if the aircraft would be too heavy for takeoff from the particular runway, he **failed to adequately monitor** the captain, who taxied past the hold short line.

The authors created a graphic to illustrate the full range of errors pilots have committed during taxi-out operations (Figure A-3). The left and right columns (grey) describe, from top to bottom, the flow of prescribed taxi activities for each of the crew members. The overlaid boxes (white) contain information about the error, the contributing factors, and the resulting outcome for each of selected incident reports.

	itted call for flaps -rushed to clear ramp/gate area for arriving aircraft -aborted takeoff FIRST OFFICER
Ask for flaps Ask for taxi clearance	Started taxi without clearance - trouble-shooting problem with engine start - Request taxi clearance - Request taxi clearance
Monitor radios Receive taxi clearance Form mental picture of	Started taxi without clearance - rushed by other aircraft waiting to pull into gate; radio congestion; marshaller's headset inoperative - query by ground controller         Monitor radios
Check for obstacles Start taxiing	CA taxied without having fully understood instructions – busy looking at other aircraft on taxiwa yand ramp – ground controller issued warning Check for obstanloo
Perform PDF TAKEOFF	Started taxi without clearance – crew discussing taxi instructions -struck pushback tug
(above line) Incorrectt	iow <u>Perform</u> PRL-1 AKEOFF flow
Failed to	above line)
Ask for PRE-TAKEOFF c	hecklist cupied with new departure clearance and packs-off operation -aborted takeoff
Monitor radio. <sup>E0</sup> failed to Monitor traffic Omitted Maintain positional and situational awareness	o monitor CA - bus y checking and correcting calculations of load data - taxi past hold short line flaps - crew discussing problem with APU, delayed flaps due to snow - aborted takeoff Monitor radios F0 failed to monitor CA - bus y with flow; night taxi - taxi in wrong direction Flaps incorrectly set, missed noticing during checklist - crew bus y with fuel problem, runway changes, programming FMC - aborted takeoff
Confuse own position on t studying NOTAMs runway	axiway diagram – new terminal; F0 failed to monitor CA –runway change; busy Checklist complete change – taxied into ditch reprogramming FMC –taxied past intended taxiway
Monitor Tower Fail to	Omitted checking reason for bleed air indicator light-busy with delayed engine start and checklists - takeoff without troubleshooting         Monitor aircraft movement           confirm flap position - evaluating heavy rain showers; rushed to         Receive clearance
Receive clearance acce	ttakeoff dearance -aborted takeoff
Omitted checklist – bus ywith	incoro consignitation of the second s
Omitted flaps – checklist in	terrupted by thrust reverser light; crew busy troubleshooting -aborted takeoff (below line)
Perform PRE-TAKEOFF ( (below line)	Iow         Misunderstood Tower instruction - new F0 on IOE, CA coaching F0 -         (Delow line)           taxi onto runway w/o clearance
	Flaps incorrectly set – late paperwork and runway change; programming FMC; short Start checklist taxi; rushed to accept takeoff Checklist complete
Line up with runway	Omitabove-line Checklist-running late,         Omitted flaps-checklist interrupted           checklist interrupted by Tower, unexpected         by Tower, crew rushed to accept           dearance for takeoff-abort takeoff         takeoff dearance-aborted takeoff
	TAKEOFF

Figure A-3. Errors Associated with Concurrent Task Demands from ASRS (Loukopoulos, et al., 2003)

Information management on the flight deck involves the organization of current tasking and timely, relevant supporting information. Typical workflows can differ across pilots based on their training, expertise, SOPs and other factors. The pilot's mental model and natural workflow are key factors in task management and interruptions during flight. Hankers, et al., (2013) looked at the potential for using a mobile aid to facilitate efficient pilot workflows for long haul flights.

The goal of pilot workflow is successful completion of the flight. Hankers breaks down the pilot's workflow taxonomy into two elements:

- Activity The smallest step regarded, every action taken by the pilot as part of the work flow.
   Ex.: Conduct a performance calculation.
- Process The combination of linked activities to realize a given goal which defines functional roles and relationships between activities.
  - Ex.: Conduct a flight from departure to destination.

Fundamentally, an activity is a step required to continue a process. The authors analyzed ATP workflow across all phases of flight and developed a tool known as the Workflow-Driven Mobile Device Pilot (WDMP), which supplements the FMS, providing a timely and user-friendly delineation of the tools and information required for duty, flight planning, flight management and monitoring as well as for

procedural flight deck activities. A screenshot of the WDMP UI (currently in development) appears in Figure A-4.



Figure A-4. Initial workflow-driven WDMP UI (Hankers, 2013)

By using tools such as the WDMP, the pilot has a one-stop consolidation of supplemental information, situational awareness of where s/he is in the process of completing the current task, and concise information about expected next tasks in the workflow.

Solodilova-Whiteley and Johnson (2006) investigated the representation of flight operations, the flight environment and the "hidden nature of the information needs" of pilots during flight. The authors believed that traditional analysis methods do not adequately capture the complex, dynamic information flow that occurs within the modern flight deck. Instead, they took a more objective and evolutionary approach to analyzing pilot behavior, employing a real-time video capture via head-mounted camera, followed by a 'cued-recall-debrief' interview (in which the pilot watches captured video with the researcher while answering questions about the flight). Their research was conducted with several flight crews using a full-motion, complete (power-up to power-down) 15-20 minute flight simulation. Participants were asked questions regarding how information was gathered, stored and applied throughout the flight operation.

The analysis supported the authors' view that (1) information flow in the aircraft environment is dynamic and time-critical, where current events are affected by past and present events and in turn affect subsequent events and (2) the information is also dynamic, constantly changing and dependent on evolution of all events. Pilot interviews and video further revealed that the information pilots use is connected to other pieces of information via an 'information structure' which pilots align with the timeline/phases of flight, in order to maintain flight path and the required aircraft behavior. Pilots also use 'information strategies' (such as scanning instruments, monitoring systems, or referencing pre-briefed information) to update and generate new references in order to keep up with evolving information.

As a result of the analysis, a model emerged illustrating how pilots acquire and use information (Figure A-5). It shows how information is coming from many sources, is constantly changing, and being affected by events throughout the flight. Additionally, the model shows that the pilots have stored 'referenced information', 'information structures' and 'information strategies', which are regularly used and evolve.



Figure A-5. Evolution of Flight Deck Information Flow (Solodilova-Whiteley and Johnson, 2006)

The authors recommended that the design and layout of information in NextGen flight deck interfaces should support the structures and strategies pilots actually use, instead of inventing new ways of presenting information.

Navigational information presented in aeronautical charts is a key consideration when it comes to information management for NextGen flight operations. As charted procedures become more and more streamlined and adaptable to heavy traffic operations, the charts themselves have become increasingly complex. Flight procedures delineate task management for the PF throughout the most workload-intensive phases of flight.

Chandra and Grayhem (2012) looked at ways to simplify/clarify Performance-Based Navigation (PBN) operational procedures such as RNAV including RNAV RNP. (RNP is RNAV with the addition of onboard monitoring and alerting capability.) Figure A-6 depicts three different approach types: conventional, RNAV, and RNP.



Figure A-6. Comparison of Three Instrument Approach Types

These procedures must be flown precisely for improved use of airspace and safety. In addition to lateral precision, they often have tighter vertical (altitude) constraints as well. An example of an instrument approach versus an RNP chart for KBOI (Boise, Idaho) appears in Figure A-7.



Figure A-7. Left - Localizer Backcourse Runway 28L at KBOI; Right - RNAV (RNP) Z Runway 28L at KBOI (Chandra, 2010)

Research (Barhydt & Adams, 2006; Chandra & Grayhem, 2012) suggests various methods for the charting of visually complex procedures, such as:

- Using unconventional graphical techniques to optimize the presentation of all appropriate information within limited available space (including use of a larger sized chart format)
- Separating (i.e., splitting out) the information across more than one chart, and

• Removing (i.e., omitting) "less important" or "contingency" information from the chart based on the needs of the specific intended user (e.g., aircraft type or available equipment).

Chandra, et al., (2012) conducted an experiment which separated complex RNAV RNP approach and RNAV SID procedure paths across pages to simplify and de-clutter the procedures. There was a large and statistically significant improvement for finding information from the modified charts in the study. For approach charts, particularly, pilots saved just over 6 seconds on average with the modified (simpler) charts. They saved 3 seconds on average with the modified SID charts. The authors noted some charts are simple enough that there may be no benefit to separating into multiple pages. Additionally, there are practical disadvantages of separated pages and having more paper to carry in the flight deck (or more charts to choose from in a database).

Further analysis was conducted to determine how some elements related to difficulty of use, such as the number of flight paths on approaches and SIDs, and the total number of altitude constraints on STARs (Chandra, et al., 2012). The authors compared 2 sets of RNAV and RNP procedures – baseline versus "problematic" (overly complex) sets.

This analysis found that:

- Problematic approach procedures had more flight paths, path segments and RF legs
- SID problematic procedures had more flight path combinations (all possible based on entry and exit points)
- STAR problematic procedures had more total altitude constraints and path segments

Butchibabu, et al., (2010) reviewed a large group of ASRS reports involving RNAV and RNP procedures. Of the 285 reports identified in this review, 202 pertained to departures, 69 pertained to arrivals, and 14 pertained to instrument approaches. As seen in Figure A-8, of the 202 departure-related reports, 175 involved lateral deviations (87%). For arrival procedures and approach procedures, deviations in the vertical domain were more frequent. Thirty reports out of the 69 arrivals (43%) and 12 out of 14 (86%) approach procedure deviations were in the vertical domain.



Figure A-8. Frequency of RNAV Deviations by Type (Butchibabu, 2010)

The authors found that issues with RNAV procedures have a complex combination of factors related to air traffic operations, pilot interpretation of procedures, and procedure design challenges related to aircraft automation and charting. Figure A-9 represents frequencies of procedural design issues identified across all the reports.



Figure A-9. Frequency of RNAV Chart Design Issues (Butchibabu, 2010)

Being regulatory in nature, instrument approach procedures and Obstacle Departure Procedures (ODPs) have little flexibility in their design and use (Butchibabu, et al., 2012). In contrast, STAR and SID procedures are not regulatory and can be modified by ATC in day-to-day operations as needed.

Through discussions with expert users, literature reviews, and focused reviews of the NASA Aviation Safety Reporting System (ASRS) database, researchers (Barhydt & Adams, 2006) attempted to document RNAV-related human factors issues and propose areas for further consideration. The authors categorized types of issues as described below:

- ATC procedures: terminology, phraseology, timing of clearance information, inter-facility coordination
- Airline Operations: training, company procedures, pilot actions, airline/flight deck communication
- Aircraft System Capabilities: equipment availability and performance, path tracking, mode transitions, navigation database.
- Procedure Design and Charting: waypoint proximity, use of waypoint constraints, interference with non-RNAV procedures, chart clutter

Major findings suggest the need for specific instrument procedure design guidelines that consider the effects of human performance.

Future ATC controller-pilot coordination under NextGen will have more shared information, automated tools and communication complexity. Researchers have begun to identify (Poage, et al., 2011; Hartmann, 2013) specific data management requirements and human factors issues with NextGen ATC coordination and TBO procedures. Research focused on developing functional requirements for the ATC controller workstation to support NextGen data communication technology. Poage, et al., (2011) conducted what they referred to as a "soft systems analysis", so-named because it is a structured human-systems analysis of a system with somewhat ill-defined or not easily quantified aspects.

In the process of determining requirements for the new system, the authors identified key human factors activities to support workstation design requirements for the ATC controller – most of which can also be considered in flight deck design for the pilot. These include, but are not limited to:

- Determining the criteria necessary for a prioritization scheme (e.g., flight time or fuel efficiency); developing and evaluating the prioritization scheme
- Determining when and how the user should be alerted to a conflict and presented with related resolutions
- Determining levels of alerting based on criticality
- Examining effects of false and nuisance alerts on user trust
- Examining acceptability (so that the user will be comfortable with and trust advisories)
- Determining the optimal location on the display for advisories
- Determining the type of presentation (e.g., graphical versus textual)
- Determining the acceptable number of advisories to display
- Examining the time required to review a complex clearance and determining whether it will interfere with other tasks
- Evaluating the ability of the user to recognize an error in a complex clearance, as compared to

clearances with a single maneuver; assess how this error recognition rate affects operations; and identify ways to assist error recognition (e.g., highlighting small changes in a trajectory)

• Evaluating the potential for an change in the duration of controller-pilot communications and the impact of this change on performance (e.g., effect on multi-tasking, likelihood of errors)

The ATC controller sends message to aircraft via text-based data communication technology. The authors identified key human factors activities to support design requirements for data communications. These include, but are not limited to:

- Comparing flight deck response times to complex clearances issued by voice versus text to understand how differences may affect operations
- Determining the best procedure for a controller to remind a clearance after sending it to the flight deck
- Determining how to identify messages that require further attention if not closed out
- Determine a time parameter appropriate to reminding the controller or pilot of such open messages
- Examining the impact of concatenated messages on pilot response, miscommunications, and time for pilot response
- Investigating any increase in pilot and controller response time in executing resolutions

# A.2.2 Summary of Findings

- 1. It is important to understand how the transition from paper to digital data in the flight deck affects pilots' planning and flight performance. Some advantages of paper include ease of manipulation, flexibility of spatial layout, direct marking, quick glance, and physicality.
- 2. Concurrent tasking and off-nominal events during preflight preparation and taxi out are important factors in many incidents and accidents. Care should be taken to align airline SOPs with the capabilities and workflows of the monitoring pilot.
- 3. Typical pilot workflows can differ across pilots based on their training, expertise, SOPs and other factors. Workflow-driven assistance tools can help by consolidating supplemental information and providing situational awareness of workflow to support task management.
- 4. Information flow for flight operations is dynamic and time-critical, where current events are affected by past and present events and in turn affect subsequent events. Flight information is dynamic, constantly changing and dependent on the evolution of events.
- 5. The design of information displays in the NextGen flight deck should support the structures and strategies pilots actually use, instead of inventing new ways of presenting information.
- 6. Navigation chart designs, particularly those for complex procedures such as RNP and RNAV, should be evaluated in terms of information content and style of presentation.
- 7. Charts must take into account all types of pilots (general, business, commercial), aircraft

capabilities (FMS and levels of automation), and presentation materials (paper charts, tablet EFB, flight deck avionics).

8. Complex charts must present information in an efficient, organized, clear and unambiguous manner. Unnecessary information should be removed and clutter reduced by splitting information across multiple charts.

### A.2.3 References

Barhydt, R. and Adams, C. (2006). Human Factors Considerations for Area Navigation Departure and Arrival Procedures. Presented at ICAS 2006 – 25th Congress of the International Council of the Aeronautical Sciences, 3-8 Sep. 2006, Hamburg, Germany. Available online at http://ntrs.nasa.glov/

Butchibabu, A., Midkiff, A., Kendra, A., Hansman, R.J., & Chandra, D. (2010). Analysis of safety reports involving area navigation and required navigation performance procedures. Proceedings of the International Conference on Human-Computer Interaction in Aeronautics HCI-Aero 2010. 3-5 November, Cape Canaveral, FL

Chandra, D. and Grayhem, R. (2012). Human Factors Research on Performance-Based Navigation Instrument Procedures for NextGen, 31st Digital Avionics Systems Conference (DASC), Williamsburg, VA.

Chandra, D., Grayhem, R., and Butchibabu, A. (2012). Area navigation and required navigation performance procedures and depictions. US DOT Volpe National Transportation Systems Center, Cambridge, MA, DOT/FAA/TC-12/8.

Hankers, T., Hecker, P., Barraci, N., & Schiefele, J. (2013). Identification of present-day transport pilot workflow and derivation of mobile aids. In 2013 Aviation Technology, Integration, and Operations Conference (p. 4357).

Hartmann, S. (2013). Information analysis for a future flight deck design in the context of 4D trajectory based operation. In Proceedings of the 3rd International Conference on Application and Theory of Automation in Command and Control Systems (pp. 140-143). ACM.

Hutchins, S., Nomura, E., & Holder, B. (2006) A Multi-Cultural Study of Paper Use in the Flight Deck. HCl-Aero 2006.

Loukopoulos, L. D., Dismukes, R. K., & Barshi, I. (2003). Concurrent task demands in the cockpit: Challenges and vulnerabilities in routine flight operations. In Proceedings of the 12th international symposium on aviation psychology (pp. 737-742).

Poage, J. L., Donohoe, C., & Lee, J. T. (2011). Soft system analysis to integrate technology & human in controller workstation. In Digital Avionics Systems Conference (DASC), 2011 IEEE/AIAA 30th (pp. 6C4-1). IEEE.

Solodilova-Whiteley, I., & Johnson, P. (2006). Uncovering the information needs in complex aerospace systems. Reliability Engineering & System Safety, 91(12), 1566-1575.

# A.3 Management of Attention, Interruptions and Workload

## A.3.1 Description of Relevant Literature

### Attention

Attention, a heavily researched topic in the domain of psychology, is composed of the moment by moment application of cognitive resources to one or more activities. Attention can be applied top-down as the intentional focus of a person to a particular task or be 'grabbed' as a bottom-up process by a salient stimulus in the environment. Selectively applying attention does not only involve focusing on a particular display or activity but also the filtering of task irrelevant information. For example, a pilot may be focused on take-off procedures during liftoff. During this task, radio communications are consistently coming providing clearances to other aircraft but do not begin with the pilots' aircraft identification. This verbal information is appropriately ignored since they are irrelevant to the pilot. As the aircraft begins to climb and the pilot lines up to the flight plan, her attention is grabbed by a collision warning from the TCAS display and he looks down at her display to see which direction the threat is.

The cockpit has a wide array of information displays and controls and a pilot can only attend to some of this environment at one time. In this way, attention is a limited resource. There have been a number of theories and metaphors for attention but the view of attention as a cognitive resource serves the discussion of attention in task management the best. Multiple resource theory states that there are multiple 'pools' of attentional resources that extend across different dimensions (modality, stage/code of processing). Dividing attention across tasks that require the same resource pool will tax overall resources more than if the task required resources from different pools (Wickens, 2008). In the previous example, the pilot is controlling the aircraft while listening to ATC communications for her aircraft's identification. This uses visual spatial and verbal auditory resources that do not overlap. Responding to the TCAS alert, on the other hand, is also a visual spatial task requiring her to temporarily look away from lining the aircraft to her flight plan. This does not mean that both tasks cannot be done, but that doing so will be more taxing and have greater potential for errors through inattention.

Despite attention being a limited resource, strategies and methods have been developed to make the best use of it. Through the development and application of training, and the accumulation of experience, pilots are able to learn to optimally apply this resource and maximize their performance. With sufficient experience it is possible to simultaneously conduct more than one task effectively, for example experienced pilots are able to simultaneously maintain active control of the aircraft while communicating with air traffic control (ATC). When too many tasks of equal importance exist, experienced pilots report that they will quickly switch between tasks in order to effectively deal with them (Wickens, 2002). In addition to the benefits of experience and training the use of attentional resources can be supported by careful design of aircraft displays and systems. For example, a system alert that is perceptually discriminable by the pilot as indicating a specific abnormal condition is superior to an alert that is difficult to notice and ambiguous in nature. Wood (1995) describes application of attentional processes as a skill in how effectively a pilot is able to evaluate interrupting tasks without allowing them to disrupt ongoing lines of thought and also identifying the importance of that task.

#### Workload

Mental workload is closely related to attention and is characterized as the level of demand experienced on the mental resources when performing a task. As discussed above, attention is a limited resource, and so task management is strongly affected by the level of workload a pilot is under. At any given moment during flight, the pilot will have one or more tasks that need to be performed. Single channel theory, single resource theory and multiple resource theory have been applied to identify how pilots tackle these situations and observations of approaches from research show support for each of them (Burian et al, 2013; Wickens, 2002; Wickens 2008). These theories take either the approach that pilots will complete tasks one by one until completion or will attempt to complete a number of tasks concurrently. For those that attempt to attempt concurrent tasks they could do so simultaneously (i.e. listening to the rest of an ATC clearance while entering a new altitude) or interleave the two tasks together switching back and forth between steps for each. As described in a literature review conducted by Minotra (2012), sufficiently high workload impact the performance of primary tasks like flying the aircraft. On the lower end of the workload continuum, workload can impact the time at which different tasks are started, pilots will defer less vital or more time consuming tasks. On the higher end of the workload continuum, increases in workload cause pilots to drop or "shed" lower priority tasks. The most successful pilots, according to Minotra (2012), manage attention in higher workload by switching tasks more frequently and scheduling higher priority tasks earlier. This solution seems to be the most effective when it is possible to intersperse sections of different tasks into a single integrated task (Dismukes, et al., 2001). However, this is not always an option considering the varied nature of some tasks. The underlying rationale of these strategies align with multiple resource theory, with the optimization of resource use by particular task demand (Burian et al., 2013).

The number of tasks alone is not the only way that workload can increase. Violations of pilot expectation for a given task, usually the result of an abnormal event, can disrupt and distract the pilot from the normal execution of that task. This can result in increasing the workload of task that is not usually demanding and the pilot can allocate more attention than necessary. Another factor that can affect the workload is the presence of dynamic hazards in the flight environment like weather conditions (e.g. thunder storms) and other air traffic (e.g. flying close to ownship). These hazards can be difficult to reliably predict and require additional mental resources to track and monitor, thereby increasing the pilot's workload (Wickens, 2002).

#### Strategies for Assisting Attention and Workload Management

Generally, as described by Wickens (2002) in a review of aviation psychology research, these tasks fall into the ANCS (aviate, navigate, communicate, system management) hierarchy which provides a loose framework for task priority. Furthermore, due to the number of different tasks that exist and in order to help pilots remember how to prioritize them, an assortment of checklists exist which remind pilots which procedures to follow and when.

In some cases this hierarchy can be broken, for example if a system emergency occurs that could affect the safety of flight, it could be prioritized over navigation and communication. As the number of active tasks increases, they begin to compete for attentional resources. When clear task prioritization is available, single task order can be maintained but as simultaneous task demands form and clear distinctions for prioritization do not exist, the pilot's limited attentional resources can be exhausted.

As mentioned above, one strategy to mitigate this type of task demand is to interleave the tasks. Unfortunately, as Wickens (2002) details, the checklists pilots use are linear in nature and do not easily accommodate switching back and forth between simultaneous tasks. Nor can they account for unexpected events or capture transient task components like maintaining SA. It is not surprising that more experienced pilots have success using this kind of strategy (Wickens, 2002).

Another mechanism in place to help decrease workload is the incorporation of increasingly complex automation which performs a variety of functions onboard modern aircraft. Although this has successfully reduced workload in some ways, it has also brought up other concerns. It is easier for individuals to remember actions that they themselves have initiated compared to those executed by others, including automated systems (Wickens, 2002). This means pilots may have trouble remembering changes in system mode made by the automation. Furthermore, in multi-task scenarios it becomes more likely that a pilot may not notice a change in mode executed by the automation at all if they are focused on other tasks. This is one of the existing issues in the domain, finding an ideal way to keep the pilot informed of changes made by the automation while maintaining lower levels of workload.

#### Additional Review of Literature

Not only do pilots need to be aware of what the tasks they need to perform are but they also need to be able to order them based on some priority scheme. Since ongoing events and task interruptions may result in new tasks or re-evaluation of existing ones, it is easy to see that this management of tasks is itself another task. Attention is applied to both actively engage in the tasks but also monitoring for changes and incoming data. The number of tasks that need to be performed and ease of each task can increase the workload and resource demands placed on the pilot. All of these factors are related to one another and research tends to manipulate all of these to identify how to best help pilots maintain good task management. This research tends to focus on three core problems:

- 1) The ability to manage multiple tasks without focusing too much on any given subset of tasks.
- 2) The ability to successfully evaluate and execute/ignore interrupting tasks without losing track of existing ones.
- 3) Appropriately capturing a pilot's attention based on the importance of an alert or change in state.

A questionnaire study conducted by Dismukes, et al., (2001) with expert pilots indicated that, in terms of tasks that were neglected, lapses in monitoring and in remembering to do an intended task were the most common problems. Although forgetting to perform tasks falls into the domain of prospective memory failures, lapses in monitoring indicate that some other task has captured their attention. There are a number of well-known tragedies in aviation where the crew of an aircraft becomes so focused on some task that they forget to monitor aircraft altitude resulting in controlled flight into terrain (CFIT). This type of occurrence can be attributed to attentional tunneling. Wickens and Alexander (2009) defined this as "the allocation of attention to a particular channel of information, diagnostic hypothesis, or task goal, for a duration that is longer than optimal, given the expected cost of neglecting events on other channels, failing to consider other hypotheses, or failing to perform other tasks". Through a series of simulation experiments, Wickens and Alexander (2009) sought to determine the prevalence of attentional tunneling and some possible causes of these events. Leveraging their experience in the field,

they used heads up displays (HUD) of varying levels of fidelity as likely candidates to induce attentional tunneling. Pilots flew different simulation scenarios and experienced a number of unexpected events (usually the appearance of weather, tall buildings or rogue aircraft). Some pilots used a HUD which simply informed them of the state of the world (level 2 automation) while others used a HUD that additionally suggested a possible course of action (level 3 automation). The results of the study found that of those pilots who did not notice the unexpected events (almost half), those using the HUD with higher level of automation seemed to be more likely to miss the event. Although other research does indicate the many benefits of these displays for flight, the authors stress the importance of attentional training for pilots to mitigate the potential for accidents based on attentional tunneling with these displays.

Cristina and Wickens (2007) looked at a similar issue in terms of the interaction between an ongoing task and an interrupting task. Specifically, they were interested in how the level of engagement of an ongoing task affects its level of interruptability. They were investigating concerns that the realism of flight deck tunnel displays (synthetic vision system) cause pilots to overly focus on them, resulting in resistance to interruptions, including from necessary task switching. Based on their research, the authors suggest that compelling displays may prevent pilots from noticing unusual events but do not greatly impact their ability to monitor more routine tasks. They also indicate that so long as the current task is not considered to be high priority, an audio signal is sufficient to capture attention for an interrupting task.

## A.3.2 Summary of Findings

- 1. Attention and workload are closely related concepts.
- 2. There are a number of variables that can cause workload to fluctuate and thereby affect the pilot's ability to attend to their tasks.
  - Number of tasks
    - Time pressures
    - Predictability of task variables
    - Pilot expectations
- 3. The ANCS hierarchy and aviation checklists are good tools for reinforcing pilot training.
- 4. Pilot experience level is important for dealing with higher workloads; more experienced pilots practice strategies that are successful in high demand situations.
- 5. Unexpected or low prevalence events pose the largest problems for attention management.
- 6. Automation is a double edged sword that helps pilots with high workload situations but can cause confusion during abnormal events.

#### A.3.3 References

Burian, B. K., Pruchnicki, S., Rogers, J., Bonny, C., Williams, K., Silverman, E., Runnels, B. (2013). Singlepilot workload management in entry-level jets. NASA. Moffett Field, CA: NASA Ames Research Center.

Cristina, I., & Wickens, C. D. (2007). Factors affecting task management in aviation. Human Factors, 49

(1), 16-24.

Dismukes, R., Loukopoulos, L. D., & Jobe, K. K. (2001). The challenges of managing concurrent and deferred tasks. Proceedings of the 11th International Symposium on Aviation Psychology. Columbus, OH: Ohio State University.

Minotra, D. (2012). The effect of a workload-preview on task-prioritization and task-performance. University Park, PA: The Pennsylvania State University.

Wickens, C. D. (2002). Situation awareness and workload in aviation. Current Directions in Psychological Science , 11 (4), 128-133.

Wickens, C. D. (2008). Multiple resources and mental workload. Human Factors, 50(3), 449-455.

Wickens, C. D., & Alexander, A. L. (2009). Attentional tunelling and task management in synthetic vision displays. Journal of Aviation Psychology, 19 (2), 182-199.

# A.4 Task Management: Switching between Tasks

## A.4.1 Description of Relevant Literature

An individual is engaged in task switching when they oscillate between two or more different tasks sequentially over a period of time. People readily task switch in their daily lives, whether it be entering navigation information into a device while already driving, answering emails during a work meeting, or performing operations on the flight deck while communicating with ATC. Juggling multiple tasks simultaneously is commonplace in modern society, yet the costs we may incur from dividing our attention – whether it be in the speed with which we apply our brakes, or the level of detail of our recollections of important information – is not yet fully understood. As a result, the impact of task switching on performance and its relationship to attention and memory have become topics of great interest, including more recently the complex and safety-criticality context of flight.

#### Relationship to Task Management

To support effective task management by pilots, an awareness of the pervasiveness of task switching and its impact on performance is critical. For example, interruptions of task flow which lead a pilot to switch between tasks unexpectedly can lead to critical missteps in procedure, such as failing to set flaps for takeoff (ASRS incident report #289346, described in Loukopoulos, et al., 2003; ASRS incident report #519061, summarized in Loukopoulos, et al., 2009). Flight procedures require pilots to execute safetycritical checklists made up of many tasks, during which time a pilot may be subject to interruption and diverted attention.

When flying we are often presented with more than one situation at a time that requires our attention. As we become more proficient, we get better at "multitasking," or handling more than one situation at a time – flying while talking on the radio, etc. However, there are times when even the most experienced pilot is task saturated. During those times we are taught to prioritize our response to multiple situations presented at the same time – Aviate first (fly the airplane), then Navigate (make sure the airplane is going where you want it to go) and finally Communicate (respond to Air Traffic Control). (McClurkin, 2009)

Despite the existence of such procedures, which are specifically designed to help pilots prioritize tasks during times of interruption and unexpected task switching, the nature of human memory still leads to errors that are difficult for even the pilots themselves to detect.

Incident 1: Tower (shortly after CRM 1 had lifted off on a soft field take off): "Crimson 1 left turn out when altitude permits, contact OKC approach 124.6." Crimson 1: "Going to OKC approach." Examiner to Pilot as aircraft approaches level off at 6500 feet: "Done all of our checklists?" Pilot: "Oh, no, didn't do the climb check." Examiner: "Did you notice we still have a notch of flaps in?"

Analysis: We normally expect the frequency change after climbing and turning out. When tower gives it to us early there is a tendency to "skip ahead" to that point in the flight. In this case that caused the pilot to skip fully retracting the flaps as well as the climb checklist. (McClurkin, 2009)

Increasing pilot knowledge of such points of weakness in human memory and performance may assist them in developing task management strategies to minimize errors. In particular, awareness of the weakness of prospective memory (memory for deferred tasks) may help pilots recognize and compensate for moments where interruptions and unexpected task switching occurs – e.g., creating reminder cues, or engaging in implementation planning (Dismukes, 2010), and carefully considering the point at which they leave one task to begin the other (Yeung & Monsell, 2003).

Furthermore, increasing pilot knowledge of the cost of task switching in even the simplest of circumstances may assist them in developing more efficient task management strategies that reduce their overall workload. In addition to improving their own processes, this could better position pilots to respond to unexpected events with less disruption.

#### Background

What constitutes "tasks" in task switching can be thought of quite broadly – here tasks refer to a set of actions and knowledge that are associated with achieving a specific goal. The difference between two tasks may be in the action the individual does (e.g., checking fuel levels or updating ATC), or the manner in which an action is completed (e.g., typing in a response or giving it verbally).

Initializing tasks relies on endogenous and exogenous control systems (Rogers & Monsell, 1995). Endogenous control systems are engaged during the configuration of a task-set, where the set of elements and procedures fundamental to a task are activated. This configuration can be done by an individual without any external stimulation or cue (e.g., you spontaneously decide to turn on the radio, which calls up the necessary motor actions and knowledge for executing that task), or can be done in response to an outside stimulus (e.g., your passenger asks you to turn on the radio, and you decide to comply). On the other hand, exogenous control processes activate task-sets automatically in response to an external cue – necessarily interrupting ongoing task processes (e.g., your phone rings while you are driving, and you automatically activate the motor actions and knowledge needed for answering the call).

When one switches between tasks, there is always a switch cost in the form of slowed reaction time and decreased accuracy (Allport et al., 1994; Rogers & Monsell, 1995). Switch costs can be substantial (>1 second) in complex tasks such as the supervision and control of unmanned air vehicles (Wickens, et al., 2006). Current research attributes this switch cost to endogenous and exogenous control system processes – time is needed to reconfigure task sets from Task A to Task B (endogenous processes), and
the information relevant to Task A will interfere with the execution of Task B (exogenous processes).

Work by Allport et al. (1994) and Rogers and Monsell (1995) have shown that the exogenous portion of switch costs (residual switch costs; Rogers and Monsell, 1995) persists in the face of many compensatory factors. For example, even when switching is entirely predictable (e.g., in an AABBAABB paradigm), there is a cost in performance that does not diminish over time. In other words, there may always be a cost to performance when switching between tasks.

On the other hand, these same studies identify several ways in which the endogenous part of switch costs (the amount of time and mental resources it takes to build or remember task-sets, and reconfigure them during switching) can be reduced. For example, Allport et al. (1994) found that participants performed better when switching between tasks where the stimuli themselves represented a cue for only one of the tasks (e.g., "name the word you see" and "state the numeric value you see"), compared to switching between tasks where the same for both (e.g., "name the word you see" and "name the color font of the word you see"). In other words, a cue to the task at hand reduces switch cost.

Furthermore, Rogers and Monsell (1995) were able to show that the endogenous portion of switch costs is reduced when the individual has time to prepare for the upcoming switch. The improvements they saw were up to 30% within .5 seconds, plateauing at approximately 1 second. From this it seems that an appropriate temporal spacing of tasks can significantly reduce switch costs.

Work by Dismukes, (2010) further suggests that when people are in greater control of the tasks, they may see improvements in performance. In other words, control processes needed to switch tasks efficiently and accurately may be better engaged proactively rather than reactively.

While the effect of interference from one task-set to another cannot be entirely eliminated, there are circumstances in which the interference will likely to be stronger or weaker, which can be taken into account. For example, if a secondary task is too similar to the primary task, there will be interference resulting in degraded performance (Cellier & Eyrolle, 1992). Therefore, greater differentiation between tasks should reduce switch costs.

While creating greater separation between tasks will help reduce interference, the familiarity, complexity, and engagement of each of the tasks should also be carefully weighed. Unfamiliar tasks are likely to require additional attentional resources, which leads to greater interference with the other task and subsequently worse performance (Rubinstein et al., 2001). This is true even in the case where one task is extremely familiar (Meuter & Allport, 1999). Similarly, the complexity or engagement of a task may draw attentional resources strongly enough that task switching will see greater costs (Rubinstein et al., 2001). For example, many studies have been performed on multitasking and task switching in the context of driving, where the focus has been on the use of devices like mobile phones (NHTSA Guidelines, 2012). These studies identify effects of how engaging the secondary device task is, including a tunneling effect of attention (Wickens and Alexander, 2009) and a significant increase in the odds of a crash (Ranney, 2008).

Odds ratios for crashes in relatively difficult driving conditions:

• 3.1 for complex secondary tasks

- 2.1 for moderate secondary tasks
- 1.0 for simple secondary tasks (no appreciable increase in risk engaging in the secondary task)

According to Horrey et al., (2009), engaging and non-engaging tasks are about equally disruptive to drivers, however in engaging tasks the drivers feel like they are less disrupted. This intuition leads to overconfidence, which then leads to greater problems. Overall, switch costs will be much higher when one task requires a great amount of attentional resources.

Finally, certain people are more likely to task switch than others, for reasons of attention or filling-in time, but comfort with the behavior does not translate into better or more accurate performance (Ranney, 2008). As with many psychological paradigms, confidence in one's ability to juggle tasks appears uncorrelated with performance, and individuals may benefit from external heuristics.

#### A.4.2 Summary of Findings and Working Recommendations

- 1. Entirely removing the cost of switching tasks is not (currently) possible
- 2. Task switching leads to costs in performance in at least two ways: RT and accuracy
  - o Somewhat less so when the user initiates than when the system does.
  - Somewhat less so when there is (i) an overt cue for the task, (ii) an appropriate temporal spacing between tasks, and (iii) differentiation between tasks
- 3. Task switching can lead to (prospective) memory errors
  - E.g., forgetting where you were in Task A after having diverted to Task B for some time
- 4. The cost of task switching is increased by interference from one task's information to another's
  - o Increased attention can enhance this interference if the tasks are too close
- 5. People are differently willing and able to task-switch
- 6. People's reports of their confidence in their task switching ability do not correspond to actual performance.
- 7. To manage switch costs:
  - Maximize prep time (and cues) for an oncoming task
    - Where possible, present cues (e.g., visual) for upcoming tasks
    - Give appropriate spacing between one task response and initiation of the next task
  - Minimize task-interference
    - alternate between tasks that are as different in their stimuli and controls as possible, to reduce interference and subsequent workload
    - Keep the complexity and familiarity of the tasks low and similar
    - Note: Be aware that attention to periphery in visual tasks may become degraded with high focus

#### A.4.3 References

Allport, A., Styles, E. A., & Hsieh, S. (1994). Shifting intentional set: Exploring the dynamic control of tasks. In C. Umilta & M. Moscovitch (Eds.), Attention and performance: Conscious and nonconscious information processing (pp. 421–452). Cambridge, MA: MIT Press.

Cellier, J. M., & Eyrolle, H. (1992). Interference between switched tasks. Ergonomics, 35(1), 25-36.

Department Of Transportation National Highway Traffic Safety Administration Docket No. NHTSA-2010-0053 (2012). Visual-Manual NHTSA Driver Distraction Guidelines For In-Vehicle Electronic Devices. Section C: The Visual-Manual NHTSA Guidelines for In-Vehicle Electronic Devices

Dismukes, R. K. (2010) Remembrance of things future: Prospective memory in laboratory, workplace, and everyday settings, In D. H. Harris (Ed), Reviews of Human Factors and Ergonomics, 6, 79-122. Santa Monica, CA: Human Factors and Ergonomics Society

Horrey, W. J., Lesch, M. F., & Garabet, A. (2009). Dissociation between driving performance and drivers' subjective estimates of performance and workload in dual-task conditions. Journal of safety research, 40(1), 7-12.

Loukopoulos, L. D., Dismukes, R. K., & Barshi, I. (2003). Concurrent task demands in the cockpit: Challenges and vulnerabilities in routine flight operations. In Proceedings of the 12th international symposium on aviation psychology (pp. 737-742).

Loukopoulos, L. D., Dismukes, R. K., & Barshi, I. (2009). Analysis of Concurrent Task Demands and Crew Responses. In The multitasking myth: Handling complexity in real-world operations. Ashgate Publishing, Ltd.. Chicago

McClurkin, D.A. (2009). Aviate, Navigate, Communicate. University of Oklahoma Department of Aviation Safety Articles. Retrieved from

http://www.aviation.ou.edu/SafetyCorner/documents/March2012AviationSafetyCorner-Aviate.pdf

Meuter, R. F. I. & Allport, A. (1999). Bilingual language switching in naming: Asymmetrical costs of language selection. Journal of Memory and Language, 40(1), 25-40.

Ranney, T. A. (2008). Driver Distraction: A Review of the Current State-of-Knowledge. DOT HS 810 704. Washington, DC: National Highway Traffic Safety Administration.

Rogers, R. & Monsell, S. (1995). Costs of a predictable switch between simple cognitive tasks. Journal of Experimental Psychology: General, 124, 207-231.

Rubinstein, J. S., Meyer, D. E. & Evans, J. E. (2001). Executive Control of Cognitive Processes in Task Switching. Journal of Experimental Psychology: Human Perception and Performance, 27, 763-797.

Yeung, N. & Monsell, S. (2003). Switching between tasks of unequal familiarity: The role of stimulusattribute and response-set selection. Journal of Experimental Psychology-Human Perception and Performance, 29(2): 455-469.

Wickens, C. D., Dixon, S. R., & Ambinder, M. S. (2006). 15. Workload and Automation Reliability in Unmanned Air Vehicles. Human factors of remotely operated vehicles, 7, 209-222.

Wickens, C. D., & Alexander, A. L. (2009). Attentional tunneling and task management in synthetic vision displays. The International Journal of Aviation Psychology, 19(2), 182-199.

# A.5 Flight Deck Task Management Errors

## A.5.1 Description of Relevant Literature

The Active Pilot Monitoring Working Group (APWG) emphasized the importance of effective monitoring of flight path management to avoid errors and deviations that "have the greatest potential to lead to accidents" (2014). (Note - The APWG used the term Cockpit instead Flight Deck Task Management.) An important goal of effective Cockpit Task Management (CTM) is to protect flight path management. Consideration of CTM errors was considered within the flight path management safety perspective. In addition to direct impact to flight path management, CTM errors can also contribute to "getting behind" the mission timeline, which could reduce safety margin as time pressure increases, tasks are rushed or forgotten. Given several monitoring-related accidents, the APWG concluded that it would be most valuable to address the greatest safety-critical aspects related to flight path monitoring, since errors and deviations of this have the greatest potential to lead for accidents.

Chou and Funk (1990) investigated CTM errors based on taxonomy from Funk's (1990) normative CTM model. This model identified seven functions performed in CTM: task initiation, task monitoring, task prioritization, resource allocation, task interruption, task resumption, and task termination. A CTM error in this framework is any error that degrades any CTM function. Chou and Funk identified the following error taxonomy based on CTM functions:

- Task Initiation (Early, Late, Incorrect, Lack) 11
- Task Monitoring (Excessive, Lack) 5
- Task Prioritization (High, Low) 2
- Resource Allocation (High, Low) 3
- Task Termination (Early, Late, Lack, Incorrect) 6
- Task Interruption (Incorrect) 1
- Task Resumption (Lack) 0

They focused on post-accident reviews and identified 14 NTSB accident reports from the previous ten years (1980 - 1990), which involved 28 total CTM errors. Accidents included 0 to 5 errors with a median of 1.5 errors; counts of errors by type are depicted above. Of the 28 errors, 39% (11) were Task Initiation errors determined to be caused by limited pilot knowledge of the aircraft (AC) and procedures related to abnormal situations. They analyzed a well-known CTM error example which was the 1972 L1011 crash in the Everglades. In this accident, the flight crew mis-allocated resources, diagnosing a faulty gear-down light bulb instead of performing the higher priority aviate task of monitoring the altimeter and autopilot (which had been inadvertently disengaged and the AC set to slow descend mode). By the time the co-pilot became aware of the low altitude state, it was too late to recover.

Later, Madhaven (1993) revisited the error taxonomy. The research objective of this Master's thesis was to investigate the impact of CTM errors on flight safety, based on an analysis of Aviation Safety Reporting System (ASRS) incidents (compared to Chou's work that focused more on NTSB reports). Chou

and Funk's taxonomy was revised to reflect CTM errors observed in ASRS incidents with a bottoms-up analysis of cockpit task errors.

Madhaven determined that some of Chou's original error taxonomy was too shallow, for example, "Task Monitoring-Lack" did not reveal the source of the monitoring failure, and so was deemed superfluous. "Task Monitoring-Excessive" was also eliminated since it usually traced to an earlier resource allocation error which was almost always a Task Prioritization error. Madhaven also concluded that it was impossible to find Task Termination in ASRS incidents.

The author identified 470 ASRS incidents and then categorized with a revised error taxonomy, as seen below with examples:

- Task Initiation (early, late, lack): early- premature descent phase, corrective actions before confirming problem; late- late in configuring AC, late altitude callouts; lack- forgot to call tower,
- Task Prioritization (incorrect): engrossed in novel approach and forgot to give timely landing warning to cabin crew; missed ATC communications while acknowledging cabin crew
- Task Termination (early, late, lack): early- early termination of AP, alt hold; late- late terminate of initial approach resulting in "high arrival"; lack- landing when weather deteriorated below minimums, landing without clearance

They determined that 231 of 470 ASRS incidents included CTM errors (49.2%), and they were broken down as follows:

- Task Initiation-Early: 9 of 35 of this type had extenuating circumstances (emergencies, weather, and high workload) that caused a prioritization error which caused them to erroneously start a task early.
- Task Initiation-Late: 83% of these were late configuration of AC, 70% caused by high workload; all of them resulted from late termination of initial descent phase resulting in confusing set of concurrent task demands (ATC comms, lost height, traffic watch, communication with cabin and passenger) -- which then resulted in mis-prioritized tasks which resulted in late initiation of other tasks.
- Task Termination-Early: Smallest specific error category-- 66% of these were early release of AP, 34% were early checklist termination (incomplete)
- Task Termination-Late: 88% of these were overshooting altitude clearances, 11% involved staying with couple approaches too longer and extended downwind and/or base legs
- Task Termination-Lack: 72% of these involved non-abortion of landing almost all of these occurred in bad weather (below FAA and company minima)

Despite the refinement of taxonomy, the categorization is not that clean. Often the final, salient error was caused by an earlier TM error, which was almost universally a Task Prioritization error.

Latorella (1999) investigated the implication of interruptions on the flight deck. Given the dynamic nature of flight operations, interruptions are inevitable and their management is a critical competency for effective task management. Chou and Funk (1993) identified 98 CTM errors in 77 accident reports;

only 5 (5.1%) were identified as the Task Interruption type. Latorella argued that one needs to consider the broader impact of interruptions across the following additional error types: Task Resumptions, Task Initiation, Task Termination, and Task Prioritization.

In a pilot-in-the-loop (PITL) simulator evaluation, Latorella found that interruptions significantly impacted procedure performance (53% more errors if procedure is interrupted) and also increased flight path monitoring activity (2 more flight path management inputs per minute).

Since flight deck task performance is typically a "team" activity between two pilots, it is worth considering team errors. Sasou & Reason (1999) defined team error as "how group of people made human errors (mistakes, lapses, and slips) in group processes". They described a taxonomy of team error types and error-recovery processes:

- Error Types
  - Individual errors-- an individual makes an error without participation of other team members
  - Independent: all information to the error-perpetrator is correct
  - Dependent: some part of the information is inappropriate
  - Shared errors-- shared by some or all team members
  - Independent: all information to the error-perpetrator is correct
  - Dependent: some part of the information is inappropriate
- Error-Recovery process (3 stages):
  - Failure to detect—when the remainder of the team does not detect an error occurrence
  - Failure to indicate-- when a detected error is not brought to the attention of the remainder of the team
  - Failure to correct-- when errors are detected and indicated by the remainder of the team, but the error-perpetrator does not correct them

Using this taxonomy, Sasou & Reason analyzed select aviation events and identified 8 team errors across 7 of 21 events. They identified the following types of Performance Sharing Factors (PSFs) that induced errors:

- External PSFs (e.g., high task requirements, high temperature)
  - Most individual and shared errors were attributed to: seriousness, poor HMI, high workload
- Internal PSFs (e.g., high stress, high fatigue)
  - Most individual and shared errors were attributed to: deficiency in knowledge, high arousal, low SA
- Team PSFs (e.g., lack of communication, inappropriate task allocation)
  - Most individual and shared errors were attributed to: deficiency in communication, excessive belief, excessive professional courtesy

The authors surmised that the most common team deficiency (poor communication) negatively impacts the team's ability to detect individual or shared errors. They concluded that insufficient resource and task management also contributed to error detection failures, since the team members may not have had the knowledge to reliably detect errors. They also concluded that many team errors result from

deficiencies in "understanding one's own responsibility and what needs to be done".

### A.5.2 Summary of Findings

From a Flight Deck Task Management error analysis standpoint, the most likely threats to flight path monitoring are task prioritization errors where flight crews attend to lower priority tasks at the expense of monitoring the flight path. Another threat would be Task Initiation--Late errors, which are precursors to getting behind the mission timeline and can lead to compressed timelines with high concurrent task workload. As a result, the overall safety margin is likely reduced due to rushed, forgotten, and missed tasks, such as checklist execution and ATC communication. As the flight crew's cognitive resources are stressed, flight path monitoring is increasingly under the threat of being under-attended due to competing demands from pop-up and interrupting tasks, most of which are lower priority but nonetheless capture the crew's attention.

Since interruptions can be causal factors across Flight Deck Task Management error types, effective management of interruptions could mitigate these error impacts. Latorella suggested training that would offer strategies to help pilots resume interrupted tasks; further, pilots should be instructed in identifying conditions when interruptions should be avoided. Training should be informed by an understanding of those tasks, conditions and personality traits that contribute to interruptions.

Based on their findings of communication and responsibility deficiencies, Sasou & Reason recommended that team errors could be mitigated by avoiding "vague responsibility" assignments and improving communication processes between pilots.

### A.5.3 References

Active Pilot Monitoring Working Group. (2014). A Practical Guide to Flight Path Monitoring: Final Report of the Active Pilot Monitoring Working Group. Active Pilot Monitoring Working Group.

Chou, C.D., & Funk, K. (1990). Management of multiple tasks: Cockpit task management errors. In Proceedings of the IEEE International Conference on Systems, Man and Cybernetics, 1154-1156.

Chou, C.D., and Funk, K. (1993). "Cockpit Task Management Errors in a Simulated Flight Operation." In Proceedings of the 7th International Symposium on Aviation Psychology, 965–69.

Funk, K. (1990). Cockpit task management. In Proceedings of the IEEE International Conference on Systems, Man and Cybernetics, 466–469.

Latorella, K. A. (1999). Investigating interruptions: Implications for flightdeck performance. NASA Technical Report, October 1999.

Madhavan, D. (1993, December 1). Cockpit Task Management Errors: An ASRS Incident Report Study. Master's Thesis.

Sasou, K., & Reason, J. (1999). Team errors: definition and taxonomy. Reliability Engineering & System Safety, 65(1), 1-9.

# **Appendix B: Accident Reports**

Table B-1 contains the list of 133 accidents and incidents involving commercial aircraft (2009-May 2016) identified by the authors. Those identified as having TM error as a contributory factor contain a "**TM**" in the year column.

#### Table B-1 List of Accidents Identified Since 2009 for this Report

Source: https://en.wikipedia.org/wiki/List\_of\_accidents\_and\_incidents\_involving\_commercial\_aircraft

Year	Accident
2009	January 15 – US Airways Flight 1549, an Airbus A320, ditches in the Hudson River just after taking off from LaGuardia Airport in New York City after total engine failure due to multiple bird strikes; all people aboard survive the accident.
2009	February 7 – In the 2009 Manaus Aerotáxi crash, a Manaus Aerotáxi Embraer EMB-110 crashes near Santo António, Brazil, killing 24 of the 28 aboard.
2009 TM	February 12 – Colgan Air Flight 3407, a Bombardier Dash 8 Q400, flying from Newark Liberty International in New Jersey to Buffalo Niagara International Airport in New York crashes into a house in Clarence, New York, killing all 49 aboard the plane and one on the ground.
2009 TM	February 25 – Turkish Airlines Flight 1951, a Boeing 737-800, flying from Atatürk International Airport in Istanbul to Amsterdam Airport Schiphol crashes in a field during final approach; of the 135 people on board, 9 are killed and 86 injured.
2009	March 12 – Cougar Helicopters Flight 91, a Sikorsky S-92, ditches in the Atlantic 34 miles (55 km) east-southeast of Newfoundland due to a main gearbox failure, killing 17 of 18 on board.
2009	March 20 – Emirates Flight 407, an Airbus A340-500 flying from Melbourne Tullamarine Airport to Dubai International Airport has a tailstrike during take off and returns to Melbourne Airport with no fatalities.
2009	March 23 – FedEx Express Flight 80, a McDonnell Douglas MD-11 flying from Guangzhou, China, crashes at Tokyo Narita International Airport, Japan; both the captain and the co-pilot of the plane are killed.
2009	April 1 – 2009 Bond Helicopters Eurocopter AS332 crash: Bond Offshore Helicopters Flight 85N, a Eurocopter AS332, crashes 35 miles (56 km) off the Aberdeenshire coast while returning from the Miller oilfield, killing all 16 on board; the cause is a catastrophic failure of the main rotor gearbox.
2009	April 19 – CanJet Flight 918 is seized on the ground by an armed man who slipped through security checks at Sangster International Airport, Montego Bay, Jamaica; all passengers are released early on; six crew members are kept as hostages for several hours before being freed unharmed.
2009 TM	June 1 – Air France Flight 447, an Airbus A330 en route from Rio de Janeiro to Paris, crashes in the Atlantic Ocean, killing all 228 occupants, including 12 crew; bodies and aircraft debris are not recovered until several days later; the aircraft itself is not found until 2011. The crash is the first fatal accident of the A330 and the worst-ever disaster involving the A330.
2009	June 30 – Yemenia Flight 626, an Airbus A310 flying from Sana'a, Yemen to Moroni, Comoros, crashes into the Indian Ocean with 153 people aboard; one 12-year-old is found clinging to the wreckage.
2009	July 13 – Southwest Airlines Flight 2294, a Boeing 737 from Nashville to Baltimore makes an emergency landing in Charleston, West Virginia, after a 14x17 inch hole opens in the skin of the fuselage at 34,000 feet (10,000 m), causing a loss of cabin pressure; the plane lands safely with no injuries.

2009	July 15 – Caspian Airlines Flight 7908, a Tupolev Tu-154, crashes 16 minutes after takeoff near Qazvin, Iran, killing all 153 passengers and 15 crew.
2009	July 24 – Aria Air Flight 1525, an Ilyushin Il-62, skids off the runway at Mashhad International Airport, killing 17 of 153 on board.
2009	August 2 – Merpati Nusantara Airlines Flight 9760, a de Havilland Canada DHC-6 Twin Otter, crashes into a mountain in good weather over Indonesia, killing all 13 passengers and 3 crew.
2009	August 4 – Bangkok Airways Flight 266, an ATR 72-200 carrying 68 passengers crashes in severe weather on landing at Samui airport in the resort island of Ko Samui in Thailand, resulting in at least 1 confirmed death and 37 injuries.
2009	August 11 – Airlines PNG Flight 4684, a de Havilland Canada DHC-6 Twin Otter carrying 11 passengers and 2 crew crashes into a mountain at Isurava, Papua New Guinea while attempting a go around at Kokoda Airport, Papua New Guinea; all passengers and crew perished in the accident.
2009	September 9 – Aeroméxico Flight 576, a Boeing 737 with 104 passengers on board, is hijacked while flying from Cancún to Mexico City; after landing at Mexico City International Airport, Mexican officials storm the plane and take 5 men into custody; there are no casualties.
2009	October 21 – Azza Transport Flight 2241, a Boeing 707, crashes on take-off from Sharjah International Airport, United Arab Emirates; all 6 crew members are killed.
2009	October 22 – Divi Divi Air Flight 014, a Britten-Norman Islander, with 10 on board, ditches in the Caribbean Sea off Bonaire due to engine failure, killing the pilot.
2009	November 12 – RwandAir Flight 205, a Bombardier CRJ-100, crashes into a terminal shortly after an emergency landing at Kigali International Airport, Rwanda; of the 10 passengers and 5 crew, 1 passenger dies.
2009	December 22 – American Airlines Flight 331, a Boeing 737-800 from Miami International Airport overruns the runway at Norman Manley International Airport, Kingston, Jamaica; there are 40 injuries and no fatalities.
2009	December 25 – Northwest Airlines Flight 253, an Airbus A330-300 is attacked by a man using a small explosive device, causing only a small fire inside the plane, which is extinguished by a flight attendant; the man is subdued by passengers and crew; there are 3 injuries.
2010	January 24 – Taban Air Flight 6437, a Tupolev Tu-154M, crashes while making an emergency landing at Mashhad International Airport, Iran, due to a medical emergency; all 157 passengers and 13 crew survive the accident with 47 receiving minor injuries.
2010	January 25 – Ethiopian Airlines Flight 409, a Boeing 737-800, crashes into the Mediterranean Sea shortly after takeoff from Beirut Rafic Hariri International Airport; the flight was heading to the Ethiopian capital, Addis Ababa; all 90 people on board perish.
2010	March 22 – Aviastar-TU Flight 1906, a Tupolev Tu-204, crashes on landing at Domodedovo International Airport in foggy weather; all eight crew on board survive, but the aircraft is written off; this is the first loss of the Tu-204.
2010	April 13 – AeroUnion Flight 302, an Airbus A300B4F, crashes on a missed approach from Mexico City, Distrito Federal, Mexico, for Monterrey, Nuevo León, Mexico. All five crew members are killed, as well as one person on the ground.
2010	April 13 – Merpati Nusantara Airlines Flight 836, a Boeing 737, overruns the runway at Rendani Airport in Indonesia; all 103 people on board survive, with 23 injured, three of them seriously.

2010	April 13 – Cathay Pacific Flight 780 from Surabaya Juanda International Airport to Hong Kong lands safely after both engines thrust controls get stuck due to contaminated fuel. 57 passengers are injured in evacuation. The two pilots receive the Polaris Award from the International Federation of Air Line Pilots' Associations, for their heroism and airmanship.[1]
2010	May 12 – Afriqiyah Airways Flight 771, an Airbus A330, crashes on landing at Tripoli International Airport, killing 103 on board; the sole survivor is a child from the Netherlands.
2010	May 17 – Pamir Airways Flight 112, an Antonov An-24 with 38 passengers and 5 crew, disappears from radar 10 minutes after takeoff from Kunduz Airport in Afghanistan.
2010 <i>TM</i>	May 22 – Air India Express Flight 812, a Boeing 737-800, crashes at Mangalore International Airport after overshooting the runway, killing a total of 158 people in the worst-ever crash involving the 737-800.
2010	June 20 – The 2010 Cameroon Aéro Service CASA C-212 Aviocar crash near Djoum, Cameroon, kills all 11 on board, including the entire board of Sundance Resources, an Australian mining conglomerate.
2010	July 27 – Lufthansa Cargo Flight 8460, a McDonnell Douglas MD-11 freighter, catches fire and breaks in half as it lands at King Khalid International Airport, injuring the German pilot and co-pilot.
2010	July 28 – Airblue Flight 202, an Airbus A321, crashes into a hill in the Margalla Hills north-east of Islamabad apparently due to bad weather resulting in 146 passengers and 6 crew members perished. It is the first fatal accident involving an Airbus A321 and Pakistan's worst air disaster.
2010	August 3 – Katekavia Flight 9357, an Antonov An-24 crashes on approach to Igarka Airport, Russia, killing twelve people.
2010	August 16 – AIRES Flight 8250, a Boeing 737 splits in three after a hard landing at Gustavo Rojas Pinilla Airport, San Andrés, Colombia. Of the 125 passengers and 6 crew members on board, two passengers are killed and another 113 injured.
2010	August 24 – Agni Air Flight 101, a Dornier Do 228, crashes outside of Kathmandu, Nepal, in heavy rain, killing all 14 people on board.
2010	August 24 – Henan Airlines Flight 8387, an Embraer E-190, overruns the runway and crashes at Yichun, Heilongjiang, northeast China, causing 43 fatalities from 91 passengers and 5 crew members; this is the first hull loss of an Embraer E-Jet.
2010	August 25 – The 2010 Bandundu Filair Let L-410 crash on approach to Bandundu Airport, Democratic Republic of the Congo, kills all but one of the 21 on board.
2010	September 3 – UPS Airlines Flight 6, a Boeing 747-400, crashes at a military base shortly after takeoff from Dubai International Airport, killing both of the two crew.
2010	September 7 – Alrosa Mirny Air Enterprise Flight 514, a Tupolev Tu-154M, suffers electrical failure and makes an emergency landing at Izhma Airport; while landing, the aircraft overruns the runway and is written off; all 81 passengers and crew survive.
2010	September 13 – Conviasa Flight 2350, an ATR-42, crashes shortly before landing in Ciudad Guayana, killing 15 of the 51 people on board.
2010	November 4 – Aero Caribbean Flight 883, an ATR-72, crashes in Sancti Spíritus, Cuba, killing all 68 on board in the joint worst-ever accident involving the ATR 72.
2010	November 4 – Qantas Flight 32, an Airbus A380, suffers substantial mechanical failure of its left inboard engine after taking off from Singapore Changi Airport. The flight turns back and lands safely. All the 433 passengers and 26 crew on board are safe. Cowling parts of the failed engine fall over Batam Island.

2010	November 5 – In the 2010 Karachi Beechcraft 1900 crash a JS Air charter crashes straight after takeoff, killing all 19 passengers and 2 crew on board.		
2010	November 11 – The Zalingei Tarco Airlines Antonov An-24 crash on landing at Zalingei Airport, Sudan, kills 6 of 44 on board.		
2010	November 28 – Sun Way Flight 4412, an Ilyushin Il-76TD, suffers an engine fire and crashes near Jinnah International Airport, killing all 8 crew on board and another 4 on the ground.		
2010	December 4 – Dagestan Airlines Flight 372, a Tupolev Tu-154, skids off the runway during emergency landing at Russia's Domodedovo International Airport, killing two of the 160 passengers on board and injuring 87.		
2010	December 15 – A Tara Air de Havilland Canada DHC-6 Twin Otter crashes in the Bilandu Forest near Shreechaur, Okhaldhunga District, Nepal, killing all 22 passengers and crew on board.		
2011	January 1 – Kolavia Flight 348, a Tupolev Tu-154, erupts in flames while taxiing at Surgut International Airport, Russia, killing 3 out of 124 people and injuring 43.		
2011	January 9 – Iran Air Flight 277, a Boeing 727, crashes at Urmia Airport, Iran, during a go-around, killing 77 of 105 people on board.		
2011 TM	February 10 – Manx2 Flight 7100, a Fairchild Metroliner III, crashes at Cork Airport, Republic of Ireland, and catches fire, killing 6 of 12 people on board.		
2011	February 14 – Central American Airways Flight 731, a Let L-410 Turbolet, crashes while on approach to Toncontín International Airport, killing all 14 on board.		
2011	March 21 – The 2011 Pointe-Noire Trans Air Congo An-12 crash: an Antonov An-12 crashes on approach to Pointe Noire Airport, Republic of the Congo, killing all 4 crew on board and another 19 on the ground.		
2011	April 1 – Southwest Airlines Flight 812, a Boeing 737, ruptures a hole in the fuselage at 36,000 feet, causing the cabin to lose pressure shortly after takeoff from Phoenix Sky Harbor International Airport. The plane lands safely at Yuma International Airport, Arizona, with 116 people aboard uninjured and 2 with minor injuries.		
2011 TM	April 4 – In the 2011 United Nations Bombardier CRJ-100 crash, a Georgian Airways plane operated by the United Nations Mission in the Democratic Republic of Congo (MONUSCO) crashes on landing at N'djili Airport, Democratic Republic of the Congo; all but 1 of the 33 on board are killed.		
2011	May 7 – Merpati Nusantara Airlines Flight 8968, a Xian MA60, crashes off the coast of West Papua, Indonesia, while on approach to Kaimana Airport in heavy rain, killing all 25 passengers and crew on board.		
2011	May 18 – Sol Líneas Aéreas Flight 5428, a Saab 340, crashes off Prahuaniyeu, Río Negro, Argentina, while en route to General Enrique Mosconi International Airport, Comodoro Rivadavia due to ice formation on the wings, propellers and under the fuselage, killing all 22 passengers and crew on board.		
2011	June 20 – RusAir Flight 9605, a Tupolev Tu-134, crashes onto the Russian highway A133 near the village of Besovets, Petrozavodsk, Russia, while on approach to Petrozavodsk Airport, killing 47 of 52 on board.		
2011	July 6 – The 2011 Silk Way Airlines Ilyushin Il-76 crash: An Ilyushin Il-76 crashes into a mountain 25 kilometres (16 mi) short of Bagram Air Base in Afghanistan, killing all 9 people on board the cargo flight from Baku, operated on behalf of NATO.		
2011	July 8 – Hewa Bora Airways Flight 952, a Boeing 727, crashes on landing at Bangoka International Airport, Democratic Republic of the Congo, killing 74 of 118 on board.		
2011	July 11 – Angara Airlines Flight 5007, an Antonov An-24, ditches in the Ob River after an engine fire, killing 7 of 37 on board.		

2011 TM	July 13 – Noar Linhas Aéreas Flight 4896, a Let L-410 Turbolet, crashes shortly after takeoff from Recife Airport, Brazil, killing all 16 on board.
2011	July 28 – Asiana Airlines Flight 991, a Boeing 747 freighter, crashes into the Pacific Ocean, 112 kilometres (70 mi) west of Jeju Island, South Korea, killing the 2 crew.
2011	July 30 – Caribbean Airlines Flight 523, a Boeing 737, overruns the runway on landing at Cheddi Jagan International Airport, Georgetown, Guyana, and breaks in two; seven are injured but all 163 passengers and crew survive.
2011	August 9 – In the 2011 Avis Amur Antonov An-12 crash, an Antonov An-12, en route from Magadan Airport to Keperveyem Airport, crashes at Omsukchan, Russia, due to an engine fire, killing all 11 on board.
2011 <i>TM</i>	August 20 – First Air Flight 6560, a Boeing 737, crashes while on approach to Resolute Bay Airport, Nunavut, Canada, killing 12 of 15 on board.
2011	September 6 – Aerocon Flight 238, a Fairchild Metroliner III, crashes near Trinidad, Bolivia, killing 8 of 9 people on board.
2011	September 7 – Yak-Service Flight 9634, a Yakovlev Yak-42, crashes just after takeoff from Tunoshna Airport, Yaroslavl, Russia, due to pilot error, killing 44 of the 45 people on board. Many were players and staff of the Lokomotiv Yaroslavl ice hockey team of the KHL, as the flight was destined for Minsk, Belarus for a league game.
2011	September 25 – Buddha Air Flight 103, a Beechcraft 1900D, crashes in dense fog while attempting to land at Kathmandu Tribhuwan International Airport, killing all 16 passengers and 3 crew members.
2011 TM	October 13 – Airlines PNG Flight 1600, a de Havilland Canada DHC-8, crashes near the mouth of the Gogol River, Papua New Guinea, killing 28 of 32 on board.
2011	October 18 – Iran Air Flight 742, a Boeing 727, en route from Moscow, Russia, to Tehran, Iran, lands without nose gear at Mehrabad International Airport; all 94 passengers and 14 crew members survive without injuries.
2011	November 1 – LOT Polish Airlines Flight 16, a Boeing 767, performs a belly landing at Warsaw Chopin Airport after its landing gear failed to deploy; all 220 passengers and 11 crew members survive without injuries.
2012	April 2 – UTair Flight 120, an ATR-72, crashes shortly after takeoff from Roshchino International Airport, Tyumen, Russia, killing 31 of the 43 passengers and crew on board.
2012 TM	April 20 – Bhoja Air Flight 213, a Boeing 737, crashes near Chaklala airbase, Rawalpindi, Pakistan, in bad weather, killing all 127 people on board.
2012 TM	May 9 – In the Mount Salak Sukhoi Superjet 100 crash, a Sukhoi Superjet 100 crashes into Mount Salak, Indonesia, on an exhibition flight, killing all 45 passengers and crew on board.
2012	May 14 – In the Agni Air Flight CHT, a Dornier Do 228 crashes near Jomsom Airport, Nepal, during a go-around; of the 21 on board, 6 survive.
2012	June 2 – Allied Air Flight 111, a Boeing 727, overruns the runway on landing at Kotoka International Airport, Accra, Ghana, and crashes through a fence; the aircraft then hits a bus on a nearby road; all 4 crew survive but 12 are killed on the ground.
2012	June 3 – Dana Air Flight 992, a McDonnell Douglas MD-83 carrying 147 passengers and 6 crew members crashes in a suburb of Lagos, Nigeria, on approach to Murtala Muhammed International Airport, killing all on board and 10 more people on the ground.
2012	June 29 – Six people attempt to hijack Tianjin Airlines Flight 7554, an Embraer E-190, 10 minutes after takeoff; passengers and crew are able to restrain the hijackers until the aircraft makes an emergency landing; of the 101 on board, 2 hijackers die and 11 passengers and crew are injured; this is China's first serious hijacking attempt since 1990.

2012	September 12 – Petropavlovsk-Kamchatsky Air Flight 251, an Antonov An-28, crashes in Kamchatka Peninsula, Russia, killing 10 of the 14 passengers and crew on board.	
2012	September 28 – Sita Air Flight 601, a Dornier Do 228, crashes on the bank of the Manohara River, Kathmandu, Nepal, after a bird strike, killing all 19 on board.	
2012	October 7 – FlyMontserrat Flight 107, a Britten-Norman Islander, crashes after takeoff from V.C. Bird International Airport, Antigua and Barbuda; of the 4 on board, only 1 survives.	
2012	November 30 – In the 2012 Aéro-Service Ilyushin Il-76T crash, an Ilyushin Il-76T freighter crashes short of runway threshold on approach to Maya-Maya Airport, Brazzaville, Republic of Congo, in bad weather, killing all 6 aboard, 26 on the ground, and injuring 14.	
2012	December 17 - The 2012 Amazon Sky An-26 crash killed a crew of four, when the aircraft hit the ground while crossing the Andes.	
2012	December 25 – Air Bagan Flight 11, a Fokker 100, crash-lands on a road near Heho Airport, Myanmar, killing one on board, one on the ground and injuring 11.	
2012	December 29 – Red Wings Airlines Flight 9268, a Tupolev Tu-204 on a re-positioning flight, overruns the runway on landing at Moscow's Vnukovo International Airport, then breaks apart and catches fire; 5 of the 8 crew on board are killed in the first fatal accident involving the Tu-204.	
2013	January 29 – SCAT Airlines Flight 760, a Bombardier CRJ200, crashes in thick fog on approach to Almaty International Airport, Kazakhstan, killing all 16 passengers and 5 crew on board.	
2013	February 13 – South Airlines Flight 8971, an Antonov An-24, crash-lands in dense fog at Donetsk International Airport, Ukraine, killing 5 of 52 people on board.	
2013	April 13 – Lion Air Flight 904, a Boeing 737 carrying 101 passengers and 7 crew members, crashes into the ocean while attempting to land at Ngurah Rai International Airport on the Indonesian island of Bali, injuring 46 people.	
2013	April 29 – National Airlines Flight 102, a Boeing 747 freighter, stalls and crashes shortly after takeoff from Bagram Airfield, Afghanistan, due to load shifting, killing all seven crew members on board.	
2013	May 16 – Nepal Airlines Flight 555, a de Havilland Canada DHC-6, overruns the runway on landing at Jomsom Airport, Nepal, injuring seven people.	
2013 TM	July 6 – Asiana Airlines Flight 214, a Boeing 777, crashes short of the runway on landing at San Francisco International Airport, killing three of 307 on board and injuring 182. The crash was the first fatal accident involving the Boeing 777.	
2013	July 7 – A de Havilland Canada DHC-3 operated by Rediske Air crashes on approach to Soldotna Airport, Alaska, killing all 10 people on board.	
2013	August 14 – UPS Airlines Flight 1354, an Airbus A300 freighter, crashes short of the runway on approach to Birmingham–Shuttlesworth International Airport, killing the two crew on board.	
2013	October 3 – Associated Aviation Flight 361, an Embraer 120, crashes shortly after takeoff from Murtala Muhammed International Airport, Lagos, killing 15 people on board.	
2013	October 16 – Lao Airlines Flight 301, an ATR-72, crashes shortly before landing at Pakse International Airport under adverse weather conditions, killing all 44 passengers and 5 crew on board.	
2013	November 17 – Tatarstan Airlines Flight 363, a Boeing 737, crashes at Kazan International Airport, Russia, during a go-around, killing all 50 people on board.	
2013	November 29 – LAM Mozambique Airlines Flight 470, an Embraer 190, en route from Maputo International Airport, Mozambique, to Quatro de Fevereiro Airport, Angola crashes into Bwabwata National Park in northern Namibia, killing all 33 people on board.	

2014	February 16 – Nepal Airlines Flight 183, a de Havilland Canada DHC-6, crashes near Khidim about 74 kilometres southwest of Pokhara, Nepal, killing all 18 people on board.		
2014	February 17 – Ethiopian Airlines Flight 702, a Boeing 767, is hijacked by the co-pilot while en route from Addis Ababa, Ethiopia, to Rome, Italy, but lands safely at Geneva, Switzerland. All 202 passengers and crew aboard are unharmed.		
2014	March 8 – Malaysia Airlines Flight 370, a Boeing 777 en route from Kuala Lumpur to Beijing with 227 passengers and 12 crew on board, disappears from radar over the Gulf of Thailand. A wing part was later found in Réunion.		
2014	July 17 – Malaysia Airlines Flight 17, a Boeing 777 en route from Amsterdam to Kuala Lumpur, is shot down over eastern Ukraine, killing all 283 passengers and 15 crew on board in the deadliest civilian airliner shootdown incident.		
2014 TM	July 23 – TransAsia Airways Flight 222, an ATR-72 en route from Kaohsiung to Penghu, Taiwan, crashes during go-around, killing 48 of the 58 people on board.		
2014	July 24 – Air Algérie Flight 5017, a chartered Swiftair McDonnell Douglas MD-83 operating for Air Algérie en route from Burkina Faso to Algiers, crashes in the northern Mali desert after disappearing from radar approximately 50 minutes after takeoff, killing all 110 passengers and 6 crew members on board.		
2014	August 10 – Sepahan Airlines Flight 5915, a HESA IrAn-140 (an Antonov An-140 built under license) crashes shortly after takeoff from Mehrabad International Airport, Iran, killing 39 of the 48 people on board.		
2014 TM	December 28 – Indonesia AirAsia Flight 8501, an Airbus A320 en route from Surabaya, Indonesia to Singapore, crashes into waters off Borneo, killing all 155 passengers and 7 crew on board.		
2015	February 4 – TransAsia Airways Flight 235, an ATR-72, stalls on takeoff and crashes into the Keelung River in Taiwan after striking the Huandong Viaduct and a passing taxi. 43 of the 58 passengers and crew on board were killed.		
2015	March 5 – Delta Air Lines Flight 1086, a McDonnell Douglas MD-88 skids off the runway at LaGuardia Airport and crashes into a fence, coming inches from Flushing Bay. Several people were injured, but there were no fatalities.		
2015	March 24 – Germanwings Flight 9525, an Airbus A320, crashes in southern France en route from Barcelona, Spain to Düsseldorf, Germany as a result of a deliberate act by the first officer. All 144 passengers and 6 crew on board the aircraft died in the crash.		
2015	March 29 – Air Canada Flight 624, an Airbus A320, crashes short of the runway and hits power lines while landing at Stanfield International Airport, en route from Toronto. All 138 passengers and crew on board survive, with 23 treated for minor injures.		
2015	April 14 – Asiana Airlines Flight 162, an Airbus A320, crashes short of the runway and hits a localizer while landing at Hiroshima Airport, after en route from Seoul. All 82 passengers and crew on board survive, but 27 are injured.		
2015	April 25 – Turkish Airlines Flight 1878, an Airbus A320, is severely damaged in a landing accident at Atatürk International Airport. All 102 passengers and crew on board are evacuated without injury.		
2015	August 16 – Trigana Air Service Flight 257, an ATR-42, crashes while en route from Sentani Airport, to Oskibil Airport in the eastern Indonesian province of Papua. All 49 passengers and five crew members are killed in the crash in the worst aviation accident ever involving the ATR-42.		
2015	September 5 – Ceiba Intercontinental Airlines Flight 71, a Boeing 737-800, collides in a mid-air with a BAe 125 air ambulance operated by Senegalair over eastern Senegal. The BAe 125 crashes in the Atlantic killing all 7 on board, while the 737 lands safely without any injuries to those on board.		
2015	September 8 – British Airways Flight 2276, a Boeing 777-200, aborts takeoff at McCarran International Airport following an engine fire. All 189 passengers and crew were evacuated safely.		

2015	October 2 – Aviastar Flight 7503, a DHC-6 Twin Otter, crashes on a mountain 11 minutes after take- off over Palopo, Indonesia, killing all 10 passengers and crew on board.	
2015	October 29 – Dynamic Airways Flight 405, a Boeing 767-200, erupts in flames while preparing for take-off at Hollywood International Airport. All 101 passengers and crew on board survive, but 21 people are injured.	
2015	October 31 – Metrojet Flight 9268, an Airbus A321, explodes in mid-air due to a terrorist bomb over the Sinai Peninsula 23 minutes after takeoff from Sharm-El-Sheikh, killing all 224 passengers and crew on board.	
2015	November 4 – In the 2015 Juba An-12 crash, an Allied Services, Ltd. Antonov An-12 crashes near the White Nile shortly after takeoff from Juba International Airport, killing 37 of 39 on board.	
2015	November 22 - Avia Traffic Company Flight 768, a Boeing 737-3YO, was on final approach to Osh Airport when it touched down hard enough to shear off the left and right main landing gear. The aircraft skidded off the runway with the left engine being torn from its mount. All 159 survive.	
2016	January 8 - West Air Sweden Flight 294, a Bombardier CRJ200 cargo freighter, crashes while in cruise near Akkajaure in Sweden. Both crew members on board are killed.	
2016	February 2 - Daallo Airlines Flight 159, an Airbus A321, suffers an explosion shortly after taking off from Aden Adde International Airport, Somalia. Two people are injured and one, the suspected suicide bomber, is killed after falling from the aircraft.	
2016	February 24 - Tara Air Flight 193, a Viking Air-built DHC-6 Twin Otter, flies into a storm and crashes into a mountain side at Dana, Myagdi district, Nepal killing all 23 on board.	
2016	February 26 - 2016 Air Kasthamandap crash, an Air Kasthamandap PAC 750XL crash lands, killing the two crew members and injuring nine passengers in Nepal.	
2016	March 19 - Flydubai Flight 981, a Boeing 737-800, crashes while landing at Rostov-on-Don, Russia, in poor weather. All 62 people on board are killed.	
2016	March 29 - EgyptAir Flight 181, an Airbus A320, is hijacked and forcefully diverted to Larnaca International Airport, Cyprus. All passengers and crew are released unharmed.	
2016	April 4 - Batik Air Flight 7703, a Boeing 737-800, collides with an ATR 42 on the runway at Halim Perdanakusma Airport in Jakarta. Both aircraft are substantially damaged.	
2016	April 13 - In the 2016 Sunbird Aviation crash, a Britten-Norman Islander crashes short of the runway while landing at Kiunga, Papua New Guinea. All 12 people on board are killed.	
2016	April 29 - In the 2016 Turøy helicopter crash, a Eurocopter EC225L Super Puma helicopter, crashed near Turøy, an island off of Norway. All 13 passengers and crew on board were killed.	
2016	May 18 - 2016 Silk Way Airlines Antonov An-12 crash, a Silk Way Airlines Antonov An-12 cargo plane crashes after an engine failure, killing seven and injuring two.	
2016	May 19 - EgyptAir Flight 804, an Airbus A320, crashes into the eastern Mediterranean Sea after a series of sharp descending turns. All 56 passengers and 10 crew are assumed killed.	

# **Appendix C: ASRS Reports**

All of the ASRS reports that were identified as being related to TM are shown in Table C-1. Each report contains the ACN, a brief synopsis, the TM error category, and the narrative. The TM categories include: Task Initiation (Early, Late, Incorrect, Lack), Task Monitoring (Excessive, Lack), Task Prioritization (High, Low), Resource Allocation (High, Low), Task Termination (Early, Late, Lack, Incorrect), Task Interruption (Incorrect), Task Resumption (Lack), and Workload (High, Low).

#### Table C-1 – TM Error Related ASRS Reports

ACN: 868417	Synopsis: CRJ-200 First Officer reports generator #2	TM Error Categorization:
	failed during climb with the Captain selecting #1	Task initiation - lack
	generator off without referring to the QRH or	Task prioritization - high
	informing the First Officer, this resulted in ADG	
	deployment with attendant cockpit system failures.	
	Flight crew returned to their departure airport.	

Narrative: The autopilot was engaged at approximately 2,000 FT and we were given a climb clearance to 12,000 FT MSL and told to proceed direct DITCH. At approximately, 10,500 FT MSL, we were given a frequency change to Center. At approximately, 11,000 FT MSL, we had GEN 2 OFF Master Caution. I acknowledged it and looked down and to my left to retrieve the QRH. While my head was down, the Captain, inadvertently, powered off Gen 1. The ADG deployed and the power transfer took place. During the transfer, multiple screens went black. After a few seconds of disorientation, I figured out what had happened and asked the Captain if he had hit Gen 1. He nodded in acknowledgement. The screens reappeared and I noticed we were still climbing and turning left with the autopilot disengaged. The flight director reappeared in Roll/Pitch mode when he pushed the autopilot button and commanded a climbing left turn. He began to follow the flight director rather than my instructions and I, again, prompted him to push the nose down and turn right to reestablish course direct DITCH. He did not and I pushed the nose down myself and begin turning the plane toward the fix. He still seemed very disoriented, so I asked him multiple times if he had the airplane. He acknowledged and I contacted our new frequency and said we had had an autopilot malfunction and were descending back to assigned altitude and needed a heading to reestablish course. This entire episode lasted maybe 90-120 seconds. We were given delaying vectors and we started on the checklists. I, then, ran the GEN 2 OFF QRH and was unsuccessful in restoring power. I ran the Inadvertent ADG Deployment QRH and reestablished normal electrical power. I called the Flight Attendant and advised her of the situation and told her we would most likely be returning. We contacted Dispatch and told them we thought returning was best option and she agreed. I called Operations and got a gate for the return and then advised the passengers of the situation. I told the Flight Attendant that there was no need to prepare the cabin and to expect a normal landing and taxi-in to the gate. We then ran normal checklists and briefed a visual approach, and the approach and landing were normal. The main issue here was the lack of CRM and following of checklist protocol/SOP's. The Captain's decision to pull a lever-locked switch without running the QRH and, more importantly, without even confirming it with me, led to much worse situation than the original Gen 2 malfunction. It is also, ultimately, what caused the altitude/course deviation. To be honest, I really do not know what I could have done differently. I was reaching down for the QRH and his arm movement was out of my sight plane. I did not even know what he, exactly, had done until after the action was taken. After figuring out what had occurred, I did the best I could to deal with the situation at hand. I tried to make sure we reestablished heading and altitude as quickly as possible. We ran the appropriate checklists and landed normally thereafter. On a separate note, the Captain seemed to have trouble reestablishing control of the airplane for several minutes after the power transfer took place. I kept having to assist him with reminders about his headings and altitudes. I am sure this was due to some level of disorientation, but it was also due to fact he kept trying to re-engage

the autopilot rather than just hand-flying the airplane. The Stab Trim had not been re-engaged at any point until I pointed it out to him. Therefore, the autopilot would not keep up. We kept having AP NU/ND caution messages and altitude deviations of about 200 FT. I wish our training department would rethink this march toward automation we have been on. I really think some emphasis of hand-flying would help in these situations because some of my stress about the airplane's flight path could have been alleviated if the Captain had not been ingrained with use of the automation to the fullest extent.

ACN: 870051Synopsis: A DHC-8-400 (Q400) crew distracted by<br/>weather, turbulence, EFB usage and passenger safety,<br/>forgot to reset a low altimeter (29.11) while climbing<br/>to FL230 and were subsequently advised by ATC of an<br/>altitude deviation.TM Error Categorization:<br/>Task prioritization - low<br/>Task monitoring - excessive<br/>Resource allocation - low<br/>Workload - high

**Narrative:** We were climbing to FL230. The altimeter departing was 29.11. There were multiple lines of thunderstorms in the valley and high winds on the east side of the mountains. We were delayed for maintenance before departure and had the passengers on board for an hour. Passengers were using the bathroom despite the turbulence. Both Pilots were distracted and did not reset the altimeter to 29.92. We had 29.11 set in from our departure resulting in a large deviation. The Controller made us aware and we fixed the problem. As pilot flying I was studying the EFB, watching the multiple lines of weather moving across the valley, and looking at reports over the mountains. I wanted to get an inflight service in, but as we had the passengers on the aircraft for a one hour mechanical fix on the ground, I was more concerned because people were using the lavatory and I wanted to find smooth air. I got sucked into the EFB and forgot to reset altimeter to 29.92. The First Officer was having some problems with a frequency change. The reception was poor and we were given a wrong frequency. It took a couple minutes to resolve and get on the correct frequency. As a result of working this out, she too forgot to reset her altimeter. As we checked on to the new frequency, the Controller asked what our altitude was. I immediately saw the problem, pushed the button, and the autopilot headed down to 230. Before I could get there the Controller cleared us to FL250 and didn't say another word.

ACN: 877092	Synopsis: A B737-300 First Officer flying an ILS	TM Error Categorization:
	entered a stall warning regime after fixating on	Task monitoring - excessive
	instruments other than airspeed as the aircraft slowed	Resource allocation - high
	while capturing the glide slope. A go-around was	Workload - high
	executed followed by a second normal approach.	_

**Narrative:** The aircraft had come from Maintenance and had not been revenue flown for approximately 14 days. Notation was made on initial takeoff that #1 engine was slow to spool. The first leg was flown by the Captain to a VFR and VMC constant descent approach and landing. Subsequent takeoff accomplished by the First Officer was also evident of an extremely slow to spool #1 engine. Autopilot was coupled throughout descent and approach. Descent was uneventful and the aircraft was vectored for an ILS to Runway 35. The aircraft entered a solid deck at approx 11,000'. The weather was approximately 400 FT OVC/5NM VIS and 10-15 KTS right crosswind at FAF. Course intercept occurred prior to initial approach fix at 5000 FT MSL. ATC requested to maintain 170 KTS until the final approach fix. 3000 FT was set in the altitude window of the MCP. A gradual descent was established. Flaps to 15 and landing gear were established sometime prior to the final approach fix. The aircraft was slightly left of the localizer course throughout with a heading a few degrees to the left. At approximately 8 NM to the final approach fix, the aircraft was slowly reaching 3000 FT MSL. The First Officer, while initiating an instrument crosscheck, began to simultaneously add power abruptly to his known reference point for the configuration, called for Flaps 30, noticed the GS V bar was descending at 1/4 dot from above the aircraft cue. The aircraft continued descent through 3000 FT upon which the First Officer fixated on the altimeter, GS reference and

VVI. The aircraft descended approximately 80 FT below. At this time the aircraft was approximately 4 NM from the final approach fix and began to pitch up to the GS reference to a VVI of 800 FPM. The First Officer immediately began forward pressure on the control column. Airspeed began to decay rapidly. The First Officer first noticed the speed decay passing through target speed, which rapidly became 5 below in less than a second. The First Officer, knowing of an impending stick shaker at this time, began applying forward column pressure and power. After the Captain had reached over to set Flaps 30, he noticed the airspeed decay and said easy now as the speed was decaying just past target realizing I was making a significant correction. At the time we were 10-15 KTS below target and the Captain and First Officer both popped the control column forward just as the stick shaker started. The First Officer now pushed full forward and shoved the power further and started to run nose down trim to disengage the autopilot. The shaker lasted less than 2 seconds. The First Officer elected to continue a descent another 350 FT leveling off until significant airspeed was acquired. At this point the aircraft was left full scale localizer deflection. The First Officer said and initiated a go-around. Another approach was executed and the aircraft landed uneventfully. Although time dilation is a factor when things go south, I feel pretty confident the time line is very close. From start to finish with all the factors impacting at once, I feel it only took seconds for this situation to fully develop from a perceived stable flight control/throttle position. I accept full responsibility for the under speed condition of the aircraft. Besides human error, three factors combined to rapidly develop a situation which should have not happened: significant semi-asymmetrical reduction in thrust, weather, and automation. I accept full responsibility for the occurrence. However, a few aggravating conditions along with human error exacerbated this occurrence within seconds. In this -300, the aircraft sought to pitch up to GS intercept while I expected the aircraft to pitch over during Flaps 30 extension which was occurring simultaneously. I set throttle position for the flight conditions/parameters at the time by feel and then fine tune them visually/auditorily (Quadrant, N1s, noise). I was not able to and frankly had to drop that from a crosscheck when I focused on an aircraft descending then ascending and wondering why this was happening. I fixated on ADI, VVI, and altimeter losing the airspeed momentarily. Once recognized, I was on the back side of the curve. I feel this was no ordinary simulator profile recovery. While all good the simulator is, it sets up only for a perfectly flown known condition. Here comes a stall configure trim, trim, trim, wait, wait, ok now. I always ride and I had ridden the flight controls during this situation. If not, with the rapidly changing dynamics, it could have been different. The only comment from the Flight Attendants was to why we went around. Automation, especially autopilot issues when intercepting, need addressing (GS descent/localizer stability). The simulator does it so perfectly, but in the real world, the aircraft do not. Engine spool up parameters need addressing. Finally, ride the controls in demanding flight conditions which this was. If it had been VMC/VFR, my workload would have been significantly reduced and a few parameters been negated. However, we don't always get to fly the simulator profile day-to-day.

<b>ACN</b> : 879960	Synopsis: A B737 First Officer discusses CRM failures	TM Error Categorization:
	of the Captain with whom he is flying for the first time.	Task termination - early
	The Captain however only addresses distractions and	Task resumption - lack
	aircraft equipment automation differences, which	Resource allocation - low
	caused an altitude deviation.	

**Narrative**: This was our first flight together. We began by discussing frost removal procedures. After pushback and before I had chance to finish reading checklist, the Captain started rolling to Deice Spot. I tried to slow down the pace due to workload and incomplete checklist. He proceeded to roll to Deice Spot without clearance. I immediately notified Ground Control that we were already taxiing to the Spot. Before the aircraft rolled to a stop, the Captain reached down and called 'Iceman' on frequency and turned packs, APU/engine bleeds off, while calling for the Deice checklist. I was quite confused. Before the truck arrived, I noticed an Autofail light had illuminated. We checked the QRH and it required further evaluation. I asked him if he wanted to complete the QRH issue before getting deiced. He said we would continue to get deiced and handle it later. The pace seemed to be all that mattered at this point. The Captain decided to handle the now intermittent light on the way to the departure runway. We taxied out after completing all

necessary checklists. After thirty minutes of consulting with Dispatch, at the end of 4R we taxied back to the gate. Fixed the issue and took off for IND. Enroute at FL210 I pulled up the ATIS via ACARS. The ATIS reported zero miles visibility; there were no RVR values listed. We both seemed a little surprised how dramatically the weather dropped and how Dispatch never clued us in. I told the Captain I was off to gather more info from the ATIS if possible. The Captain was now in charge of radios and flying the aircraft. I needed a little extra time to figure out if we could get in with the lack of RVR reports. I contacted Dispatch and got the info I needed. Tower visibility was zero; the RVR was greater than 6,000 FT.I had just returned from listening to the radios when the Captain asked ATC if we could get direct to the airport. Center responded, 'Uh, Sir. You were supposed to cross JAKKS at 13,000.' I looked up and saw he had put it in the altitude alerter, but not in the FMC. We were now about 1 mile north of JAKKS and 8,000 FT high. This added to my frustration to say the least. ATC gave us a couple of vectors to get down and we landed uneventfully. Slow down the pace! This is not single Pilot Ops. I do not understand why so many Captains think it's do or die when flying the jet. Instead of trying to release the brakes before the door closes, rush through checklists, fly the aircraft, talk to Maintenance, deice crews, the flight attendants, and taxi at 30.9 mph, I think the Captain needs to look at the big picture. The First Officer is a resource many Captains ignore. I feel like nothing more than a radio man for some of the guys.

ACN: 880605	Synopsis: B737-400 flight crew reports forgetting to	TM Error Categorization:
	reset altimeters to 29.92 passing 18,000 FT in the	Workload - high
	climb, resulting in a 1,300 FT overshoot due to very	Task prioritization - high
	low altimeter setting. Crew cites fatigue and ATC	Task initiation - late
	distractions as contributing factors.	

**Narrative**: I departed on day 4 of a 4 day trip. First flight of the day, [we had a] low altimeter setting, 28.59. On climb we did not get the altimeter set to 29.92 passing 18,000 FT. This resulted in us being 1,300 FT above our assigned altitude at level off. ATC informed us we were off altitude. I see 3 reasons why this happened. First when we were passing 18,000 FT we were working with ATC on a reroute. There was confusion on what our new route was. This confusion over the clearance distracted us at the time we should have set the altimeter to 29.92. Second, we have no climb check. Third, we were on the last day of a 4 day trip that we flew over 28 hours. The 4 day trip involved many weather issues, holding, and many operational irregularities. We were tired. Our trip had swapped early flying for late flying for early flying. We ended up overflying by 3.5 hrs. I don't think we realized just how fatigued we were. We corrected the altimeter setting and corrected the altitude. Trip parings should be built that try to avoid flipping the circadian clock, also two five leg days in a 4 day trip that also flies two transcontinental flights has a very high potential for fatigue to build up over the course of the trip. Any way you look at it flying over 28 hrs in four days is fatiguing.

<b>ACN</b> : 883145	Synopsis: A B757-200 flight crew overshot a hard	TM Error Categorization:
	altitude at PAYSO on the EAGUL 3 RNAV STAR to PHX.	Workload - high
		Task prioritization - low
		Task initiation - late
		Resource allocation - low

**Narrative**: While descending via the EAGUL3 RNAV into PHX, 12000 was set in the MCP altitude window and VNAV was initially selected. During descent the First Officer opened the speed brakes and selected speed intervene to get the green arc on PAYSO. This was his first trip after IOE so I explained with 12000 in the MCP and 240 programmed for PAYSO the green arc would not be on PAYSO. The First Officer then closed the speed brakes and I thought closed the speed intervene - in fact he selected FLCH (flight level change). Descent continued and shortly thereafter I expected the aircraft to level at 240 for PAYSO but about 3 miles prior it continued descent through 240 [a required crossing flight level]. I then saw FLCH and said we needed to level at 240. The aircraft dipped to FL23.6 and was returned to 240. The rest of the descent continued normally. My not noticing the selection of FLCH, radio calls, new MCP SOP, being somewhat tired and First Officer 'newness' with Boeing were all contributing factors.

<b>ACN</b> : 883679	Synopsis: B757 Flight Crew reports runway change by	TM Error Categorization:
	ZLA prior to KONZL on the SEAVU arrival to LAX,	Workload - high
	resulting in an altitude deviation at KONZL.	Task interruption -
		incorrect
		Task initiation - early
		Task prioritization - low

Narrative: We were on the SEAVU arrival into LAX. ATC cleared us to cross KONZL at 17,000 FT. I was using vertical speed because VNAV had been inconsistent earlier during the flight. Approximately 5 NM from KONZL, as we were approaching 17,000 FT, but not yet in altitude hold, ATC simultaneously changed our runway assignment and cleared us for the descent via the arrival. I entered the next altitude in the window as the Captain reprogrammed the FMS for the new runway. A few seconds later, as we reviewed the new runway information, I realized we were descending through 16,700 FT and still 2.4 NM from KONZL. I quickly disengaged the autopilot and corrected to 17,000 FT as we crossed KONZL. I believe the altimeter touched 16,600 during my correction. We checked the TCAS and saw no aircraft within 5 NM at any altitude. ATC didn't mention our altitude deviation. My use of vertical speed combined with the altitude change just prior to level off (and therefore prior to ALT CAP) allowed vertical speed to briefly fly through our assigned altitude. Nothing new here. Just a reminder of good old fashioned pilot sense. Perhaps we had been missing some entry in the FMS which caused VNAV to work incorrectly. That caused a break in our habit patterns (using vertical speed instead of VNAV), which during a busy moment caused me to lose attention momentarily. In the future, I will make sure one pilot is always watching the plane and making sure it is conforming to the clearances (KONZL at 17,000) instead of both of us scrambling to implement multiple changes to our clearance.

ACN: 884478	Synopsis: The crew of a B737-300 missed an altitude	TM Error Categorization:
	crossing restriction because the FMC was used to get	Task monitoring - lack
	ATIS while a descent to the restriction should have	Task initiation - early
	begun.	Workload - high

**Narrative**: We were at cruise at FL 230 and told to cross a fix at FL 190. I was the pilot not flying so I read back the radio call and the pilot flying put 19,000' in the altitude window. We both verified it and I finished copying down the ATIS. When I was done, the pilot not flying immediately put the crossing restriction in the LEGS page and we saw we were close. We started down and got a frequency change. When we checked on with the Center, the frequency was extremely congested and we weren't able to ask for relief on the altitude by the time we reached the fix. When we were finally able to check on, they asked if the previous Controller had issued a crossing restriction and we said they had. If in an aircraft with one FMC, make sure to put in crossing restrictions before continuing on with copying down the ATIS.

ACN: 885577	Synopsis: B737-700 flight crew experienced difficulties	TM Error Categorization:
	attempting to practice a RNAV approach in VMC.	Task prioritization - high
	Control wheel steering was inadvertently selected and	Task monitoring - excessive
	the aircraft descended prematurely triggering a low	Task initiation - lack
	altitude alert from ATC and an EGPWS warning. A	Task termination - late
	visual approach ensued.	
Nemetice: On ve	stars with approach into IAV we requested the DNAV/(CDC)	21 Up palead if we pould go

**Narrative**: On vectors with approach into JAX, we requested the RNAV (GPS) 31. He asked if we could go direct NIBLE (IAF), we accepted, and then started the turn. At this point we were past NIBLE and had to turn about 140 degrees, virtually entering a downwind. Approach then cleared us for the RNAV approach. The Captain was the pilot flying. I believe it was his first attempt at practicing an RNAV approach. I have

only done one myself. Due to the close proximity to NIBLE, the autopilot was turning right towards the fix and shortly started a left turn towards POTME. At some point, the Captain unknowingly disengaged LNAV and went into Control Wheel Steering. I alerted him that he was in Control Wheel Steering, but he did not respond. I'm not positive what happened next, but we were off course, confused with what the airplane was doing, and descending. The Captain disengaged the autopilot and continued descending while flying away from the field. I instructed him a couple times to stop descending and that he needed to level off. I pointed in the direction of the field and told him we needed to climb and get back on glidepath. Due to being uncomfortable and fixated with the new RNAV procedures, the Captain was unresponsive to my verbal alerts. As we started turning towards the field, we were off course and low. We had descended below the charted altitude at POTME of 2,600 FT to about 1,700 FT MSL which is about nine miles from the TDZ. ATC alerted us to our altitude, I responded with 'correcting,' and requested the visual to 31. He cleared us for the visual. We got back on glidepath and landed. This event occurred as direct result of being unfamiliar with the new RNAV procedures. We, as pilots, must be extra aware and alert of our own limitations with these procedures. Always fly the airplane! I felt I was assertive as the pilot not flying, but there was room for improvement on my end as well. Listen to other crew members and always practice good CRM.

ACN: 892019	Synopsis: An overwater B767ER flight crew failed to	TM Error Categorization:	
	comply with a time restricted climb clearance when	Task initiation - late	
	they mistook an ATC clearance uplink chime for a call	Task prioritization - low	
	from the Flight Attendants.	Workload - low	
Narrative: Flight	had obtained Oceanic Clearance normally from New York O	ceanic, and had entered NAT	
track at JOBOC,	FL 340 proceeding to 41N060W. At approximately XA02Z, the	e Flight Crew heard a chime	
and responded t	o a cabin call from Flight Attendants. About ten minutes afte	er the conversation had ended	
on the interphor	ne, the Captain noticed the upper EICAS screen had white 'AT	۲C' displayed. ATC key on the	
FMS was selecte	d and an ATC UPLINK was present: 'Climb to reach FL 350 by	XA17Z. Report level FL 350.' A	
climb was initiat	ed and the CPDLC message was acknowledged at XA23Z with	າ WILCO. We then received	
confirmation at 2	XA25Z with 'Level at FL350'. Obviously we had misinterprete	d the CHIME as a cabin call,	
when in fact it was an ATC Uplink chime directing an altitude change. Preventative measures could include			
emphasis in brie	fings that CPDLC equipped aircraft have the possibility of rec	eiving revised Oceanic	
Clearances via A	TC Uplink as well as via SELCAL.		
	_		
<b>ACN</b> : 900143	Synopsis: B737-700 flight crew missed their ATC	TM Error Categorization:	
	assigned crossing restriction on arrival to LAX.	Task initiation - late	
		Task prioritization - low	
		Workload - high	

**Resource allocation - low** 

**Narrative**: On the arrival, we were set up for 24R and were told to cross RIIVR at 13,000 and expect 25L. We requested 24R and was told it didn't look good. The Captain started to set the FMC up for 25L and, approximately ninety seconds later, we were told to cross SEEVU at 250 knots and then cleared for the 25L approach. We were at 280 knots previously assigned. I then went heads-down to finish setting up for the 25L approach. A few seconds later, ATC asked us to start our descent to 13,000, which is when I saw we were high on the arrival. The Captain started the descent with the speed brakes. We would have met the crossing, but then we were asked if we were at 250 knots. I confirmed we were at 280 and told to slow to 250 at SEEVU. We were then told he wanted us at 230 knots immediately. We started to slow and I realized we would never meet the crossing. I informed ATC who then gave us a heading south of the arrival and we were told to descend to 11,000 and to expect a turn back on course in one minute. We were then turned back in and landed without incident. (Of note, the Captain later told me we were given relief for the crossing restriction to slow, but I never heard it.) We never missed a crossing because of the vector after informing ATC we would miss it, but it was enough of a cluster to file an ASAP Report.

Synopsis: An air carrier First Officer failed to select the	TM Error Categorization:
MCP Altitude Capture during a descent to an ILS and	Resource allocation - low
subsequently descended below the glide slope which	Task initiation - incorrect
caused ATC to issue a low altitude alert.	Workload - high
	<b>Synopsis</b> : An air carrier First Officer failed to select the MCP Altitude Capture during a descent to an ILS and subsequently descended below the glide slope which caused ATC to issue a low altitude alert.

Narrative: Descended too soon inbound to JFK via LENDY 5 arrival, then vectors for VOR/DME 13L. Approach Controller was giving final speed adjustments to us, when midstream he said Tower just advised that a layer was moving in and we were now cleared to 'stay where you are for now' (descending to 2,000 FT) and 'you're cleared to cross Canarsie at 1,000 FT (which are the lower altitudes allowed on the approach when cleared by ATC) cleared approach, contact Tower 119.1 good day.' So the Captain, thinking we were closer in then we actually were, reached up to change the altitude in the MCP window, while I was reaching cross cockpit to adjust speed and continue slowing. So the airplane no longer had a 'floor' of 2,000 FT at which to get Alt Cap and Alt Hold instead we kept descending in FLCH so as soon as I detected we were not level nor slowing as swiftly as I was expecting, I'm cross checking speed/distance and note we should be higher 'out here' and immediately arrested the descent with V/S vertical speed mode. As we're doing this the Tower calls us and says altitude alert so I then initiate a climb to get back up to profile. We were over the Van Wyck Expressway on the Canarsie arrival and could see through the numerous holes/patches in the clouds so we verified our position and continued the approach without any further complications. To prevent recurrence, get down sooner, drag it in (which is hard in New York). That way last minute changes would occur while the aircraft is already in Alt Hold or better adherence from crewmembers to SOP which would have included stating the change to the MCP altitude window.

ACN: 01529/	Supersic: An A221 Captain executed a go around at	TM Error Catagorization
ACN. 913284	Synopsis. An ASZI Capitain executed a go around at	The Error Categorization.
	3000 FT on an unstabilized approach after ATC asked	Task termination - early
	him to keep his speed up while IMC and then changed	Task initiation - incorrect;
	runways. During the go-around the automation was	late
	disconnected, he got vertigo and oversped the flaps.	

**Narrative**: During ILS Approach to Runway XX while I was the flying pilot, an aircraft anomaly and my failure to address it in a timely manner caused an unstabilized approach and subsequent go-around during which the selected flaps were overspeed by 15 KTS for approximately 5 seconds. We were initially cleared for the arrival to Runway YY at but then changed to the ILS XX at the IAF. We were also told to maintain 220 KTS on the approach but, when switched to the final Controller, were asked to increase to 250 KTS for spacing. We were in IMC during the whole approach. At about 5,000 FT, just as we were intercepting the glide slope, we were told to decrease to 220 KTS or less and Contact Tower. I selected managed speed and deployed the speed brake at this time. The First Officer had already activated and confirmed the ILS XX approach on his MCDU at my request (I watched him do it). As we started down the glide slope, I did not

initially notice that the engine thrust had not reverted to idle, and I couldn't understand why the airspeed was not decreasing. After a few seconds, I saw the positive thrust indications and in an attempt to salvage the approach, I disconnected the autothrust and autopilot. As I maneuvered above the glide slope in an attempt to slow the aircraft more quickly, I began to experience spatial disorientation and vertigo but did not recognize what was happening to me right away. I continued to try to slow the aircraft and fly the approach, but after s-turning on the localizer a few times and remaining well above the glide path, I finally realized I needed to make a go-around at about 3,000 FT. The go-around was not pretty because of my disorientation but I finally got everything under control with the exception of overspeeding the flaps in position 1 (I estimate I increased to 250 KTS for about 5 seconds before they were up). The second approach was uneventful and, when we arrived at the gate, Maintenance did an overspeed inspection of the flaps with no damage noted. We ended up pushing back 11 minutes late for our next leg. Several things contributed to this event happening. First, the high workload associated with flying into this high density airport during IMC operations where runway changes at the last minute and speed changes during the approach are common. Secondly, the aircraft anomaly of the thrust not coming back to idle when you expect it to (I have had this happen to me one other time, but it was during a VMC approach, so was not a serious problem). Thirdly, the fact that this was an A321 aircraft - an airplane I rarely fly and one which is harder to slow down and has different flap speed limits than the A319/A320 model. And last and most importantly, because I made several bad decisions - to keep my speed up as long as I did, to disconnect the autopilot in IMC hence causing the subsequent spatial disorientation, to try saving the approach for as long as I did, and to not be prepared for the missed approach when it became obvious I needed to do it. I want to add that the First Officer wasn't just sitting on his hands while all this was going on - he was attempting to help me by stating localizer and glide slope deviations, airspeeds and altitudes, and reminding me of gear and flap settings but neither of us really recognized I was experiencing vertigo until after the fact. A few ways I could have handled this situation better are: 1) Not letting ATC dictate my speed schedule so much - just say no! 2) Staying with the automation in IMC. 3) Not trying to salvage unstable approaches. 4) Being prepared for a go-around on every approach.

<b>ACN</b> : 915610	Synopsis: A CRJ900 crew became distracted by a FLT	TM Error Categorization:
	SPLRS caution and after an uncommanded roll the	Task initiation - incorrect
	Captain was communicating with the cabin while the	Workload - high
	First Officer began a descent to FL240 when the	Resource allocation - low
	clearance was to FL270.	Task interruption -
		incorrect

**Narrative**: I was the pilot not flying and my First Officer was the pilot flying. Our cruise altitude was FL340, on our decent approximately at FL300 the First Officer deployed the flight spoilers, at which I noticed the airplane beginning an uncommanded roll. I immediately advised the First Officer to stow the spoilers. We then got an OB Spoiler on caution message accompanied by a FLT SPLRS caution message. At this point I was still working the radios and trying to access the problem, as well as communicate with the Flight Attendant in the back who had called up. Somewhere in this mass confusion ATC gave us a clearance to FL270. I scrolled the altitude selector to FL240 and confirmed it with the First Officer, and he began the descent. As the descent was in progress I called to the Flight Attendant and communicated with her for a little bit, and then noticed the First Officer beginning a climb. I switched back over to the radios and asked the First Officer what was going on why was he climbing? He informed me that Center gave us a clearance to FL270 and Not FL240. We got to 25,800 when ATC questioned us. The First Officer and I were extremely tired from the continuous duty overnight. Our layover time was 6 hours 42 minutes, after taxi time to and from the hotel, hotel check in, we only had approximately a little over 5 hour at the hotel, which equaled approximately 3 hours of sleep. The fatigue of such a short rest period was evident on this flight. I believe with the new rest rules coming into effect soon, this will eliminate many simple mistakes like this.

<b>ACN</b> : 917857	Synopsis: A CRJ700 crew failed to begin a descent to	TM Error Categorization:	
	make a previously issued altitude constraint until	Task prioritization - high	
	reminded by ATC because they became distracted by	Task monitoring - lack	
	the disintegration of the First Officer's watch.	Resource allocation - low	
		Workload - low	
Narrative <sup>•</sup> ATC a	udvised that this was not a problem but we have decided to r	eport this anyway. We were	
issued a 'nre' cle	parance to cross at the intersection at EL240. In other words	this clearance came a long	
time before we	needed to descend. We had planned on descending at aroun	d 1 500 FPM, but just as we	
got to that point	the flying pilots watch fell apart into several pieces causing	a distraction at the exact	
moment we play	aned on descending. We both missed our descent until ATC of	alled just as we were nearing	
the intersection	We immediately descended from FL290 to FL240 within 3-5	miles past the intersection.	
Again, the Contr	oller said there was no problem and to 'NOT WORRY ABOUT	IT'. With almost 27.000 hours	
of flight time thi	s is actually my first time with an incident like this. Situationa	al awareness was not properly	
maintained by n	nyself, the pilot in command. A pilot's watch coming apart sh	ould NEVER distract a pilot	
from their flight	duties, period. We were fortunate that no conflict occurred	and that it was most likely a	
descent for a Ce	nter airspace change than for traffic. There were NO TCAS ta	rgets on our screen at the	
time. DON'T GET	DISTRACTED BY THE LITTLE STUFF. HEADS UP. That's why th	ere are two of us up there.	
When both pilot	s are distracted by something, nobody is flying the plane. Re	member [an air carrier] going	
down in the Eve	rglades because all 3 crew members were dealing with a bur	ned out gear position bulb.	
RememberI h	have the controlsyou have the controls. We do that for a v	very good reason. I let myself	
down and let my	, crew member down by not complying with that simple mar	ntra.	
ACN: 921634	Synopsis: NCT Controller described a possible MVA	TM Error Categorization:	
	infraction during SOIA procedures when distracted by	Task prioritization - low	
	a sudden PRM failure requiring an immediate change	Resource allocation - low	
	to conventional approach procedures	Task monitoring - excessive	
		Workload - high	
Narrative: SEO I	L Itilizing SOIA (Simultaneous Offset Instrument Approach) pro	cedures IIS/PRM 281 and	
IDA/PRM 28R S	OIA in use due to visibility instead of overcast layer (vis 5 HZ)	A B737-800 was #2 for 28	
behind a heavy	3747, and was going to be paired with an A319 from over CE	DES. I was focused on	
ensuring the B73	37-800 was in front of the A319 while still not too tight behin	d the B747. My trainee was	
monitoring me a	and preparing for his first SOIA session, only has minimal hou	rs on finals. I was explaining	
to him the impo	rtance of keeping aircraft on vectors at a higher airspeed tha	n the straight-ins to insure the	
28L traffic in fro	nt by 2,100 FT. I descended the B737-800 to 4,000, I think. As	s I was preparing to issue the	
turn to final the	re was a loud pop in the area and an aural alarm sounded. Th	e Wiley PRM had stopped	
working correct	y and had turned off. I turned the B737-800 to a 280 heading	and told him there would be	
a delay due to th	ne monitor malfunction. The Foster Controller told me to just	run the B737-800 in because	
he thought we c	ould establish visual separation and issue visual approaches.	Since traffic was light I	
elected to issue	the B737-800 a left turn from a 280 heading to 030 which we	ould take the B737-800 behind	
the 28R traffic. A	As the B737-800 was making his turn I observed him at 3,900	. I issued a clearance to	
maintain 4,000, advised him he was outside of Bravo and would re-enter at 4,000. He climbed to 4,000 and			
landed at SFO without any problems. The B737-800 didn't enter the 4,000 MVA but he was right on the			
3,000/4,000 boundary. I don't think I missed a read back when I issued the B737-800 4000. I may have			
missed the B737-800 reading back 3,000 when I issued the left turn to 030. I was very focused on getting			
the B737-800 in front of the 28R traffic and was distracted by the monitor failure and the technicians in			
the area and everyone calling for a Supervisor. I may have issued the B737-800 3,000 prior to the monitor			
going out and then forgetting about the altitude as I turned the B737-800 around. I was trying to force the			
B737-800 down so the FOSTER Controller wouldn't have to hold the 28R traffic to high prior to issuing the			
approach clearance.			

<b>ACN</b> : 925114	Synopsis: A320 flight crew becomes concerned with	TM Error Categorization:
	ice build-up during climb and selects MCT to expedite	Task prioritization - high
	the climb. When the autopilot levels off at FL230 the	Workload - high
	aircraft rapidly accelerates. The pilot flying disengages	Resource allocation - high
	the autopilot and begins to climb before the altitude	
	chime alerts him to the altitude clearance and that the	
	MCT setting is causing the airspeed increase.	
Narrative: ATC ir	formed us that there was reported light to moderate icing f	rom FL185 to FL225. We were
in moderate icin	g from 14,500 to approximately FL270. We had engine and v	wing anti-ice systems on and
operating. We w	vere both very concerned about the amount of ice building o	on the airplane as evidenced
by the significant	amount building on the probe between the windscreens an	nd all of the way around the
two front windso	reens. I selected Maximum Continuous Thrust (MCT) at abc	out FL180 to facilitate climbing
through the icing	more quickly. Our clearance was to FL230 which was set in	the FCU window with the
autopilot flying.	We were both significantly distracted talking about and obse	erving the icing and also
coming up with a	a plan of action, that our brains were focused on climbing ou	t of the icing. So when the
autopilot leveled	off at FL230, the airplane kept accelerating since we were s	till in MCT. Thinking we were
getting unreliabl	e airspeed due to icing, and expecting to keep climbing inste	ad of being level, I
disconnected the	e autopilot and pulled up. The altitude alert went off at 23,3	00 FT and I realized what
happened and st	arted back down to FL230 after reaching 23,400 FT. Also co	ntributing was that during the
climbout, the VV	I (Vertical Velocity Indicator) fluctuated between -300 and +	1,100, so seeing the VVI at 0
was somewhat e	xpected in the back of my mind. Our concern was the unknown	own amount and weight of
the ice on the un	heated parts of the airplane since the ice did not sublimate	enroute.
<b>ACN</b> : 927620	Synopsis: A B737-700 Captain reported missing a	TM Error Categorization:
ACN: 927620	<b>Synopsis</b> : A B737-700 Captain reported missing a crossing restriction after becoming confused by the	<b>TM Error Categorization</b> : Task initiation - late
<b>ACN</b> : 927620	<b>Synopsis</b> : A B737-700 Captain reported missing a crossing restriction after becoming confused by the altimeter display inaccuracy caused by the First	<b>TM Error Categorization</b> : Task initiation - late Task prioritization - low
<b>ACN</b> : 927620	<b>Synopsis</b> : A B737-700 Captain reported missing a crossing restriction after becoming confused by the altimeter display inaccuracy caused by the First Officer's altimeter setting being different from his.	<b>TM Error Categorization</b> : Task initiation - late Task prioritization - low
ACN: 927620 Narrative: We w	Synopsis: A B737-700 Captain reported missing a crossing restriction after becoming confused by the altimeter display inaccuracy caused by the First Officer's altimeter setting being different from his. ere cleared to 16,000' and then to cross the airway intersect	TM Error Categorization: Task initiation - late Task prioritization - low ion at 11,000. I was late in
ACN: 927620 Narrative: We w calling the Desce	Synopsis: A B737-700 Captain reported missing a crossing restriction after becoming confused by the altimeter display inaccuracy caused by the First Officer's altimeter setting being different from his. ere cleared to 16,000' and then to cross the airway intersect nt Checklist and went to level off at 16,000'. I noticed the ye	TM Error Categorization: Task initiation - late Task prioritization - low ion at 11,000. I was late in llow box was flashing around
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ACN: 927620 Narrative: We w calling the Desce the altitude box. the ALT setting o	Synopsis: A B737-700 Captain reported missing a crossing restriction after becoming confused by the altimeter display inaccuracy caused by the First Officer's altimeter setting being different from his. ere cleared to 16,000' and then to cross the airway intersect nt Checklist and went to level off at 16,000'. I noticed the ye I became distracted with the flashing box and had shifted be f 30.43. This, of course, changed the altimeter about four hu	TM Error Categorization: Task initiation - late Task prioritization - low ition at 11,000. I was late in solve box was flashing around etween ALT, STD and back to undred feet every time I
ACN: 927620 Narrative: We w calling the Desce the altitude box. the ALT setting o switched. I becau	<b>Synopsis</b> : A B737-700 Captain reported missing a crossing restriction after becoming confused by the altimeter display inaccuracy caused by the First Officer's altimeter setting being different from his. ere cleared to 16,000' and then to cross the airway intersect nt Checklist and went to level off at 16,000'. I noticed the ye I became distracted with the flashing box and had shifted be f 30.43. This, of course, changed the altimeter about four hume confused at what was causing the yellow flashing box so	TM Error Categorization: Task initiation - late Task prioritization - low ion at 11,000. I was late in llow box was flashing around etween ALT, STD and back to undred feet every time I I leveled off at 16,000' on
ACN: 927620 Narrative: We w calling the Desce the altitude box. the ALT setting o switched. I becar altimeter 30.43,	Synopsis: A B737-700 Captain reported missing a crossing restriction after becoming confused by the altimeter display inaccuracy caused by the First Officer's altimeter setting being different from his. ere cleared to 16,000' and then to cross the airway intersect nt Checklist and went to level off at 16,000'. I noticed the ye I became distracted with the flashing box and had shifted be f 30.43. This, of course, changed the altimeter about four hu ne confused at what was causing the yellow flashing box so but was not positive I was at 16,000'. I then noticed a 'ALT D	TM Error Categorization: Task initiation - late Task prioritization - low ion at 11,000. I was late in flow box was flashing around etween ALT, STD and back to undred feet every time I I leveled off at 16,000' on DISAGREE' and checked the
ACN: 927620 Narrative: We w calling the Desce the altitude box. the ALT setting o switched. I becar altimeter 30.43, First Officer's alt	<b>Synopsis</b> : A B737-700 Captain reported missing a crossing restriction after becoming confused by the altimeter display inaccuracy caused by the First Officer's altimeter setting being different from his. ere cleared to 16,000' and then to cross the airway intersect nt Checklist and went to level off at 16,000'. I noticed the ye I became distracted with the flashing box and had shifted be f 30.43. This, of course, changed the altimeter about four hune confused at what was causing the yellow flashing box so but was not positive I was at 16,000'. I then noticed a 'ALT Dimeter. It was at 29.43 not 30.43. I had him input 30.43. In the	TM Error Categorization: Task initiation - late Task prioritization - low tion at 11,000. I was late in ellow box was flashing around etween ALT, STD and back to undred feet every time I I leveled off at 16,000' on DISAGREE' and checked the time we were trying to
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ACN: 927620 Narrative: We w calling the Desce the altitude box. the ALT setting o switched. I becar altimeter 30.43, First Officer's alt figure out the co then got the call	<b>Synopsis</b> : A B737-700 Captain reported missing a crossing restriction after becoming confused by the altimeter display inaccuracy caused by the First Officer's altimeter setting being different from his. ere cleared to 16,000' and then to cross the airway intersect nt Checklist and went to level off at 16,000'. I noticed the ye I became distracted with the flashing box and had shifted be f 30.43. This, of course, changed the altimeter about four hume confused at what was causing the yellow flashing box so but was not positive I was at 16,000'. I then noticed a 'ALT E meter. It was at 29.43 not 30.43. I had him input 30.43. In the nflicting signals, I missed the Top of Descent point for the 11 from Center, 'You gonna make it at 11,000'' I started a Vertice.	TM Error Categorization: Task initiation - late Task prioritization - low ion at 11,000. I was late in flow box was flashing around etween ALT, STD and back to undred feet every time I I leveled off at 16,000' on DISAGREE' and checked the ne time we were trying to .,000' crossing restriction. We cal Speed descent but was too
ACN: 927620 Narrative: We w calling the Desce the altitude box. the ALT setting o switched. I becan altimeter 30.43, First Officer's alt figure out the co then got the call late. We crossed	<b>Synopsis</b> : A B737-700 Captain reported missing a crossing restriction after becoming confused by the altimeter display inaccuracy caused by the First Officer's altimeter setting being different from his. ere cleared to 16,000' and then to cross the airway intersect nt Checklist and went to level off at 16,000'. I noticed the ye I became distracted with the flashing box and had shifted be f 30.43. This, of course, changed the altimeter about four hume confused at what was causing the yellow flashing box so but was not positive I was at 16,000'. I then noticed a 'ALT Dimeter. It was at 29.43 not 30.43. I had him input 30.43. In the noticed is ginals, I missed the Top of Descent point for the 11 from Center, 'You gonna make it at 11,000'' I started a Verticat about 12,800'. Obviously, calling for the Descent Checklis	TM Error Categorization: Task initiation - late Task prioritization - low tion at 11,000. I was late in ellow box was flashing around etween ALT, STD and back to undred feet every time I I leveled off at 16,000' on DISAGREE' and checked the ne time we were trying to .,000' crossing restriction. We cal Speed descent but was too t passing FL 180 would have
ACN: 927620 Narrative: We w calling the Desce the altitude box. the ALT setting o switched. I becar altimeter 30.43, First Officer's alt figure out the co then got the call late. We crossed rectified this situ	<b>Synopsis</b> : A B737-700 Captain reported missing a crossing restriction after becoming confused by the altimeter display inaccuracy caused by the First Officer's altimeter setting being different from his. ere cleared to 16,000' and then to cross the airway intersect nt Checklist and went to level off at 16,000'. I noticed the ye I became distracted with the flashing box and had shifted be f 30.43. This, of course, changed the altimeter about four hume confused at what was causing the yellow flashing box so but was not positive I was at 16,000'. I then noticed a 'ALT Dimeter. It was at 29.43 not 30.43. I had him input 30.43. In the noticities ginals, I missed the Top of Descent point for the 11 from Center, 'You gonna make it at 11,000'' I started a Verticat about 12,800'. Obviously, calling for the Descent Checkliss ation, but that one error quickly compounded into several is	TM Error Categorization: Task initiation - late Task prioritization - low tion at 11,000. I was late in ellow box was flashing around etween ALT, STD and back to undred feet every time I I leveled off at 16,000' on DISAGREE' and checked the time we were trying to .,000' crossing restriction. We cal Speed descent but was too t passing FL 180 would have ssues at once.
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ACN: 927620 Narrative: We w calling the Desce the altitude box. the ALT setting o switched. I becar altimeter 30.43, First Officer's alt figure out the co then got the call late. We crossed rectified this situ ACN: 948654	Synopsis: A B737-700 Captain reported missing a crossing restriction after becoming confused by the altimeter display inaccuracy caused by the First Officer's altimeter setting being different from his. ere cleared to 16,000' and then to cross the airway intersect nt Checklist and went to level off at 16,000'. I noticed the ye I became distracted with the flashing box and had shifted be f 30.43. This, of course, changed the altimeter about four hu ne confused at what was causing the yellow flashing box so but was not positive I was at 16,000'. I then noticed a 'ALT D meter. It was at 29.43 not 30.43. I had him input 30.43. In the nflicting signals, I missed the Top of Descent point for the 11 from Center, 'You gonna make it at 11,000'' I started a Verti- at about 12,800'. Obviously, calling for the Descent Checklis ation, but that one error quickly compounded into several is Synopsis: An A321 flight crewdistracted by weather,	TM Error Categorization: Task initiation - late Task prioritization - low tion at 11,000. I was late in ellow box was flashing around etween ALT, STD and back to undred feet every time I I leveled off at 16,000' on DISAGREE' and checked the time we were trying to .,000' crossing restriction. We cal Speed descent but was too t passing FL 180 would have ssues at once.
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ACN: 927620 Narrative: We w calling the Desce the altitude box. the ALT setting o switched. I becar altimeter 30.43, First Officer's alt figure out the co then got the call late. We crossed rectified this situ ACN: 948654	Synopsis: A B737-700 Captain reported missing a crossing restriction after becoming confused by the altimeter display inaccuracy caused by the First Officer's altimeter setting being different from his. ere cleared to 16,000' and then to cross the airway intersect nt Checklist and went to level off at 16,000'. I noticed the yet I became distracted with the flashing box and had shifted be f 30.43. This, of course, changed the altimeter about four hume confused at what was causing the yellow flashing box so but was not positive I was at 16,000'. I then noticed a 'ALT Dimeter. It was at 29.43 not 30.43. I had him input 30.43. In the flicting signals, I missed the Top of Descent point for the 11 from Center, 'You gonna make it at 11,000'' I started a Verticat about 12,800'. Obviously, calling for the Descent Checklis at about 12,800'. Obviously, calling for the Descent Checklis at about 12,800'. Boy of the about an ailing Flight Attendant and simultaneous clearances for an off route holding pattern and a further descent to FL220mistakenly set the altitude alert window to FL200 and an altitude	TM Error Categorization: Task initiation - late Task prioritization - low tion at 11,000. I was late in ellow box was flashing around etween ALT, STD and back to undred feet every time I I leveled off at 16,000' on DISAGREE' and checked the the time we were trying to .,000' crossing restriction. We cal Speed descent but was too t passing FL 180 would have issues at once. TM Error Categorization: Task interruption - incorrect Workload - high
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a further descent to FL220 and holding instructions at a fix not on our route. The Captain dialed in FL200

[in the altitude alert window] by mistake and we both missed it. At about FL214 ATC gave us a traffic alert and told us we were supposed to level off at 220. Captain turned off autopilot and climbed immediately back up to 220. We got as low as 213. We also got a TA from the TCAS. We saw the traffic ahead at approximately four miles away. This event was caused by many simultaneous distractions. [We were] dealing with a medical in the cabin, a descent and a holding clearance all at once. The off route holding was a bit confusing at first. We were already close to the holding fix and had to figure it out quick. ATC was very busy and we couldn't get through to ask a question about our holding instructions. We got complacent with altitude assignment. We simply got overloaded all at once and missed the Captain's mistake on ALT knob.

ACN: 952490	Synopsis: An EMB170 Captain whose unilateral SOP is	TM Error Categorization:
	to remove all 'at or above and at or below' FMS	Task prioritization - low
	crossing altitudes so as to make them 'hard crossing	Resource allocation - low
	altitudes' inadvertently altered the glide slope crossing	
	altitude at the ZAB marker at CYEG typing in 2,620	
	MSL vice the published 3,620 MSL. The terrain at that	
	point is about 2,400 MSL.	

Narrative: On descent into CYEG I was letting the automation (VNAV) descend us for the approach. In an effort to cross fixes 'AT' specific altitudes and not 'AT OR ABOVE,' or 'AT OR BELOW' with the VNAV, I have recently started editing the crossing fixes to remove the 'A' or 'B' when desiring to cross fixes at a hard altitude. When preparing for the approach to Runway 30 I input into the FMS to cross the outer marker ZAB 'AT' 3,620 instead of 'AT OR ABOVE' 3,620, as Canada often times brings us in high I wanted to cross the marker 'AT' the required altitude and not be high and then dive for the runway. Everything was going fine, although after being cleared for the straight in for Runway 30, we encountered an IMC and icing layer south of the field without the field in sight yet. This required some distraction with updating the speeds. Also after being cleared for the straight in I removed the vectors portion in the FMS which separates the arrival and approach segments so the FMS would descend us right onto the approach, at which time I would arm the approach. Everything [was] still good. However, outside the marker when I set the step down altitude for the outer marker my brain figured out something wasn't quite right but I could not see what it was. What I could not see just yet was that when I had earlier changed the marker crossing altitude to 'AT' instead of 'AT OR ABOVE,' apparently I 'fat fingered' it and input 2,620, instead of 3,620. Needless to say this made for crossing the marker and starting the approach at a low altitude. As this was all coming together mentally we broke out VMC and as I arrested the descent and headed to intercept the VASI, we received a single one word announce of 'TERRAIN.' I then leveled and climbed to intercept the VASI for a normal landing. ATC did not acknowledge or comment on our low altitude but I estimate we were as low as 300-400 FT. In probably 6,000 plus hours in this aircraft this is the worst mistake I have ever made. I will no longer be adjusting altitudes (A/B indicators) for ANY final approach fixes. The potential seriousness of making an input error like this at low altitudes far exceeds any down side of being high on the approach. This was my error plain and simple. Things I would recommend to mitigate this from happening again are never adjusting FAF altitudes to be hard crossing fixes, even if you are using CAMI this late at night and after an 18 hour day with commuting, you can still make a '2' into a '3' and miss it. I think all FAF should just be hard altitudes by default in the FMS and not 'AT OR ABOVE' crossings, but I'm sure there is probably a good reason for having them as 'At or Above' that I don't know about. Also, I had a top notch First Officer so no dings there. However, I would say it has become common place now that the landing speeds and any adjustments are being input by the flying pilot. I think this should strictly be a pilot not flying duty but I understand that now with the ACARS it's easier to hold the page up and let the pilot flying input them as opposed to writing them down or memorizing them. Also, an ergonomically challenging factor we have all been dealing with is having an Electronic Flight Bag (EFB) mounting bracket for a chart holder. There is no convenient place to have your charts visible at a glance for easy reference, especially at

night. Many times while flying and taxiing my charts are not visible because they are on the floor, my flight bag, the little trash can, or clipped down between my legs where I don't have a prayer of reading them without a total distraction. There has to be some chart holder modification that can be mounted over this bracket until the EFBs finally start working. Alternatively, drill out the rivets and put the chart holders back. The amount of time these mounting brackets have been there (months, years?) versus the time to put the chart holder back is insignificant in my opinion in light of how distracting this is.

<b>ACN</b> : 953784	Synopsis: B737-300 flight crew missed a crossing	TM Error Categorization:
	restriction while descending in level change mode and	Workload - high
	failing to adequately monitor flight progress.	Task monitoring - low
		Task prioritization - low

**Narrative**: On arrival, we were issued and acknowledged crossing at the intersection 250/11,000 and then continue the descent to 6,000 FT. The Captain was the pilot flying and selected 6,000 on the MCP and descended in level change. Approaching the fix we got a runway change to the left runway (we were expecting the right and eventually the runway was changed back to the right for landing). Both pilots were heads-down approaching the fix programming and verifying the left runway. As the pilot not flying, I did not realize the Captain was descending in level change (we had been in VNAV initially, but switched to level change at some point in the descent to the intersection). About four miles out from the intersection, I noted that we were descending on schedule to cross the intersection at 250/11,000. Just after we crossed the intersection, ATC called and asked if we had instructions to cross the intersection at 11,000 FT. I noted our altitude at about 10,200 FT and we were about a mile inside the intersection on the arrival. After landing at the airport, Ground provided a number for the Captain to call ATC for a possible pilot deviation. Descending in VNAV would have prevented this possible deviation. As the pilot not flying, I should have been aware of the pitch mode used in the descent.

ACN: 976585	Synopsis: An MD80 Captain reported receiving a	TM Error Categorization:
	GPWS terrain warning on approach to TUS. Failure to	Resource allocation - high
	recognize LOC did not capture and fatigue played a	Task initiation - late
	part.	Workload - high

**Narrative**: Received vector for ILS 11L approach to TUS from the ZONNA1 arrival, descending from 11,000 on heading 260, was cleared to 6,000 while in downwind north of airport. As we were given a turn to base of 230 degrees approach asked if we had RJ traffic in sight at our 10 o'clock on approach to runway, picked up traffic in the turn and was cleared to follow traffic cleared for the visual Runway 11L. We had briefed the LOC 11L IAP (NOTAMs indicated glideslope out of service) with visual back-up, and the terrain considerations around the airport including the Eng Out alt MA procedure prior to the descent. As we acquired the traffic I turned toward CALLS on the LOC course and asked for 4,600 to be set in the alt MCP window descending to intercept the LOC, armed the LOC on the MCP and was heading to intercept. We lost visual with the traffic and while looking and descending, I did not notice the LOC did not capture, once this was identified while still descending to 4,600, we received a CAUTION TERRAIN alert. I quickly turned back to intercept, but immediately started getting advisories from Approach Control about terrain and simultaneously received a TERRAIN, TERRAIN PULL UP PULL UP (closure rate) warning. I executed the escape and climbed, we heard the warning twice as we climbed away from the threat. Once clear and turning back toward the LOC course, with the runway back in sight we quickly verified our position, configured to continue the approach visually and landed. However in getting back to a reasonable descent path to land I was about 10-15 KTS above Vref at touchdown with displaced threshold - all else was uneventful. Throughout the GPWS event my First Officer (pilot not flying) executed her duties exceptionally well providing me callouts, and suggestions both while flying the escape maneuver, and then to get back into a position where we could still safely re-establish the approach and landing. I would say our training kicked in with the terrain alerts and despite the tasking workload her crew coordination was

commendable. We had both commuted into base earlier in the day prior to the late departure for this first leg and I believe some fatigue was a contributor to the late LOC Not captured identification.

<b>ACN</b> : 978110	Synopsis: B737-700 flight crew reports distractions	TM Error Categorization:
	and omissions during descent on the HONIE arrival	Task monitoring - lack
	into ATL resulting in descent below assigned altitude.	Task initiation - lack
	ACARS ATIS update function had retrieved information	Workload - low
	from the departure airport, which resulted in an	
	incorrect altimeter setting, and a conversation with	
	the Jumpseater delayed completion of the Descent	
	Checklist.	

Narrative: During descent on the HONIE arrival into ATL, the Captain and I were involved in a conversation with a pilot on the jumpseat. While in contact with Atlanta Center, we were descending to FL210. We were cleared to cross HONIE at 14,000' and 250 kts. I am fairly sure that the Atlanta Center Controller did not issue an altimeter setting for Atlanta, as I believe it is their policy to do. However, because I was engrossed in conversation with the jumpseater, I didn't query ATC on the matter. I simply read back the clearance, confirmed that the Captain (PF) set the MCP and FMC correctly, then returned to our conversation with the jumpseating pilot. Also around this time, the ACARS alerted us to a new ATL arrival ATIS. I selected the ACARS on the MCDU, glanced at the new ATIS, noted the altimeter setting of 30.26, and preset my altimeter setting to 30.26. I also printed the ATIS, but did not retrieve it from the ACARS printer. Upon passing through FL180, I set my altimeter setting to 30.26, and I believe the Captain did the same thing. Instead of running the Descent Checklist, the Captain and I returned to the conversation with the jumpseater. We were handed off to ATL Approach, who cleared us to descend to 11,000'. The Captain set 11,000' in the MCP and started the descent, and I verbally confirmed the same. As our altitude approached 11,000, we got one, then two TCAS TA's on traffic which appeared to be at 10,300'. When we leveled at what we thought was 11,000', we noticed that both TCAS targets were now 700' below us. We both started to mention to each other that the situation didn't look right, but were interrupted by the Atlanta approach controller saying 'maintain 11,000'. I replied, and he again repeated the clearance, along with something along the lines of 'check your altitude'. I asked for the altimeter setting, and he read back '29.88'. At this point, the Captain had disengaged the autopilot and begun to climb. I reset my altimeter, then his, to 29.88. It was evident at this point that we were a little more than 300' low. The Captain flew the aircraft back to 11,000' and then asked me to re-engage the autopilot. I then retrieved the ATIS printout from the printer, and read it. For some reason, the ACARS had been delivering the (departure airport) ATIS to us the whole time, instead of the ATL ATIS. I realized that I failed to read the header line of the ATIS carefully, and did not notice the aberrant behavior of the ACARS ATIS function. The Captain then called for the Descent Checklist, which we completed. THREATS: ongoing non-pertinent conversation in the flight deck (which we did conclude by 10,000'), failure of ATC to provide altimeter setting, aberrant ACARS behavior. ERRORS: failure to complete Descent Checklist at appropriate time, failure to read ATIS display/printout carefully. Sometimes, going sterile at 10,000' isn't enough. Switching to any approach control marks the beginning of a busy phase of flight, and consideration should be given to extending sterile cockpit from 10,000' to whenever we switch to approach control.

<b>ACN</b> : 989059	Synopsis: An A320 Captain on the LAS TYSSN THREE	TM Error Categorization:
	RNAV calculated his descent constraint compliance	Task prioritization - low
	incorrectly and failed to meet one of the constraints	Task initiation - late
	before realizing his error even though his First Officer	Resource allocation - low
	was cautioning about the error.	
Narrative: This w	use a flight to LAS. Enroute to PGS ATC cleared us to EL260 ar	ad assigned us 280 KIAS After

**Narrative**: This was a flight to LAS. Enroute to PGS ATC cleared us to FL260 and assigned us 280 KIAS. After we leveled off I re-cruised us at FL260. Our planned Cost Index was 36 which calculated a managed

descent speed of 282 KIAS. However I had selected 280 on the FCU. East of PGS ATC cleared us to descend via the TYSSN THREE RNAV arrival for a visual approach to Runway 25L. I dialed in 8,000 to meet the restriction at PRINO. Both the First Officer and I had triple checked all the altitude constraints on the arrival, and we both had the constraints pb pushed. PGS has an 'at or above FL200' constraint and CEJAY has an 'at or below FL190' constraint. With a top of descent arrow displayed about halfway between our position and PGS, I engaged managed descent. I calculated we needed 21 miles to get below FL190 over CEJAY from FL260. PGS to CEJAY is 19 miles so I felt safe. I engaged managed descent, with the airplane starting a nominal 900 FPM descent, still in selected speed of 280. I selected the PROG (Progress) page on the MCDU and it showed I was approximately 2,400 FT low on the path but slowly decreasing deviation. The Descent Path Indicator (donut) on the Primary Flight Display (PFD) was at the top of the scale but moving down slowly. I felt very confident (not complacent) that we could meet all constraints without any problem. I was expecting a slower than normal descent since I had started down prior to the computed Top of Descent and we had a roughly direct headwind of 60 plus KTS. Prior to reaching PGS my very sharp First Officer remarked that we had an amber missed constraint circle around CEJAY on the Nav Display (ND). I acknowledged his concern, noted the PROG page showed we were still slightly low on the path with the donut slightly above center. In my mind we were intercepting the path from below. I did briefly check the VERT REV page for CEJAY (on the MCDU) and made sure it showed ALT CSTR -190. But for the life of me I did not think to cross check for an ALT ERROR. My mental math told me I had 19 miles to lose a bit over 5,000 FT. The First Officer again questioned me about the amber missed constraint circle. We were now past PGS still descending at approximately 1,000 FPM, but the donut was centered and the PROG page showed we were on the path. Not once did I think to check the FLT PLAN page and read the altitude over CEJAY. I was trying to come up with an answer as to why I was not getting a MORE DRAG message in the Flight Management Annunciator (FMA) since we had crossed one way point with a constraint. Or why I did not have a vertical discontinuity with a TOO STEEP PATH AHEAD message in the MCDU scratch pad. I became preoccupied with trying to diagnose the conflicting information between my Primary Flight Display (PFD) and my Nav Display (ND). I failed to recheck my mental math or aggressively correct our flight path. I erred in not advising ATC of my mistake. ATC did not mention my mistake. We crossed CEJAY in excess of 1,500 FT high. The First Officer reported he saw FL207 as we crossed. The MCDU showed FL209. At this point I assessed that the airplane would not meet the next restriction 22 miles ahead at KADDY. I disconnected the autopilot and selected full speedbrakes in order to cross KADDY at 250 KIAS and 12,000 FT. About 5 miles prior to KADDY at 12,000 FT and 250 KIAS I re-engaged the autopilot and managed descent. The rest of the profile from KADDY to PRINO was uneventful. PREVENTIVE MEASURES My First Officer deserves a great deal of credit for voicing his concerns about the amber missed constraints circle on the ND. We were anything but complacent. I was mentally scrambling trying to sort out conflicting information and determine a possible input error while thinking any moment the airplane is going to lower the nose and pick up the descent rate. For the life of me I cannot figure out what I did incorrectly.

<b>ACN</b> : 1008161	Synopsis: A B737 crew requested FL390 as the final	TM Error Categorization:
	altitude but became distracted and failed to set the	Task monitoring - lack
	MCP or FMC which resulted in climb to FL399.	Task prioritization - low
		Resource allocation - high

**Narrative**: On preflight 40,000 [was] entered in cruise altitude. On climb out [we were] issued FL410, we checked weight and optimal altitude temperature was +17 and we were heavy for FL410, requested FL390 instead. It took a couple of calls to understand ATC's acknowledgement. Somewhere in this process the Flight Attendant called for [warmer] temperature in cabin. Captain answered and told me to adjust temperature. This interruption distracted [us] from entering FL390 in MCP and FMS. Aircraft climbed to 39,800 before we caught it, then center reminded us we were given 39,000 and [to] descend.

<b>ACN</b> : 1015343	Synopsis: A Medium Transport flight crew on a	TM Error Categorization:
	Constant Angle Non Precision Approach (CANPA) set	Task prioritization - high
	the Mode Control Panel at the Decision Altitude. After	Resource allocation - low
	becoming distracted they descended early, 600 FT	Task monitoring - excessive
	below the Final Approach Fix altitude.	Workload - high

Narrative: We had thoroughly briefed the approach for the VOR/DME-2 Runway 13 before commencing the approach. The current weather included a scattered layer of clouds reported at 1,500 FT AGL and good visibility. We had begun the 10 DME arc to intercept the final approach course and were stepping down in altitude as depicted on the approach. The pilot flying had briefed the approach as a Continuous Angle Non Precision Approach (CANPA) and had determined a descent rate of 800 FPM once we passed the 8.0 DME position on the final approach course. We had leveled at 2,000 FT prior to reaching the 8 DME fix and the pilot flying set the descent altitude in the altitude selector on the Flight Guidance Control Panel FGCP since we had agreed to monitor our progress with regards to both altitude and distance as there was an altitude constraint of 1,500 FT at the 5 DME fix from the VOR. However, during the segment from 8 DME to 5 DME, the VOR CDI began to swing well to the left of center without any change in aircraft heading. The pilot flying and pilot not flying were both focused on the VOR needle and neglected to notice the airplane descending below the 1,500 FT floor as the airplane had not yet reached 5 DME. By the time the deviation was noticed, the aircraft had descended to 900 FT MSL at the 5 DME point. By this point we had been in VMC for approximately 400-500 FT. The pilot flying continued on a 'visual' approach since we had acquired the airport and landed without further incident. The threats encountered were a rushed descent as ATC had left us high until a relatively close distance to the airport. This shortened the time available to prepare for the approach. A second threat was an unfamiliar approach to an airport that the pilot not flying had never flown into before. It was also the first time than the pilot not flying had flown a CANPA approach since completing initial new-hire training. Further threats were numerous step downs on the approach, a lack of recommended altitudes and distances on the approach plate, and finally, the VOR signal that began wandering for no apparent reason during the final portion of the approach which served as a major distraction to the flight crew. An error on the part of both pilots was focusing too much attention on the VOR CDI deflection and neglecting the vertical progress of the aircraft which led to an undesired aircraft state of being 600 FT below the altitude restraint at the FAF. As the pilot not flying, I should have been more vigilant to monitor the descent progress of the aircraft. I could have asked the pilot flying what he would have liked me to focus on: troubleshooting the faulty VOR signal, or monitoring the aircraft's progress. After discussing the event, the pilot flying and I both decided that the appropriate course of action that SHOULD have been taken was to set the altitude to 1,500 FT until passing the 5.0 DME fix THEN setting the MDA in the altitude selector. This would have arrested the aircraft's descent at 1,500 FT preventing us from descending below the minimum altitude for that segment of the approach. For future approaches similar to this example I plan to verify each step-down with the pilot flying and verify that it is set appropriately in the altitude selector so as to prevent another incident similar to this one.

<b>ACN</b> : 1017650	Synopsis: A B737 First Officer responded incorrectly to	TM Error Categorization:
	a TCAS RA after he increased the aircraft's rate of	Workload - high
	descent when the resolution was to decrease the	Task monitoring - lack
	descent rate.	Task initiation - incorrect

**Narrative**: ATC gave us a descent clearance from our cruise altitude of FL360 to FL340. The Copilot started the descent using the Vertical Speed mode of the autopilot. I was the pilot not flying. As the aircraft passed through FL350, we received a TCAS Traffic Alert. Because the Copilot had selected a high rate of descent on the Vertical Speed selector, our traffic alert quickly change to a TCAS Resolution Advisory (RA), telling us to 'Monitor Vertical Speed.' At that time, the Copilot turned off the autopilot and responded to the RA. We were still in a steep descent. Events were starting to take place rapidly. ATC called us and told us of traffic below at FL330. He must have asked what we were doing and I told him we were responding to a TCAS RA.

He questioned my response and again I told him that we were responding to a RA. I responded to the ATC call while monitoring the Copilot's actions. This is where we probably descended through our clearance altitude of FL340. When I looked at the TCAS information on the Vertical Speed indicator, it seemed to me the Copilot was not reacting properly for the information displayed. The green arc was a band about 500 FPM wide starting at about minus 2,000 FPM and ending at about 2,500 FPM. The red arc started at minus 2,500 FPM and went below that. I told the Copilot he had to reduce his descent rate, but he believed he needed to increase his rate of descent; that made me hesitate and rethink my interpretation of the display. I again told him we needed to stop descending. I believe the aircraft was descending 3,000 FPM or more. The Copilot still believed he needed to continue this descent. I told the Copilot I had the aircraft while I grabbed the control yoke and pulled up. This action stopped the aircraft's descent and started a shallow climb. I remember seeing a solid red colored traffic symbol with a -300 next to it. The traffic passed under us and slightly to our right. For a two thousand foot descent, the Copilot selected a high rate when first descending out of FL360 for the altitude loss required (2,000 FT). That probably is what triggered the TCAS Alert. I should have taken over aircraft control earlier. My decision was delayed because of my expectation that my experienced Copilot would respond correctly to the TCAS display; that made me hesitate and question my correct interpretation. That cost valuable time and critical loss of altitude. Also the calls from ATC distracted me and delayed my processing of the situation.

<b>ACN</b> : 1027160	Synopsis: An ERJ flight crew on the TEB RUUDY 4	TM Error Categorization:
	climbed directly to 2,000 FT before WENTZ because	Task prioritization - high
	the Captain was task saturated with the unfamiliar	Task initiation - early
	departure and weather avoidance.	Resource allocation - low
		Workload - high

**Narrative**: While departing TEB on a charter the First Officer and I were reviewing the departure procedures and noise abatement procedures for our runway when I made an error in my take off briefing. We were assigned the RUDDY 4 RNAV departure that requires you to cross a fix at 1,500 FT then continue the climb to 2,000 FT. While at the terminal I briefed a climb to 2,000 FT and a crossing restriction of making sure we cross the restriction at or above 1,500 FT. Upon taxi out we were held on the ground for delays and spent our time going over an ATC reroute as well as making sure the weather was suitable when departing 24. After takeoff I continued my climb to 2,000 FT too early because I was concentrating on weather cells that lined the departure. ATC told us that we should be at 1,500 and by that time it was too late to fix our mistake. They said nothing else, and the First Officer and I realized what we had done. I was in an unfamiliar airport on a charter that had complicated noise procedures combined with weather and the standard difficulties of a charter. I briefed a chart incorrectly and then went on to concentrate on the weather and route planning without reviewing it except just before takeoff. It was my mistake in the initial briefing that led me to think I was correct in my climb to 2,000 FT.

<b>ACN</b> : 1034997	Synopsis: A320 Captain reports failing to verify that	TM Error Categorization:
	the FMA shows that descent has been initiated after	Task prioritization - low
	being assigned a crossing restriction on the BOJID ONE	Task monitoring - lack
	Arrival to PHL.	Task initiation - late

**Narrative**: On the BOJID ONE arrival we were cleared out of FL330 to cross COFAX at FL240. We set the altitude in the FCU and the restriction in the FMGC. I pushed to initiate the descent and failed to verify the FMA's [Flight Mode Annunciator] that we were indeed in the descent, the First Officer noticed as we checked in with a frequency change and I took the autopilot off, autothrust off, and immediately attempted the crossing restriction but failed to do so as the First Officer simultaneously got relief from the Controller and vectors for the descent. We were inadvertently distracted by our conversation in the cockpit.

ACN: 1043609	Synopsis: CRJ-900 flight crew stated that during	TM Error Categorization:
	approach they reported airport in sight and were given	Task prioritization - low
	a visual approach by ATC. Pilot flying entered the first	Task initiation - lack
	ILS fix into the FMS and set the altitude preselect to	Task initiation - late
	the first fix altitude, which was below the minimum	
	safe altitude for the aircraft position and received an	
	GPWS aural alert. ATC additionally issued an altitude	
	alert, and aircraft was climbed to a safe altitude and	
	then landed uneventfully.	
Narrative: Cente	r handed us off to Approach. The Captain (pilot not flying) cl	necked in and reported the
airport in sight. A	Approach immediately cleared us for the visual approach. I m	noved the first fix on the ILS to
the 'direct-to' po	osition in the FMS and executed the change, then dialed 5,00	0 FT into the altitude
preselect, as tha	t is the 'at or above' altitude that coincides with the fix. I was	s demonstrating a flight idle
descent techniqu	ue that I prefer to the Captain and continued that descent to	ward the final approach
course. At approximately 5,200 FT, the GPWS warning flasher illuminated and the aural alert 'TERRAIN,		
TERRAIN, PULL UP!' sounded. I immediately disengaged the autopilot, added power and began climbing. At		
the same time, the Approach Controller issued an altitude alert. Once clear of the conflict, I continued		
very long day, having already flown three legs before this leg. Both of us were quite tired and had		
very long day, na	aving aiready flown three legs before this leg. Both of us wer	e quite tired and had
discussed now fa	atiguing our schedule was. Neither of us had terrain display a	reart (we've both flown this
route probably hundreds of times complacency?) Unless an arrival transition is selected, our aircraft's		
FMS begins the ILS at the first fix. This hides the higher minimum altitudes at the previous fixes that		
guarantee terrai	n separation. Also, our approach angle from slightly west of	final compounded the terrain
separation problem, as the ILS final skirts the east edge of the ridge line in the vicinity of high terrain. Since		
conditions were severe clear and I was flying a visual approach. I was not referencing the ILS approach		
plate, which might have reminded me of the higher minimum altitudes. Bottom line: we screwed up. We		
should have had terrain display turned on. We should have asked for vectors to final, given our level of		
fatigue and the fact that it was nighttime. Instead we were focused on getting to the hotel for some sleep.		
and took the shortest route direct to the runway. I should have been 100% focused on a safe arrival and		
postponed my idle descent demo for a daytime flight when we were both fresh. The GPWS worked as		
designed and the	e Controller was alert and proactive. One sobering note: Yest	terday we flew an aircraft with
the GPS system I	MELed. Several times that day we saw a 'Terrain Unavailable	' message from the FMS
(common with th	nis aircraft type when position accuracy is degraded). Had we	e been flying that aircraft
tonight, the outo	come might have been very different.	

<b>ACN</b> : 1047918	Synopsis: Air Carrier flight crew failed to initiate	TM Error Categorization:
	descent in time to make assigned crossing restriction	Task prioritization - low
	on the POLAR3 arrival into DTW.	Task initiation - late
		Task monitoring - lack

**Narrative**: ATC cleared us to cross MUNKY Intersection on the POLAR3 arrival into DTW at the expected, planned, and standard FL230. Our altitude was FL270. The Captain and I were talking. MUNKY fix started flashing indicating station passage. I recorded the fuel on the dispatch release. I then realized I had not begun descending. I told the Captain I had forgotten to descend and selected power idle, full spoilers, vertical speed down 3,500 FPM. As I began descending, ATC told us to change to Cleveland Center. We leveled at FL230 5 to 6 miles after MUNKY fix. The threats were the crossing restriction on a quiet morning and the conversation in the flight deck to keep our minds active. My error as the flying pilot was not initiating the descent when assigned by ATC, not perceiving the snow flake or 3 degree guidance in my scan, and the Captain not catching my error in his monitoring cross check. The undesired aircraft state was

being 4,000 FT too high above our crossing fix. I should, as I usually do, begin descending immediately when assigned crossing fixes. I should, if planning a 3 degree descent, ask the Captain to remind me if he sees me not acting at the 3 degree descent point. I should be aware that conversation, though good in keeping the mind active, also leads to distraction from flying responsibilities especially during low levels of activity, such as at cruise.

<b>ACN</b> : 1055369	Synopsis: An Air Carrier flight crew, distracted while	TM Error Categorization:
	viewing a meteor shower, turned to heading 360 when	Task prioritization - low
	ATC's call was actually to climb to FL360. ATC detected	Task initiation - lack
	the error.	Task monitoring - lack

Narrative: Flight was routine and operations normal on night flight along the East Coast with only six passengers onboard. I was the pilot flying on this flight. We were filed for FL360. As part of the cockpit chatter above 10,000 FT, I talked to First Officer on climbout about how the East Coast has you at an odd altitude when you are headed westbound vs. the normal odd altitude when eastbound everywhere else in the USA. We requested FL370 for final altitude and received that altitude. This particular night was the height of a meteor shower as we had seen quite a few meteors the previous night and seen a news report on TV about the shower. We had the cockpit lights turned down lower than normal and were scanning the sky more than normal for meteors. About mid flight the First Officer answered a radio call from ATC to turn to heading 360. I was looking out the left window and was viewing the Milky Way and thinking about the meteors and missed part of the transmission. I heard '360' and reached over and set FL360 on the FCP, checked the FMA and said 'FL360'. The First Officer did not confirm that. We leveled off at FL360 and were there about a minute or two when ATC said 'Climb to FL370'. We climbed back up and, after a couple of minutes; ATC said that they had given us a heading of 360 vs. altitude. At that time, the First Officer and I said that we would fill out a report on this. Contributing factors to this occurrence: Cockpit lighting was lower than normal. Extra attention was being paid outside the aircraft as a result of the spectacular meteor showers [and] previous conversation about East Coast sometimes wrong way altitudes. Breakdown of CRM in that I did not press the First Officer to confirm my FCP action (she turned and was looking out the right side for meteors). A suggestion to avoid future occurrences is to follow existing pilot flying/pilot not flying duties as outlined in our manuals. These CRM procedures would prevent this occurrence every time.

<b>ACN</b> : 1314775	<b>Synopsis</b> : CRJ-200 Captain reported an excursion from cleared altitude due to fatigue, distractions, and lack	<b>TM Error Categorization</b> : Task initiation - lack
	of autoflight mode awareness.	Task monitoring - lack
		Resource allocation - high
		Workload - high
Narrative: Climb	ing out of MKE this afternoon, we broke out around 5,000 fe	et. When we broke out, we
were looking rig	nt into the sun. I used my right arm to shield my eyes, but it v	was still difficult to see the
instruments. The	PO asked me if I wanted the autopilot, but I declined becau	se I wanted to get the aircraft
stabilized in the climb. I was decreasing the pitch to accelerate to 250kts. After I got the plane to 250kts, I		
was going to ask for autopliot to get my sun shade, but Departure called us then and cleared us up to		
10,000 feet. I heard the clearance and kept climbing. When the FO was done reading back the clearance, I		
asked for autopilot on. He turned it on. Neither of us realized that the airplane had captured at 5000 feet,		
he hadn't set 10000 feet yet, and I hadn't asked for a vertical mode. He said, 'Autopilot on' and I turned to		
get my sun shade. I got it in place, looked down at my instruments and the FO said, 'We're descending.'		
We had been at probably around 6500 when he turned the autopilot on. When he said we were		
descending, I bumped the stab trim to disable the autopilot and got the plane climbing again. At that		
point, we realized we still had 5000 feet bugged and no vertical mode. We corrected those problems and		
re-engaged the a	autopilot and continued the flight. It's hard to pinpoint the ro	oot cause of the event because

there were so many causes. We were both struggling to see in the glare of the sun in our eyes. We had task saturation because we were trying to fly the plane in that challenging situation while reading back and complying with a new clearance, and also trying to get the autopilot on. We were both tired. I made several minor mistakes that we caught right away after that on this flight. We were tired because almost every leg of this trip we had to fly an instrument approach past the final approach fix, and almost every leg had some kind of issue (MX, security, passenger deplaning, etc).Very simply, regardless of the flight conditions, after having the autopilot engaged, verify the aircraft flight path before turning away to take care of other items (like getting the sun shade).

<b>ACN</b> : 1317104	Synopsis: A319 Captain reported receiving a terrain	TM Error Categorization:
	warning while changing the FMGC from ILS Runway 12	Task prioritization - high
	to the RNAV Runway 9. TOGA thrust is used	Task initiation - lack
	momentarily to recover and an object is heard falling	Resource allocation - low
	onto the ground in the galley. The approach is	Workload - high
	continued to landing. A Flight Attendant stated that no	
	prepare for landing PA was ever given.	

**Narrative**: Set up for runway 12 ILS, ATC changed us to runway 9 and cleared us to intercept final and cross HODLE at 3000 ft. I initially set up ILS LOC for runway 9 in the box and the aircraft was intercepting. I started to set in the RNAV (GPS) 9 in the box while descending then the first officer took over to set the approach up. When it was inserted the autopilot disconnected. I flew the airplane manually. I continued to descend and received a low altitude alert at that time I went to toga and back to climb to level then flew manually to touchdown. When I went to toga a container in the galley fell down and hit the floor. Upon arrival the flight attendant said I did not give the prepare pa which was missed because I was making my first runway change and getting prepared for that. My worst day flying ever! Should have asked for a vector to get more time for preparation. Should have gone around the moment things didn't look right. Should have asked for our expected approach to allow more prep rather than anticipating and being wrong. Should make the prepare PA more ahead of time so it doesn't get overlooked.

<b>ACN</b> : 1317493	Synopsis: CRJ-900 flight crew reported descending	TM Error Categorization:
	below cleared altitude on approach to MKE due to	Workload - high
	distractions, workload, and failure to follow SOP.	Task initiation - incorrect
		Task prioritization - low

**Narrative**: The altitude deviation occurred while being vectored to final for the ILS 19R into MKE. While on a base vector I noticed that neither of our ghost needles had popped up so I went heads down into the FMS to make sure the right approach was loaded. It was not so I began loading the ILS 19R during the high workload situation. The most current altitude clearance at that time was to 2800 feet which was the GS intercept altitude. At some point while loading the correct approach we were given a new clearance with an intercept heading of 220, maintain 2800 feet until established, cleared for the ILS 19R approach. Once established on final ATC reiterated to maintain 2800 feet at which point I looked at the altitude selector set to 2100 feet for unknown reasons. I replied to ATC that we were climbing back up to 2800 feet at which point he sent us over to tower. The deviation was brought to our attention when ATC repeated that our clearance was to maintain 2800 until established. At that point I looked at the altitude selector and saw the wrong altitude selected. The event occurred because I was fixing a mistake I made earlier in the flight, my first officer was task saturated, and we did not follow SOP for altitude changes and confirmation. I was not made aware or realized that he had selected a new altitude in the altitude selector. We climbed back up to our assigned altitude and continued the approach with no further issues. This could have been prevented had I not been distracted by the FMS and we had followed SOPs when selecting a new altitude.

Resource allocation - low

<b>ACN</b> : 1339058	Synopsis: B737 flight crew reported they were cleared	TM Error Categorization:		
	to 3100 ft on an approach to OAK, but misunderstood	Task initiation - early		
	the clearance and descended to 2500 ft, prompting a	Task prioritization - high		
	low altitude call from ATC.	Workload - high		
Narrative: Appro	paching OAK from the east, we requested the RNAV Z Runwa	y 12 from HIRMO intersection		
and were told th	at the request would be forwarded to the Final Controller. U	Ipon check-in with the Final		
Controller, we m	entioned that we were set up for the RNAV Z and were told	to expect it. As we neared the		
HIRMO intersect	ion, and still not cleared for the approach, we queried the Co	ontroller to see if we should		
track the RNAV a	approach track and were told to do so. It became clear, as we	e progressed a few more miles		
past HIRMO with	nout a clearance for the approach, that spacing might not be	working out with other		
aircraft on other	approach transitions and others being vectored for the ILS.	Then we were vectored off		
the HIRMO trans	ition of the RNAV Z 12R and were assigned a heading to inte	rcept the final approach		
course for the RI	NAV Z (different transition) and also assigned an altitude. I re	ad back heading 250 descend		
and maintain 25	00 feet. Shortly after the descent, we were told that our last	assigned altitude was 3100		
feet. We were in	VMC conditions and there were no threats indicated on the	terrain display. We climbed		
back to 3100 fee	t and then were subsequently cleared for the approach and	landed. Looking back at the		
clearance having	a heading of 250 and my reading back the altitude of 2500 f	feet, I might have mistakenly		
read back 2500 f	eet when that altitude was not issued. I believe that I felt rus	shed when we were vectored		
off of the planne	d approach near the initial fix. Knowing that we were being	vectored to a different		
transition requir	ing reprogramming of the FMC, I might have mistakenly prio	ritized making the necessary		
changes in the F	VIC for the PF (Pilot Flying) ahead of the more important task	k at hand which was to make		
sure that the nea	ading and altitude were correctly acknowledged. I remember	r thinking that 2500 feet		
seemed like it wa	as assigned a few miles early, but the VFR conditions at the f	leid and no terrain threats		
anead kept me f	rom querying the clearance as we quickly discussed the chan	iges to the approach. Also,		
requesting the R	NAV RNP approaches while its approaches are in use increas	ses controller workload and		
late in the arriva	Equencing. This can reduce the RNAV approach clearance be	ang with the US involves much		
loss chance for la	ast minute changes and resultant errors associated with bein	ng with the LS involves much		
the approach en	vironment			
	vironinent.			
ACN: 1345803	Synopsis: B737-800 flight crew reported an altitude	TM Error Categorization		
ACN: 1343003	deviation on approach to JEK that resulted when they	Task resumption - lack		
	lost autoflight mode awareness	Task monitoring		
	lost automgrit mode awareness.	Markland high		
Norrativo: Arriva	linto IEK weather CAVIL Cantain was nilet flying. First Offic	workload - High		
Plannod and brid	of ad the visual 121 with the PNIV PNP PMV 121 approach as h	er was pliot monitoring.		
direct to ASALT	cross ASALT 2 000 closed approach. During the descent we	received several calls for a		
UFP target at our 10, 12 o'clock position. We power acquired the traffic visually, but had him on TCAS				
Fventually Appr	ach advised traffic no factor contact Tower. On contact with	h Tower we were cleared to		
Land Approaching ASALT I noticed we were approximately E00 feet below the 2,000 feet crossing altitude				
Somewhere during the descent while our attention was on the VEP traffic the plane dropped out of VNAV				
somewhere during the descent while our attention was on the VFK traine the plane dropped out of VNAV				
VNAV and completed the approach with no further problems				
ACN: 1346068	Synonsis: FMB-145 flight crew reported track and	TM Frror Categorization		
	altitude deviations resulted when they misunderstood	Task interruntion -		
	the ATC clearance on arrival into DEW	incorrect		
		Task initiation lack		
1				
		Workload - high		

**Narrative**: On descent into DFW arrival [was] changed due to north flow. Experiencing moderate turbulence. Requested lower altitude to try and get out of turbulence. Clearance was direct VKTRY, descend via the JOVEM. Both FO and I still thought VKTRY was the proper arrival. Moderate turbulence was a giant factor on our early descent. 10000 ft was selected in the altitude preselect. On the descent ATC asked what altitude we were descending to. At that time we answered 10000 for VKTRY. He then told us we were supposed to be on the JOVEM and to be at VKTRY intersection between 15000 and 18000. At that time the FO and I immediately climbed back to 15000. The FO and [I] were distracted with moderate turbulence. We did not review the new arrival before we descended. Honestly it is a mistake anyone could have made given the circumstance. The autopilot had kicked off along with a SPS Advanced caution on the EICAS due to moderate turbulence. We were trying to find smooth air for the safety and comfort of our passengers. We could have been more vigilant on reviewing the arrival procedure.

<b>ACN</b> : 1349504	Synopsis: B737 flight crew reported descending well	TM Error Categorization:
	below charted altitude on the HAWKS 4 RNAV Arrival	Resource allocation - high
	into SEA, citing lack of FMC mode awareness as a	Task prioritization - high
	factor.	Task monitoring - lack

Narrative: [Our flight to SEA] was a normal flight until cruise when we were cleared to descend to FL240. As pilot monitoring, out of an assigned cruise altitude of FL360, the aircraft went immediately out of VNAV, I temporarily saw an amber Control Wheel Steering PFD cue that was soon overridden [by] FO, first with a Vertical Speed selection (to get the nose down now!) followed soon thereafter with by Level Change selection, and immediately thereafter with a frequency change. Upon my checking in, we were immediately cleared to descend via the HAWKS 4 RNAV arrival landing south, which was exactly what we had briefed 100 miles before beginning the initial descent. As PNF I set the lowest altitude on that STAR at 6,000, saw it through to be verified, then accidentally abrogated my PM duties by not stating 'I'll set the next lowest altitude of FL220' as we approached HAWKZ in a Level Change pitch mode. Already high on the profile, well above crossing restrictions, it wasn't of IMMEDIATE concern but completely improper procedure on my part. Instead of correcting that, I passed the radios to the FO as I took to the PA to offer a good bye to our customers, making note of the (unusually) beautiful Seattle weather with splendid views of snow shaped volcanic mountains out the right window and the beautiful Pacific Ocean out of the left. Once [done] with the PA, I reported 'back on number 1 radio' to FO, who said he had switched us to Approach but had not yet checked in. I asked him if anybody had reported a newer version of the ATIS yet than we had onboard, as one was expected, and then checked in descending via the HAWKS RNAV arrival. I did not refer to the PFD to check what pitch mode we were in, but the Controller said 'Climb and maintain 10,000 feet'. Knowing we were on a Star and therefore this was such an unusual call, and somehow that made me unsure of what I had just heard, I said 'say again 'and the Controller unemotionally repeated, 'Climb and maintain 10,000 feet' which we immediately complied with as by that time I was seeing the bottom window of the next fix on my moving map display showed 10,000 feet at BREVE. The Controller then asked, 'why were you down at 6,000 feet?' and I said 'my bust'; as there was no excuse for this performance. I had been relying on the VNAV automation instead of the old fashioned, 'Set the next lowest altitude', which forces both pilots situationally aware with respect to the profile. Today I think I was a lured by the pure beauty of a clear spring Seattle day and was obviously much less aware than I needed to be.
## Glossary

Attention Allocation – the activity of defining what the pilots should attend to at a given point in time.

- Automation one general definition of automation is "the use of control systems and information technologies that reduce the need for human intervention." Within the context of aviation there are a number of levels of automation from complete system control where the pilot has no need of awareness of the automation and is not informed as to the status or intent of the automation to levels in which the pilot needs to be kept continuously informed as to the status and intent of the automation. Where the term automation is used in this report it is generally referring to the later level of automation such as an autopilot system, autothrottle function, or auto-braking system where the pilot needs to understand the status of automation as well as the intent in some cases.
- **Crew Resource Management** at the most general level crew resource management (CRM) is the use and management of all available resources, information, equipment, and people to achieve safe and efficient flight operations. Characteristics of CRM as defined in AC 120-51E include: a comprehensive system of applying human factors concepts to improve crew performance, embraces all operational personnel, and concentrates on crewmembers' attitudes and behaviors and their impact on safety.
- **Disruption Management** the ability to prioritize and handle emergent events that interrupt or distract the pilots from carrying out current or planned tasks.
- **Flight Path Management** the planning, execution, and assurance of the guidance and control of aircraft trajectory and energy, in flight or on the ground.
- **Information Management** the activity of controlling the pace, flow, and construction of information needed for task performance is part of information management. This includes ensuring that the information needed to perform tasks is accurate, complete, understood, and is integrated into the overall workflow in a timely manner.
- **Monitoring** the on-going observation and assessment of various components of the mission. This includes monitoring of systems, flight path, external situation, completion of tasks, etc.
- **Pilot Flying** per AC 120-71A, this is the flight crewmember that monitors and controls the aircraft regardless of the level of automation employed.
- **Pilot Monitoring** per AC 120-71A, this is the flight crewmember that monitors the aircraft and actions of the pilot flying. The term pilot monitoring has replaced the previously used term Pilot Not Flying in order to designate clearly what each pilot role is responsible for.
- Task Allocation the assignment of a task to a person or entity such as an automated system.
- **Task Loading** the number of tasks pilots need to perform within a set period of time. It has been used synonymously with workload.
- **Task Management** the strategic orchestration and tactical adaption of pilot tasks performed over the course of a flight, to ultimately protect the aircraft flight path, while balancing other operational objectives.

Task Priority – the ranking of task importance by pilots within the operational context.

- **Task Resources** within the context of the flight deck, these resources include information, knowledge, skills, procedures, policies, other people, tools, and briefings that the pilots use to support and inform task accomplishment.
- **Threat and Error Management** a systems approach to aviation safety originally developed by human factors researchers at the University of Texas that promotes a proactive philosophy and provides techniques for maximizing safety margins. It proposes that threats (such as adverse weather), errors (such as a pilot selecting a wrong automation mode), and undesired aircraft states (such as an altitude deviation) are everyday events that flight crews must manage to maintain safety.
- **Time Management** the managing of time available to initiate and complete a task with the goal of using one's time effectively.

VNAV PTH and VNAV SPD- Vertical navigation modes for the control of vertical path

**Workload** – the ratio between the number of tasks and the available time and resources available to complete them.

**Workload Management** – sometimes used synonymously with task management, it includes time management, prioritization, task allocation, and information management.