SITUATION AWARENESS INFORMATION REQUIREMENTS FOR COMMERCIAL AIRLINE PILOTS

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ABSTRACT

Situation awareness is presented as a fundamental requirement for good airmanship, forming the basis for pilot decision making and performance. To develop a better understanding of the role of situation awareness in flying, an analysis was performed to determine the specific situation awareness information requirements for commercial aircraft pilots. This was conducted as a goal-directed task analysis in which pilots' major goals, subgoals, decisions and associated situation awareness information requirements were delineated based on elicitation from experienced commercial airline pilots. A determination of the major situation awareness information requirements for visual and instrument flight was developed from this analysis, providing a foundation for future system development which seeks to enhance pilot situation awareness and provide a basis for the development of situation awareness measures for commercial flight.

ACKNOWLEDGMENTS

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TABLE OF CONTENTS

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INTRODUCTION

Piloting an aircraft is a complex and demanding activity. It requires a highly specialized skill set, discipline and judgment in the presence of considerable uncertainty and risk, and quick but prudent decision-making based on knowledge of one's aircraft, environment, team and self (Kern, 1997).

A pilot relies on his or her expertise in all of these areas to successfully accomplish a flight. In the process, s/he must be able to continuously input and evaluate a myriad of diverse and dynamic data to maintain an accurate, complete and up-to-date understanding of the evolving situation. Pilots often refer to this as "staying ahead of the airplane." Formally, it is referred to as "situation awareness" (SA), and it encompasses the pilot's mental model of the situation upon which all of his/her decisions rely. Fostering a pilot's ability to maintain good SA may prove to be a daunting challenge as the environment inside and outside the cockpit becomes even more complex and demanding.

While several definitions of SA have been offered, the most generally applicable definition is that provided by Endsley (1988). "Situation awareness is the perception of the elements in the environment within a volume of time and space, the comprehension of their meaning, and the projection of their status in the near future." While a description of these elements has been developed for several classes of military aircraft (Endsley, 1989; Endsley, 1993) and air traffic control systems (Endsley & Jones, 1995; Endsley & Rodgers, 1994), this has not previously been done for commercial aircraft. A clear elucidation of the elements in this definition as they apply to commercial airline pilots is a crucial step towards understanding situation awareness in this unique environment. The objective of this effort was to determine those elements for commercial airline pilots.

An overview of the role of situation awareness in decision making and performance in dynamic environments such as flight is provided in Endsley (1995b). Figure 1 presents a schematic description of SA in relation to decision making and performance. The pilot's perception of the elements in the environment as determined from various instruments, displays and communication channels forms the basis for situation awareness. The quality of a given pilot's SA based on that information is largely affected by his or her abilities, training and experience, preconceptions and objectives, and ongoing task workload.

Situation awareness forms the critical input to—but is separate from—decision making, which is the basis for all subsequent actions. Proper implementation of rules and procedures will depend on the quality of the pilot's SA. Even the best-trained and most experienced pilots can make wrong decisions if they have incomplete or inaccurate SA. Conversely, an inexperienced pilot may accurately understand what is occurring in the environment, yet not know the correct action to be taken. For this reason, it is important that SA be considered separately from the decision-making and performance stages. To further expand on the above definition, SA can be described in three hierarchical phases, as depicted in Figure 1.

Level 1 SA – Perception of the elements in the environment

The first step in achieving SA involves perceiving the status, attributes, and dynamics of relevant elements in the environment. The pilot needs to accurately perceive information about his/her aircraft and its systems (airspeed, position, altitude, route, direction of flight, etc.), as well as weather, air traffic control (ATC) clearances, emergency information, and other pertinent elements.

Level 2 SA – Comprehension of the current situation

Comprehension of the situation is based on a synthesis of disjointed Level 1 elements. Level 2 SA goes beyond simply being aware of the elements that are present to include an understanding of the significance of those elements in light of the pilot's goals. Based upon knowledge of Level 1 elements, particularly when put together to form patterns with the other elements, a holistic

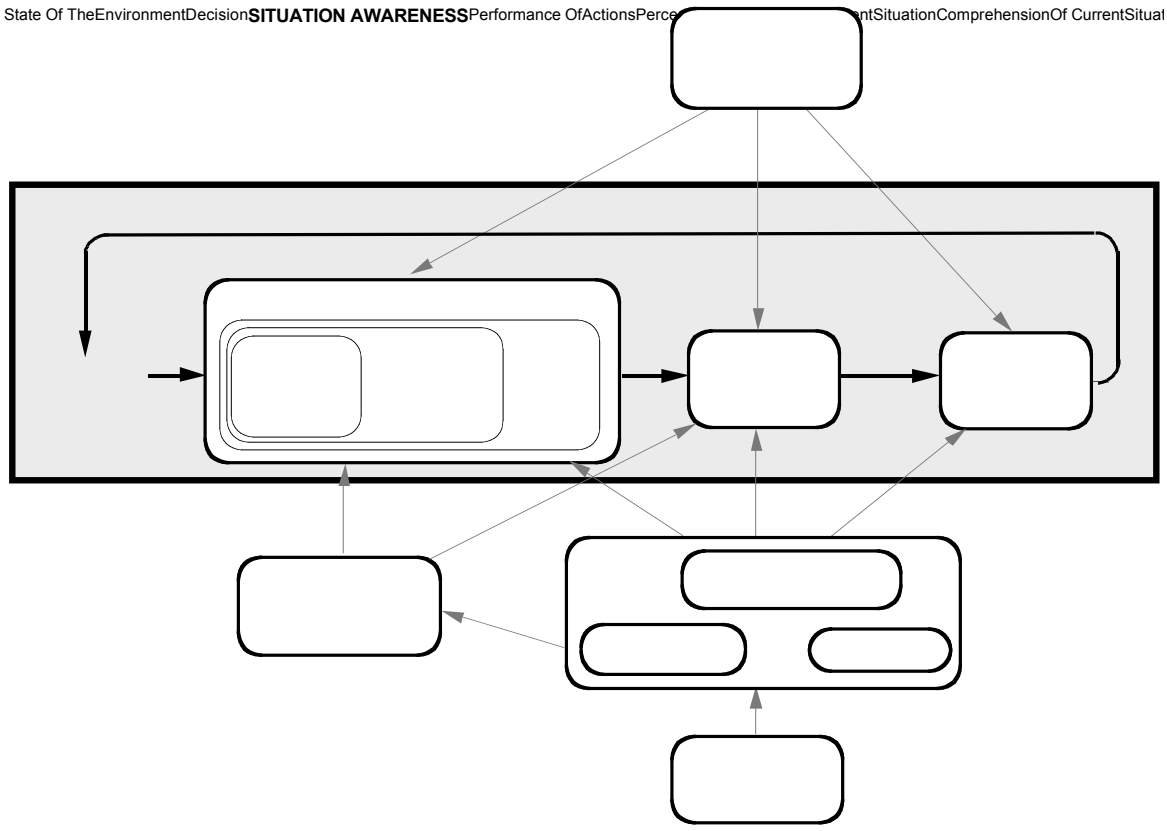

Figure 1. Model of Situation Awareness in Pilot Decision Making (from Endsley, 1995b)

picture of the environment will be formed, including a comprehension of the significance of information and events. The pilot needs to put together disparate bits of data to determine the impact of a change in one system's status on another, or deviations in aircraft state from expected or allowable values. A novice pilot might be capable of achieving the same Level 1 SA as a more experienced one, but may fall short in the ability to integrate various data elements, along with pertinent goals to comprehend the situation as well.

Level 3 SA – Projection of future status

It is the ability to project the future actions of the elements in the environment, at least in the near term, that forms the third and highest level of situation awareness. This is achieved through knowledge of the status and dynamics of the elements and a comprehension of the situation (both Level 1 and Level 2 SA). For example, the pilot must not only comprehend that a weather cell—given its position, movement and intensity—is likely to create a hazardous situation within a certain period of time, but s/he must also determine what airspace will be available for route diversions, and ascertain where other potential conflicts may develop. This ability gives the pilot the knowledge (and time) necessary to decide on the most favorable course of action.

Attributes of SA

While SA can be described as the pilot's knowledge of the environment at a given point in time, it should be recognized that SA is highly temporal in nature. It is not acquired instantaneously, but is built up over time. When assessing convective weather dynamics, a pilot relies in part on past experience and current conditions to project the state of the environment in the near future.

Second, SA is highly spatial in nature in this environment. In addition to a consideration of the spatial relationships between one's aircraft and the ground, other aircraft, weather patterns, winds, etc., there is also a spatially-determined and goal-determined specification of just which subsets of the environment are currently important to SA, based on the tasks at hand. A pilot's scope of responsibility is typically focused on the safety of flight of his/her own aircraft. Within this focus, attention may be further subdivided based on importance to SA. For example, the focus may

shift spatially and temporally inside and outside the aircraft, depending on current goals and tasks, or may shift functionally to include different aspects of a system being monitored. This subdivision can be dynamically modified as various tasks present themselves by refocusing on different elements within the problem space or by changing the boundaries of the problem space itself.

Within the list of elements that pilots find necessary for good SA, not all elements have equal importance at all times. When conditions are clear, for instance, weather may not be a primary consideration. Pilots may opt to shift attention away from some tasks to concentrate on others that may pose problems. It is important to note, however, that elements never become irrelevant or unimportant, just secondary at certain points in time. At least some SA on all elements is required at all times, in order to know which can be made secondary and which should be primary. And at least some SA is required even on secondary elements in order to know that they have not become primary.

Many times it is those elements that are deemed as secondary that cause serious errors when SA on those elements is totally lost. For example, in December 1978, a DC-8 crew preparing for landing at Portland, Oregon was faced with a landing gear problem. To give them time to diagnose the problem, they elected to circle in a holding pattern east of the airport. Soon preoccupied with the problem, the captain failed to recognize a developing low-fuel condition, despite the indications of his crew. The aircraft ran out of fuel and crashed, killing 10 people (NTSB, 1978).

SA and Performance in Aircraft Systems

Having a high level of SA can be seen as perhaps the most critical aspect for achieving successful performance in aviation. Problems with SA were found to be the leading causal factor in a review of military aviation mishaps (Hartel, Smith, & Prince, 1991). Endsley (1995a) conducted an investigation of causal factors underlying aircraft accidents involving major air carriers in the United States based on National Transportation Safety Board (NTSB) accident investigation reports over a four year period. Of the 71% of the accidents that could be classified as having a substantial human error component, 88% involved problems with SA. Of 32 SA errors identified in these accident descriptions, twenty-three (72%) were attributed to problems with Level 1 SA, a failure to correctly perceive some pieces of information in the situation. Seven (22%) involved a Level 2 error in which the data were perceived but not integrated or comprehended correctly, and two (6%) involved a Level 3 error in which there was a failure to properly project the near future based on the aircrew's understanding of the situation.

In the majority of serious accidents and mishaps, pilots are not having trouble ascertaining the correct action for the situation, nor in carrying out those actions, but rather are deficient in fully understanding the situation that they are in. For this reason, understanding situation awareness in aircraft cockpits and finding means of improving situation awareness through system design or pilot training has become a major goal.

OBJECTIVE & SCOPE

The objective of this effort was to determine the situation awareness information requirements of the commercial airline pilot, including perception (Level 1), comprehension (Level 2), and projection (Level 3) of elements per the prior definition of SA. These requirements can be used as input to system/equipment design, training, and research and evaluation efforts which need to consider the situation awareness needs of the pilot.

APPROACH

The requirements analysis was performed as a goal-directed task analysis based on the methodology of Endsley (1993). The SA information requirements were defined as those dynamic information needs associated with the major goals or subgoals of the pilot in performing his or her job. To accomplish this, the major goals of the job were identified, along with the major subgoals necessary for meeting each of these goals. The major decisions that needed to be made, pursuant to each subgoal, were identified. The SA information requirements for making these decisions and carrying out each subgoal were then identified. These requirements focused not only on what data the pilot needed, but also on how that information was integrated or combined to address each decision. Several caveats need to be mentioned in relation to this analysis.

(1) At any given time, more than one goal or subgoal maybe operating, although these will not always have the same priority. The analysis does not assume any prioritization among goals, or that each subgoal within a goal will always be relevant.

(2) The analysis is based on goals or objectives, and is as technology-free as possible. How the information is acquired is not addressed. In some cases, it may be through the cockpit displays, aural or visual alerts, communications with

controllers or other pilots, or the pilot may have to determine it on his/her own. Many of the higher-level SA information requirements fall into this category. Information may be acquired differently on different aircraft equipped with different technological systems or differently per individual pilot preferences, training or airline directives. Nonetheless, the information that is needed to have perfect SA remains essentially the same.

(3) The analysis sought to define what pilots would ideally like to know to have perfect SA, even though they must routinely work with less than this ideal. Thus the analysis serves as a design goal, not necessarily a description of an existing system.

(4) Static knowledge, such as procedures or rules for performing tasks, is outside the bounds of this analysis. The analysis focused only on the dynamic situational information that affects what the pilots do.

(5) Most commercial cockpits operate with two or more crew members. This analysis does not specify which crew member is responsible for which information or tasks, as this division tends to be highly varied and dynamic and there is much overlap among crew members with regard to situation awareness requirements. The analysis was conducted from the point of view of the pilot flying the aircraft who must assure that all the goals and objectives of the flight are being met, either personally or through delegation to another crew member.

METHODOLOGY

Analysis to determine the SA information requirements for commercial airline pilots was comprised of several inter-related activities: (1) prior task analyses and available documentation were reviewed, (2) expert elicitation was conducted with experienced airline pilots, (3) initial review and revision of the resulting goal-directed task analysis by the participating subject matter experts, and (4) final review of the task analysis by independent subject matter experts.

Task Analysis Documentation Review

Several task analyses have been completed for commercial aircraft. For the most part these analyses document how tasks and functions are to be completed on specific models of aircraft. From the standpoint of SA, however, they do little to document the cognitive tasks that airline pilots must perform. Why are the tasks performed? What do pilots do with the information on the displays? What assessments are made? How are the different pieces of information used and integrated with each other to come up with intelligent decisions that meet operational objectives?

While very incomplete on these issues, two task analyses were used to form a basic foundation for the SA requirements analysis: a detailed job analysis for current airline pilots (Hoffman & al., 1997) and an analysis of the future flight deck environment (Alter & Regal, 1992). These documents were reviewed to ascertain the basic functional areas that needed to be covered and form questions for the subject matter experts in the next phase. They also served to insure completeness of the resulting analysis.

Expert Elicitation

Two active airline pilots served as subject matter experts. Together, they possessed a broad experience base, including international, domestic, regional and military aviation, with type ratings in six aircraft between them, as shown in Table 1. Each pilot was interviewed individually. In the first session, pilots were provided an introduction to the objectives of the project. Each pilot was interviewed over numerous sessions, each lasting between one and four hours. In the early sessions, the pilots were interviewed to determine the their overall goals and tasks. From this a basic goal structure was developed.

Table 1. Subject Matter Expert Experience

	Pilot 1	Pilot 2
Commercial Aircraft Experience and Type Ratings	ATP A-310 B-727 B-757 B-767 DC-9 MD-11	ATP B-727 B-757 B-767 DC-9 MD-11
Years of Commercial Flight Experience	12	15
Total Flight Hours	8,700	11,000

During following sessions, a detailed discussion of one or more major piloting goals (e.g., assess flight plan, avoid hazardous weather) was conducted. The pilots were queried as to: subgoals, decisions, and processing requirements associated with each goal, and thereby, the SA needed for successful fulfillment of each goal. Particular attention was paid to determining the desired form of information, and how that information was used (i.e., the higher-level SA information requirements), which could not be readily determined from available documentation.

Based on the information obtained from the pilots, a goal-directed task breakdown was created for each of the commercial pilots' major goals. This lists the major goals, relevant subgoals, questions to be determined in meeting each subgoal, and first-, second- and third-level SA elements required for addressing these questions.

In subsequent sessions, the goal-directed task breakdown**s** from previous session**s** were reviewed with the pilot. Necessary corrections and additions to the breakdown were determined by the pilot. This occurred iteratively over a period of sessions until each pilot was satisfied that the depth and breadth of the job had been covered adequately.

Initial Review

A draft version of the complete goal-directed task analysis for all of the commercial pilot's major goals and tasks was then developed based on the inputs of the two pilots. The draft analysis was circulated to both of the subject matter experts for review. They were asked to examine the analysis for completeness and accuracy and to make any changes needed. This process allowed each of the subjects to review the document at his leisure, taking into account the SA information requirements of the entire job, and resolving any inconsistencies or language problems. These reviews were then incorporated to form a final draft of the SA analysis.

Final Review

The final draft SA analysis was distributed to ten commercial airline pilots for review. Reviews were returned by six of them. The mean years of experience in flying commercial aircraft for this group was 14.8 years (10,580 hours). Type ratings and experience are shown in Table 2.

The reviewers were instructed to make any corrections, changes, or additions that they felt were important. They were specifically asked to address the following questions: (1) Are there any major goals or subgoals that have been left out? (2) Are there other major decisions that you make in achieving each goal? (3) Do you need other information in order to make these decisions (in terms of dynamic situational information, not procedures, systems knowledge, flight skills, etc.)? They were asked to focus on what it is that they really wanted to know (as opposed to what may be available) in each case. The results of the reviews were then compiled into a single document which comprises the final SA requirements analysis.

RESULTS & DISCUSSION

From the above procedures, a goal hierarchy, presented in Appendix A, was constructed which contains the pilot's major goals and subgoals. Although the two pilots participating in this analysis were from different airlines and each approached problems and tasks differently, there was a good consensus regarding the major goals and objectives of the airline pilot. For example, while the pilot from one airline was more likely to follow the original flight plan provided by the airline and the other was more likely to rely on his own judgment, both were in agreement as to the basic questions that needed to be asked in assessing a flight plan and the information that was needed to make these assessments.

At the highest level, the overall goal was described as "getting the aircraft from the origin to the destination, safely, legally, with satisfactory levels of comfort and service to passengers, on schedule and in an efficient manner." Five major objectives can be seen in this goal statement: Safety, legality, passenger comfort and service, schedule, and efficiency. These high-level objectives recurred throughout the analysis. Airline

Table 2. Reviewer Experience

	Reviewer	Reviewer	Reviewer	Reviewer	Reviewer	Reviewer

	1	2	3	4	5	6
Commercial Aircraft Experience and Type Ratings	ATP B-737 B-757 B-767 DC-9 Lear Jet	ATP B-737 B-757 B-767 MD-11	ATP B-727 B-737 B-757 B-767 DC-9	B-737 B-737-200 MD-88	ATP B-737	ATP B-727 B-737 DC-8 DC-9 L-1011 CV-440 CV-880
Years of Commercial Flight Experience	13	21	12.5	1.2	12	29
Total Flight Hours	6,570	17,000	13,000	910	8,000	18,000

pilots must routinely attempt to optimize these five factors in face of a variety of system perturbations (e.g., weather systems, other traffic, etc.).

Of particular note is the fact that these objectives may at many times be at odds with one another. For example, to meet schedule one may need to increase speed, although this may reduce flight efficiency. While safety was almost always considered to be the overriding objective, followed by meeting all legal requirements, pilots are forced to make constant tradeoffs among the goals of service, schedule and efficiency.

Application of these overriding goals was considered across four major task areas: (1) Selecting the best path to the destination, (2) executing the desired flight path safely, efficiently and with ride comfort, (3) managing resources effectively, and (4) satisfying the customer. Relevant subgoals associated with each are listed in Appendix A.

A listing of the major decision tasks and situation awareness information requirements at all three levels for each goal and subgoal shown in Appendix A were determined, and are contained in the goal-directed task analysis presented in Appendix B. Situation awareness requirements at all three levels are shown, including basic information requirements (Level 1 SA), the higher-level assessments that are made based on that information (Level 2 SA) and the projections that must be made to function effectively (Level 3 SA) in regard to each subgoal. It will be noted that considerable overlap is present in situation awareness information requirements between subgoals, as well as a large degree of inter-relatedness between subgoals, as would be expected.

The goal-directed task analysis in Appendix B was carefully reviewed to ascertain a list of SA requirements across the goals of the airline pilot. This is presented in Table 3. This list includes the pilot's major SA information requirements (for dynamic information), exclusive of static knowledge requirements, sources of the information, or associated tasks. These requirements have been broken down into each of the three levels: perception of elements (Level 1), comprehension of their meaning (Level 2), and projection of the future (Level 3).

As shown in Table 3, SA requirements for the commercial pilot are quite extensive. While some of these requirements are only important during certain phases of flight (e.g., taxiway information, approach plan), in many cases accurate knowledge of this information is needed in advance to allow good planning (and in some cases correct programming of the flight management system) in advance of that phase of flight. Other information, such as heading, altitude, and airspeed, remain high priority SA requirements almost throughout the flight.

The effect of automated systems, such as flight management computers or automated alerting systems, on these requirements should be mentioned, both because these systems are prevalent on many commercial aircraft and because more such automation is being incorporated into future aircraft systems. The use of automation to perform many of the tasks of the pilot does not in actuality remove major SA requirements from this list. The pilot still is required to insure that each goal is being properly met, either personally or through the automated system. The pilot still needs to have SA regarding the state of the automated system and the state of the parameters that system is controlling or monitoring. For instance, while the autopilot may keep the aircraft on a programmed course, the pilot is still responsible for insuring that the aircraft is holding to that course. In effect, a good form of automation for the cockpit will be one that helps insure the pilot has a high level of SA regarding information that must be monitored and which assists the pilot in getting the information that is needed (e.g., details regarding an alternate airport, or assessment of the impact of a system degradation on other system performance), rather than one which seeks to remove information from the pilot and subsume tasks independently.

This analysis should be useful for guiding the design and development of future cockpit systems.

An explicit consideration of pilot SA information requirements, particularly at the higher levels, should be beneficial for designing more efficient interfaces and suitable automated assistance to ease pilot workload and enhance SA in the performance of their tasks. Obviously, all SA requirements do not need to be presented to the pilot simultaneously and at all times. This analysis provides a basis for ascertaining which information is needed and how that information needs to be combined in the pursuit of different subgoals. For some information, simply providing high-level information to allow the pilot to ascertain that a given subgoal does not need to be active is adequate (e.g., the system is working properly). For other subgoals, this analysis can be used to provide pilots with information in an integrated form rather than forcing them to go to multiple sources to find the information that is needed.

In addition, this list of SA information requirements can be used to direct SA measurement efforts as they pertain to system design evaluation, training technique evaluation, error investigation, or construct exploration. One measure of the adequacy of a given aircraft system design is the degree to which it provides the pilot with the SA needed to achieve good performance, as well as the degree to which it allows him or her to execute needed actions in a timely manner. Such an assessment can be made of existing system designs and future designs that are contemplated based on this standard.

Table 3. Pilot SA Information Requirements

LEVEL 1

Aircraft data
- Call sign
- Weight
- Weight distribution
- Center of gravity
- Aircraft type
- Engine type/capabilities
- Equipment on board
- CAT II/III qualified
- First aid on board
- Performance capabilities/restrictions
  - Maintenance carryover items

Aircraft state
- Heading
  - Magnetic
  - True
- Altitude
  - Absolute altitude
  - Pressure altitude
  - True altitude
  - Density altitude
    - Temperature
    - Elevation
  - Altimeter setting
- Airspeed
  - Indicated
  - Max and min airspeed for current configuration
  - Ground speed
- Airspeed rate of change
- Vertical speed
- Acceleration / deceleration
- Position
- Pitch attitude
- Roll attitude
- Turn rate
- Configuration
  - Gear position
  - Flap position
  - Slat position
  - Spoiler position
  - Stabilizer trim
  - Elevator trim
- Thrust setting
- Engines spooled evenly for takeoff
- Fuel
  - Fuel quantity
  - Fuel temperature
    - Fuel type
  - Fuel distribution
  - Fuel burn rate
  - Arrival fuel requirement
- Engine area clear/blocked
- Braking force
- Reverse thrust
- Stall
- Angle of attack
- System settings
  - Anti-ice
  - Packs
  - Autopilot engagement
- Wait time for de-ice
- De-ice fluid
  - Type
  - Mix ratio

Equipment malfunctions
- Areas of aircraft damage
- Operational status of aircraft systems
  - Reliability of systems
  - Severity of system failure/degrade
  - Validity of system failure/degrade
    - Pneumatic
      - Air conditioning
      - Pressurization
      - Thrust reversers
    - Hydraulic
    - Flight control
      - Flaps, slats
      - Control surfaces
      - Spoilers
    - Fuel
    - Electrical
    - Landing gear, brakes, antiskid and nosewheel, autobraking
    - Navigation and instrumentation
      - Altimeter setting
      - Navigation system alignment
      - FMS programming
      - INS
      - GPS
      - ACARS
    - Powerplant
      - Engines
      - APU
    - Autoflight
      - Autopilot
      - FMS
    - Weather radar
    - Anti-ice
    - Fire protection
    - Audio panel
    - Communication system
    - Emergency systems and equipment
      - Oxygen
      - Smoke goggles
    - Doors
      - Unsafe exits
    - Lights
    - Warning systems
    - Cockpit voice recorder
- Operational status of ATC/NAS systems
  - System failures/degrades
  - Validity of system failure/degrade
    - Navigation aid
    - Communication system
  - Area of ATC outage
  - Command center outage

- Confidence level in airspace systems functioning
- Airport lighting

Airports
- Location
- Altitude
- Familiarity/recency
- Closures
- Altimeter setting
- Active runway(s)
- Approach in use
- Runway information
  - Length & width
  - Weight restrictions
  - Surface conditions
  - Closures
  - Procedures in effect
- Taxiway information
  - Width
  - Weight restrictions
  - Surface conditions
  - Slopes/grades
  - Closures/caution areas
  - Communication procedures
- Alternate airport
  - Refueling capabilities
  - Tug capabilities
  - De-icing capabilities
  - Passenger accommodations
    - Customs
    - Stairs/jetway
    - Availability of medical care
  - Served by airline
- Special information
  - Obstacles
  - Procedures
    - Noise abatement
    - Ground movement
    - Missed approach
    - Parallel approaches
  - Limitations
    - Landing curfew
- Lighting/signage
- Navigation ID and location

Flight plan
- Available routes
- Available altitudes
- Planned flight path
  - Distance
  - Altitude
  - Waypoints
  - Bearing
  - Discontinuities
  - Direction
  - Number of changes required
  - Difficulty of changes required
- Dispatcher's concurrence with plan
- Fuel reserve requirement
- Arrival fuel requirement
- Assigned runway
- Takeoff plan/settings/ critical points
- Planned airspeed profile
- Planned climb profile
- Planned cruise altitude
- Planned cruise airspeed
- Planned descent profile
- Approach plan
  - Approach category
  - Reference speed
  - Initial approach altitude
  - Marker-crossing altitude
  - Final approach fix altitude
  - Decision height
  - Minimum descent altitude
  - Missed approach point
- Scheduled time of arrival
- Terminal/Gate assignment
- Gate availability
- Door for deplaning

ATC
- Appropriate ATC organization/frequency
- Success rate of other aircraft requesting clearance
- English proficiency
- Local transition altitude
- Status of:
  - Checklists
  - Procedures
  - Briefings

Traffic
- Traffic on taxiway
- Traffic on runway
- Traffic on final
- Delays on ground
- Number of aircraft holding ahead
- Assigned sequence
- Spacing on final
- Expected Further Clearance time
- Other aircraft
  - Aircraft type/ capabilities
  - Position
  - Altitude
  - Communications present
  - Altitude rate
  - Airspeed
  - Pilot competence/ reliability
- TCAS instructions

Terrain/Obstacles
- Location
- Height
- Minimum altitudes

Weather
- Area affected
- Altitudes affected
- Conditions
  - Temperature
  - Dewpoint
  - Precipitation (level and type)
  - Visibility
  - Ceiling
  - Wind
    - Direction
    - Magnitude
    - Rate of change
    - Altitudes
    - Gusts
    - Crosswind component
  - Darkness
- Direction and speed of movement

- Intensity and rate of change of intensity
- Present ice buildup
- Ice accumulation rate
- Turbulence
  - Altitudes
  - Area
  - Intensity
- Airspeed gain/loss reports from other aircraft
- Wind shear location/ severity
- Aircraft go-arounds
- Airport conditions
  - Precipitation accumulation
  - Runway visibility
  - CAT II/III status
  - Minimums

NAS
- Special use airspace
  - Boundaries
  - Status
    - Activation level
  - Limits and restrictions
- Navaid information
  - Frequency
  - Identifier
  - Availability
  - Course

Clearance
- Pushback clearance
- Departure clearance
- Taxi clearance
- Position and hold clearance
- Takeoff clearance
- Clearance to transition
- Descent clearance
- Approach clearance
- Landing clearance
- ATC instructions / vectoring
  - Assigned heading
  - Assigned altitude or altitude restriction
  - Assigned time-to-fix
  - Assigned spacing or sequence
  - Assigned airspeed or airspeed restriction
  - Time by which to comply with clearance
- Reporting points
- Assigned runway
- Assigned taxiway
- Restrictions

Passengers/cargo
- Number
- Cargo load
  - Weight
  - Hazardous material
  - Human organs
- Serious illnesses/ injuries
- Medical personnel on board
- Sensitivity to descent rate
- Cabin temperature
- Cabin status
  - Seat belts on
  - Flight attendants seated
  - Carts stowed
- Type/status of meal service
- Provision status
  - Meals
  - Beverages
  - Pillows/blankets
  - Communications equipment
  - Movie
- Points of interest
- Hijacker(s)
  - Number
  - Profile
  - Demands

Human Resources
- Flight crew ability/ reliability
  - Cat II/III qualified
  - Experience in aircraft
  - Experience in crew position
  - Currency in aircraft
  - Familiarity with route and airport
  - Correctness of tasks executed
- Cabin attendants ability/reliability
  - Experience
  - Number
  - Time on duty
  - Languages
- Self (pilot) ability/ reliability
  - Fatigue
  - Stress
  - Attitude
  - Alertness
  - Time on duty
  - Workload level
- ATC ability/reliability
  - ATC facility
  - Stress/workload
  - Flexibility
- Ability/reliability of
  - Maintenance
  - Ground crew
  - Dispatch
- Communication channels
  - Dispatch
  - Maintenance

LEVEL 2

Aircraft parameters
- Confidence level in aircraft systems
- Deviation between aircraft state & aircraft limitations
- Deviation between current attitude and desired attitude
- Deviation between current gross weight and allowable gross weight
- Deviation between aircraft state & planned settings
- Severity of degrades
- Margin to V_1
- Airspeed relative to max turbulence penetration airspeed
- Margin to stall
- Validity of indications
  - Airspeed
  - Altitude
  - Fuel quantity
  - Stall
- Electrical power demands

Aircraft control
- Required control inputs
  - Heading correction
  - Pitch correction
  - Thrust correction
- Directional control responsiveness
- Stability of approach
- Available thrust
- Ramp maneuvering requirements
- Ability to abort / go around
- Deviation between current maneuver and optimal maneuver

Airport
- Availability of suitable alternate
- Ability to reach alternate

Flight planning
- Runway suitability
- Taxiway suitability
- Ability to reach destination
- Deviation between hold time and safe hold time

Flight plan conformance
- Deviation between plan and
  - Optimal profile
  - Safety/legal requirements
  - Aircraft capabilities
  - ATC requirements
- Fuel sufficiency
- Schedule deviation
- Track deviation
- Heading deviation
- Altitude deviation
- Airspeed deviation
- Allowable tolerance for deviations
- Discontinuities in plan

ATC conformance
- Deviation from assigned
  - heading or vector
  - altitude
  - time-to-fix
  - spacing
  - airspeed
- Conformance of clearance with expectations

Traffic
- Current separation from other aircraft
- Trajectory of other aircraft relative to ownship
- Closure rate
- Other aircraft's intended actions/path
- Maneuver
  - Aircraft
  - Timing
  - Type
- Aircraft ahead
  - Spacing
  - Type
- Wake turbulence areas

Passengers/cargo
- Comfort level
- Safety
  - Unsafe exits
  - Urgency of medical needs
- Hijacker(s)
  - Level of threat
  - Ability to meet demands

Compliance with Regulations/Procedures
- Compliance with noise abatement requirement
- Compliance with Standard Instrument Departure (SID) requirements
- Compliance with Standard Arrival Route (STAR) requirements
- Cleared to depart gate
- Distance from special use airspace
- Time until next communication needed
- Controller's understanding of own intent/needs

Terrain/Obstacles
- Relative distance, bearing and altitude
- Min/max climb/descent rate to clear obstacle

Priorities
- Relative priority of safety, legality, comfort schedule, efficiency

Customer satisfaction
- Acceptable schedule deviation
  - Connection requirements

Emergencies
- Risk of hazard to passengers/crew

Weather
- Confidence level in weather information
- Timeliness of information
- Hazard level
- Takeoff minimums
- Landing minimums
- Potential for

    - Icing
    - Thunderstorms
    - Turbulence
- Effectiveness of anti-ice measures
- Path of minimum weather exposure
- Deviation between current weather and projected weather
- Relative distance and bearing to weather areas

Impact
- Of aircraft malfunction / damage / abnormal condition on:
    - Aircraft performance/safety
    - Aircraft stability/ control
    - Stopping ability
    - Flight plan
    - Operational parameters / system status
    - Procedures
    - Passenger/crew safety
- Of weather on:
    - Aircraft performance
    - Fuel system
    - Aircraft control
    - Passenger comfort
    - Passenger/crew safety
    - Flight plan
    - Takeoff
    - Landing
- Of traffic on:
    - Separation / safety of flight
    - Schedule
- Of change in flight plan / aircraft maneuver on:
    - Safety of flight
    - Legality
    - Schedule
    - Fuel usage
    - Ride quality
    - Passenger connections
- Of deviations on:
    - Safety of flight
- Of action on:
    - Hazard potential
    - Safety of flight
- Of clearance on:
    - Safety of flight
    - Schedule
    - Efficiency
- Of thrust level / configuration / system settings on:
    - Aircraft performance
    - Safety of flight
    - Passenger comfort/ safety
    - Fuel usage/ economy
    - ATC clearances/ restrictions
- Of emergency on:
    - Safety of passengers/crew
- Of conditions/flight status/information on:
    - Passenger comfort
- Of automation on:
    - Safety of flight
    - Crew workload
    - Crew skills

Workload
- Time available to perform tasks
- To execute change in flight path
- Resources available
- Utility of automation
- Likelihood and cost of automation error
- Time and effort to program and monitor automation
- Time and effort to operate manually

Cost / Benefit
- Of change in:
    - Lateral flight path
    - Vertical flight profile
    - Takeoff runway
    - Departure route
    - Approach
    - Arrival route
    - Landing runway
    - Speed profile
    - Destination airport
- Of holding vs. diverting
- Of start/shut down of each engine
- Of level of automation
- Of evacuation

Equipment malfunctions/ Aircraft condition
- Deviation between system status and expected values
- Deviation between plan and programmed automation
- Impact of ATC degrade/outage on aircraft separation/ safety
- Emergency status

Human Resources
- Confidence level in human resources
    - Flight crew
    - Self
    - Cabin attendants
    - ATC
    - Crew of other aircraft
    - Dispatch crew
    - Gate agent
    - Maintenance/ ground personnel
- Areas of strength/weakness
- Workload level
- Ability to contain/calm unruly passenger(s)

LEVEL 3

Aircraft
- Projected trajectory
  - Own aircraft
  - Other aircraft
- Projected relative trajectories
- Projected separation between aircraft

Flight plan
- Projected taxi time
- Projected schedule deviation
- Estimated time of arrival
  - At destination
  - At fix
- Projected fuel requirements
- Predicted fuel usage
- Predicted fuel burn rate
- Projected time available on current fuel
- Probability of ATC granting clearance for change in flight path
- Probability of staying reliably on route
- Predicted duration of hold
- Predicted areas of congestion
- Predicted periods of congestion
- Predicted duration of delays
- Predicted time:
  - On taxi
  - To departure
  - In each phase of flight
  - To destination
  - To alternate
  - In hold
  - To next clearance
  - Aircraft can safely remain in present/ anticipated conditions
  - Until maneuver required

Weather trends/forecast
- Projected hazard level
- Projected area/severity of hazardous weather encounter
- Predicted wind shear
- Predicted turbulence along route
- Predicted changes in visibility
- Estimated time for weather to lift above minimums
- Projected escape routes
- Projected impact of changes/maneuvers/ weather on:
  - Safety of flight
  - Deviation from flight path

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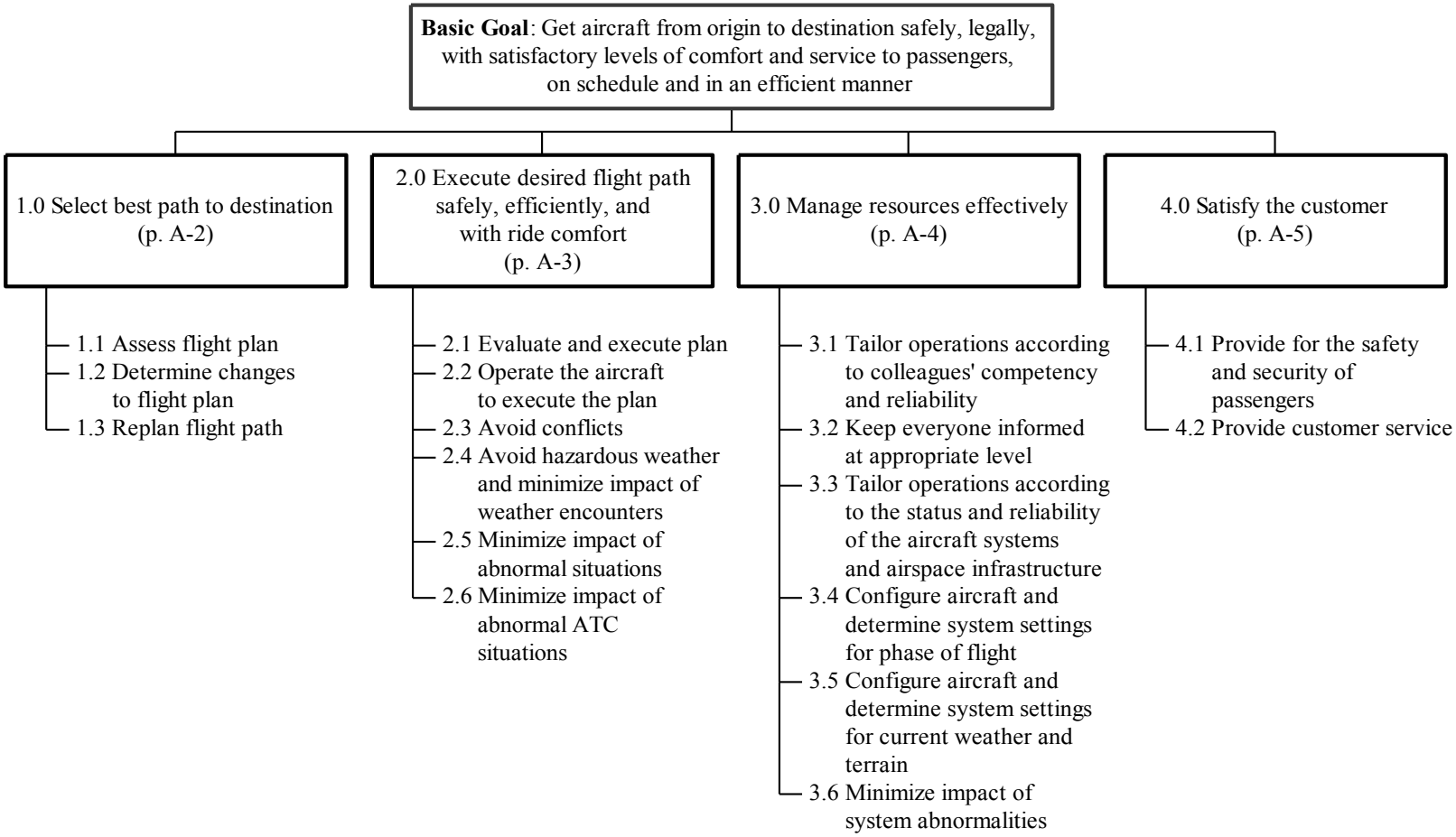
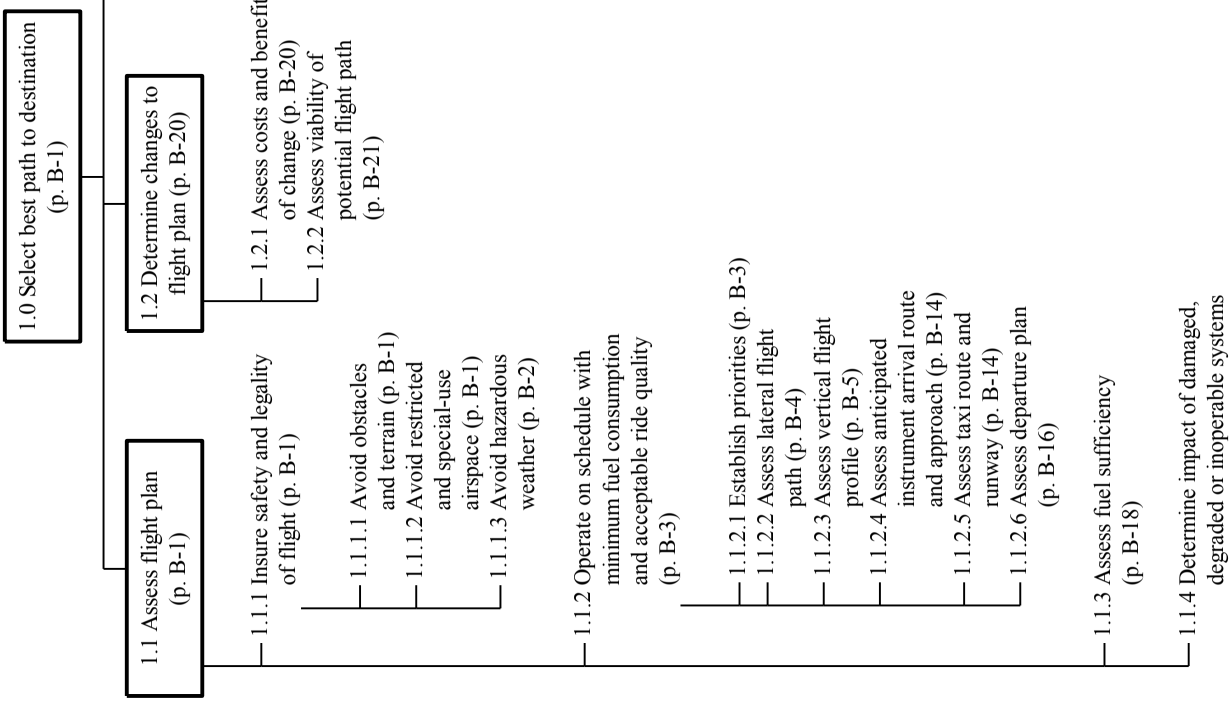
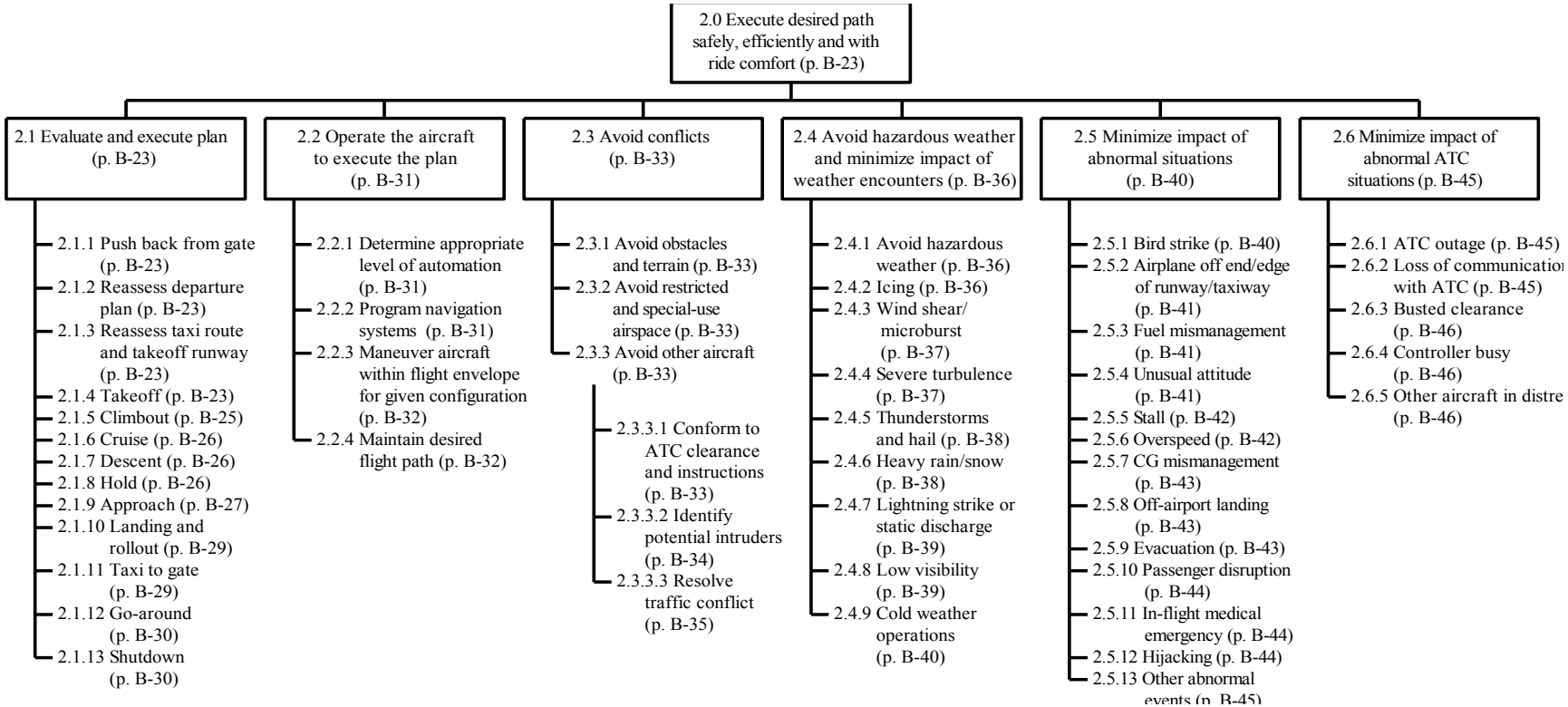
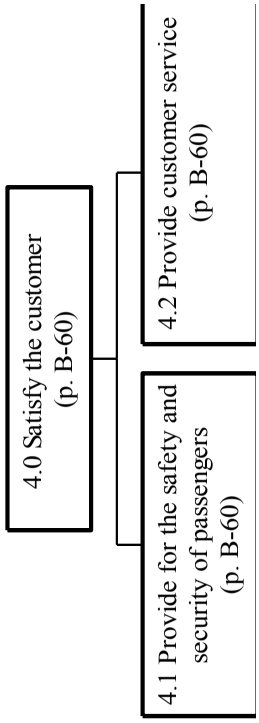
Appendix A. Goal Hierarchy




1.0 Select best path to destination (p. B-1)
1.1 Assess flight plan (p. B-1)
1.1.1 Insure safety and legality of flight (p. B-1)
1.1.1.1 Avoid obstacles and terrain (p. B-1)
1.1.1.2 Avoid restricted and special-use airspace (p. B-1)
1.1.1.3 Avoid hazardous weather (p. B-2)
1.1.2 Operate on schedule with minimum fuel consumption and acceptable ride quality (p. B-3)
1.1.2.1 Establish priorities (p. B-3)
1.1.2.2 Assess lateral flight path (p. B-4)
1.1.2.3 Assess vertical flight profile (p. B-5)
1.1.2.4 Assess anticipated instrument arrival route and approach (p. B-14)
1.1.2.5 Assess taxi route and runway (p. B-14)
1.1.2.6 Assess departure plan (p. B-16)
1.1.3 Assess fuel sufficiency (p. B-18)
1.1.4 Determine impact of damaged, degraded or inoperable systems (p. B-20)
1.2 Determine changes to flight plan (p. B-20)
1.2.1 Assess costs and benefits of change (p. B-20)
1.2.2 Assess viability of potential flight path (p. B-21)
1.3 Replan flight path (p. B-21)
1.3.1 Determine need for replan (p. B-21)
1.3.2 Change destination (p. B-21)
1.3.3 Change route (p. B-22)
1.3.4 Change speed profile (p. B-22)


2.0 Execute desired path safely, efficiently and with ride comfort (p. B-23)
2.1 Evaluate and execute plan (p. B-23)
2.1.1 Push back from gate (p. B-23)
2.1.2 Reassess departure plan (p. B-23)
2.1.3 Reassess taxi route and takeoff runway (p. B-23)
2.1.4 Takeoff (p. B-23)
2.1.5 Climbout (p. B-25)
2.1.6 Cruise (p. B-26)
2.1.7 Descent (p. B-26)
2.1.8 Hold (p. B-26)
2.1.9 Approach (p. B-27)
2.1.10 Landing and rollout (p. B-29)
2.1.11 Taxi to gate (p. B-29)
2.1.12 Go-around (p. B-30)
2.1.13 Shutdown (p. B-30)
2.2 Operate the aircraft to execute the plan (p. B-31)
2.2.1 Determine appropriate level of automation (p. B-31)
2.2.2 Program navigation systems (p. B-31)
2.2.3 Maneuver aircraft within flight envelope for given configuration (p. B-32)
2.2.4 Maintain desired flight path (p. B-32)
2.3 Avoid conflicts (p. B-33)
2.3.1 Avoid obstacles and terrain (p. B-33)
2.3.2 Avoid restricted and special-use airspace (p. B-33)
2.3.3 Avoid other aircraft (p. B-33)
2.3.3.1 Conform to ATC clearance and instructions (p. B-33)
2.3.3.2 Identify potential intruders (p. B-34)
2.3.3.3 Resolve traffic conflict (p. B-35)
2.4 Avoid hazardous weather and minimize impact of weather encounters (p. B-36)
2.4.1 Avoid hazardous weather (p. B-36)
2.4.2 Icing (p. B-36)
2.4.3 Wind shear/ microburst (p. B-37)
2.4.4 Severe turbulence (p. B-37)
2.4.5 Thunderstorms and hail (p. B-38)
2.4.6 Heavy rain/snow (p. B-38)
2.4.7 Lightning strike or static discharge (p. B-39)
2.4.8 Low visibility (p. B-39)
2.4.9 Cold weather operations (p. B-40)
2.5 Minimize impact of abnormal situations (p. B-40)
2.5.1 Bird strike (p. B-40)
2.5.2 Airplane off end/edge of runway/taxiway (p. B-41)
2.5.3 Fuel mismanagement (p. B-41)
2.5.4 Unusual attitude (p. B-41)
2.5.5 Stall (p. B-42)
2.5.6 Overspeed (p. B-42)
2.5.7 CG mismanagement (p. B-43)
2.5.8 Off-airport landing (p. B-43)
2.5.9 Evacuation (p. B-43)
2.5.10 Passenger disruption (p. B-44)
2.5.11 In-flight medical emergency (p. B-44)
2.5.12 Hijacking (p. B-44)
2.5.13 Other abnormal
2.6 Minimize impact of abnormal ATC situations (p. B-45)
2.6.1 ATC outage (p. B-45)
2.6.2 Loss of communicatio
with ATC (p. B-45)
2.6.3 Busted clearance (p. B-46)
2.6.4 Controller busy (p. B-46)
2.6.5 Other aircraft in distre
(p. B-46)

- 3.0 Manage resources effectively (p. B-47)
  - 3.1 Tailor operations according to colleagues' competency and reliability (p. B-47)
    - 3.1.1 Determine colleagues' competency and reliability (p. B-47)
    - 3.1.2 Determine impact of colleagues' competency and reliability (p. B-48)
  - 3.2 Keep everyone informed at appropriate level (p. B-48)
    - 3.2.1 Advise cabin crew of schedule and safety issues (cabin readiness) (p. B-48)
    - 3.2.2 Communicate with maintenance (p. B-49)
    - 3.2.3 Coordinate with dispatch (p. B-49)
    - 3.2.4 Manage crew resources (p. B-49)
    - 3.2.5 Inform ATC (p. B-49)
  - 3.3 Tailor operations according to the status and reliability of the aircraft systems and airspace infrastructure (p. B-49)
    - 3.3.1 Determine aircraft condition and equipment functionality (p. B-50)
    - 3.3.2 Determine condition and functionality of air transportation system infrastructure (p. B-51)
  - 3.4 Configure aircraft and determine system settings for phase of flight (p. B-52)
    - 3.4.1 Determine optimal engine start sequence (p. B-52)
    - 3.4.2 Set configuration and system parameters for optimal takeoff performance (p. B-53)
    - 3.4.3 Set configuration and system parameters for optimal climb performance (p. B-54)
    - 3.4.4 Set configuration and system parameters for optimal cruise performance (p. B-54)
    - 3.4.5 Set configuration and system parameters for optimal descent performance (p. B-54)
    - 3.4.6 Set configuration and system parameters for optimal approach performance (p. B-55)
    - 3.4.7 Set configuration and system parameters for optimal landing performance (p. B-55)
    - 3.4.8 Set configuration and system parameters for optimal taxi performance (p. B-55)
    - 3.4.9 Set configuration and system parameters for aircraft shutdown
  - 3.5 Configure aircraft and determine system settings for current weather and terrain (p. B-56)
  - 3.6 Minimize impact of system abnormalities (p. B-56)
    - 3.6.1 Engine malfunction/fire (p. B-57)
    - 3.6.2 Smoke in cabin (p. B-57)
    - 3.6.3 System malfunction (p. B-57)
    - 3.6.4 Cabin depressurization/ emergency descent (p. B-57)
    - 3.6.5 Structural damage (p. B-58)
    - 3.6.6 Flight control/surface failure (p. B-58)
    - 3.6.7 FMS malfunction (p. B-58)
    - 3.6.8 Autoflight malfunction (p. B-59)
    - 3.6.9 Flight instrument/control contamination (p. B-59)


4.0 Satisfy the customer
(p. B-60)
4.1 Provide for the safety and security of passengers
(p. B-60)
4.2 Provide customer service
(p. B-60)

APPENDIX A. GOAL HIERARCHY

Basic Goal: Get aircraft from origin to destination safely, legally, with satisfactory levels of comfort and service to passengers, on schedule and in an efficient manner.

1. Select best path to destination

1.1 Assess flight plan

1.1.1 Insure safety and legality of flight

1.1.1.1 Avoid obstacles and terrain

1.1.1.2 Avoid restricted and special-use airspace

1.1.1.3 Avoid hazardous weather

1.1.2 Operate on schedule with minimum fuel consumption and acceptable ride quality

1.1.2.1 Establish priorities

1.1.2.2 Assess lateral flight path

1.1.2.3 Assess vertical flight profile

1.1.2.3.1 Assess climb profile

1.1.2.3.2 Assess cruise altitude profile

1.1.2.3.3 Assess descent profile

1.1.2.3.4 Assess speed profile

1.1.2.4 Assess anticipated instrument arrival route and approach

1.1.2.5 Assess taxi route and runway

1.1.2.6 Assess departure plan

1.1.2.6.1 Assess aircraft weight & balance

1.1.2.6.2 Assess takeoff plan

1.1.3 Assess fuel sufficiency

1.1.4 Determine impact of damaged, degraded or inoperable systems

1.2 Determine changes to flight plan

1.2.1 Assess costs and benefits of change

1.2.2 Assess viability of potential flight path

1.3 Replan flight path

1.3.1 Determine need for replan

1.3.2 Change destination

1.3.3 Change route

1.3.3.1 Change lateral flight path

1.3.3.2 Change vertical flight profile

1.3.3.3 Change runway and/or departure route

1.3.3.4 Change arrival route and/or runway

1.3.4 Change speed profile

2. Execute desired flight path safely, efficiently and with ride comfort

2.1 Evaluate and execute plan

2.1.1 Push back from gate

2.1.2 Reassess departure plan (1.2.2.6)

2.1.3 Reassess taxi route and takeoff runway (1.2.2.5)

2.1.4 Takeoff

2.1.5 Climbout

2.1.6 Cruise

2.1.7 Descent

2.1.8 Hold

2.1.9 Approach

2.1.10 Landing and rollout

2.1.11 Taxi to gate

2.1.12 Go-around

2.1.13 Shutdown

2.2 Operate the aircraft to execute the plan

2.2.1 Determine appropriate level of automation

2.2.2 Program navigation systems

2.2.3 Maneuver aircraft within flight envelope for given configuration

2.2.4 Maintain desired flight path

2.3 Avoid conflicts

2.3.1 Avoid obstacles and terrain (1.1.1.1)

2.3.2 Avoid restricted and special-use airspace (1.1.1.2)

2.3.3 Avoid other aircraft (maintain separation)

2.3.3.1 Conform to ATC clearance and instructions

2.3.3.2 Identify potential intruders

2.3.3.3 Resolve traffic conflict

2.4 Avoid hazardous weather and minimize impact of weather encounters

2.4.1 Avoid hazardous weather (1.1.1.3)

2.4.2 Icing

2.4.3 Wind Shear / Microburst

2.4.4 Severe turbulence

2.4.5 Thunderstorms and hail

2.4.6 Heavy rain/snow

2.4.7 Lightning strike or static discharge

2.4.8 Low visibility

2.4.9 Cold weather operations

2.5 Minimize impact of abnormal situations

2.5.1 Bird strike

2.5.2 Airplane off end/edge of runway/taxiway

2.5.3 Fuel mismanagement

2.5.4 Unusual attitude

2.5.5 Stall

2.5.6 Overspeed

2.5.7 CG Mismanagement

2.5.8 Off-airport landing

2.5.9 Evacuation

2.5.10 Passenger disruption

2.5.11 In-flight medical emergency

2.5.12 Hijacking

2.5.13 Other abnormal events

2.6 Minimize impact of abnormal ATC situations

2.6.1 ATC outage

2.6.2 Loss of communication with ATC

2.6.3 Busted clearance

2.6.4 Controller busy

2.6.5 Other aircraft in distress

3. Manage resources effectively

3.1 Tailor operations according to colleagues' competency and reliability

3.1.1 Determine colleagues' competency and reliability

3.1.2 Determine impact of colleagues' competency and reliability

3.2 Keep everyone informed at appropriate level

3.2.1 Advise cabin crew of schedule and safety issues (cabin readiness)

3.2.2 Communicate with maintenance

3.2.3 Coordinate with dispatch

3.2.4 Manage crew resources

3.2.5 Inform ATC

3.3 Tailor operations according to the status and reliability of the aircraft systems and airspace infrastructure

3.3.1 Determine aircraft condition and equipment functionality

3.3.2 Determine condition and functionality of air transportation system infrastructure

3.4 Configure aircraft and determine system settings for phase of flight

3.4.1 Determine optimal engine start sequence

3.4.2 Set configuration and system parameters for optimal takeoff performance

3.4.3 Set configuration and system parameters for optimal climb performance

3.4.4 Set configuration and system parameters for optimal cruise performance

3.4.5 Set configuration and system parameters for optimal descent performance

3.4.6 Set configuration and system parameters for optimal approach performance

3.4.7 Set configuration and system parameters for optimal landing performance

3.4.8 Set configuration and system parameters for optimal taxi performance

3.4.9 Set configuration and system parameters for aircraft shutdown

3.5 Configure aircraft and determine system settings for current weather and terrain

3.6 Minimize impact of system abnormalities

3.6.1 Engine malfunction/fire

3.6.2 Smoke in cabin

3.6.3 System malfunction

3.6.4 Cabin depressurization/emergency descent

3.6.5 Structural damage

3.6.6 Flight control/surface failure

3.6.7 FMS malfunction

3.6.8 Autoflight malfunction

3.6.9 Flight instrument/control contamination

4. Satisfy the customer

4.1 Provide for the safety and security of passengers

4.2 Provide customer service

APPENDIX B. GOAL-DIRECTED TASK ANALYSIS

Basic Goal: Get aircraft from origin to destination safely, legally, with satisfactory levels of comfort and service to passengers, on schedule and in an efficient manner.

1. Select best path to destination

1.1 Assess flight plan

1.1.1 Insure safety and legality of flight

- *Can I proceed along this route?*
- *Do I need to modify plans or procedures?*

1.1.1.1 Avoid obstacles and terrain

- *Is a change in flight path needed to avoid obstacle or terrain?*
  - Distance and bearing to obstacle/terrain feature
    - Planned flight path
    - Location of obstacle or terrain feature
  - Relative altitude of obstacle or terrain feature
    - Height of obstacle or terrain feature
    - Planned aircraft altitude

1.1.1.2 Avoid restricted and special-use airspace

- *Is a change in flight path needed to avoid restricted or special-use airspace?*
  - Distance and bearing to airspace
    - Planned flight path
    - Airspace characteristics
      - Location and area
      - Active / inactive status
      - Clearance to transition the airspace
      - Limits and restrictions of airspace

1.1.1.3 Avoid hazardous weather

- *Is hazardous weather expected en route?*
  - Likelihood of hazardous weather encounter
    - Planned flight path
    - Weather pattern
      - Current weather conditions
        - Area affected
        - Altitudes affected
    - Projected weather conditions
      - Direction and speed of movement
      - Increasing or decreasing intensity
  - Confidence level in weather information
  - Timeliness of weather information
- *How hazardous are the anticipated weather conditions?*
  - Projected hazard level of weather conditions
    - Projected weather conditions
      - Snow (2.4.6)
      - Icing (2.4.2)
      - Low visibility (2.4.8)
      - Hail (2.4.5)
      - Rain (2.4.6)
      - Convective activity
    - Temperatures
    - Intensity of weather area
      - Rate of change of intensity
    - Low visibility (2.4.8)
    - Turbulence (2.4.4)
      - Altitudes
      - Area
      - Intensity
    - Winds

- Winds
  - Direction
  - Magnitude
  - Altitude
  - Gusts
  - Variance
  - Wind shear (2.4.3)
  - Rate of change
- *Is a change in flight path needed?*
  - Potential impact of weather on…
    - Aircraft performance
    - Passenger comfort and safety

1.1.2 Operate on schedule with minimum fuel consumption and acceptable ride quality

- *Does planned flight path meet schedule?*
- *Is planned flight path the most fuel-efficient available?*
- *Does planned flight path provide acceptable ride quality?*

1.1.2.1 Establish priorities

- *What is the current objective function?*
  - Operator's objective function
    - Relative importance of schedule, economy and passenger comfort
  - *Is projected schedule performance acceptable?*
    - Schedule criticality
      - Projected schedule deviation
        - Scheduled arrival at destination
        - Estimated time of arrival at destination
          - Distance along planned route
          - Projected ground speed along planned route
            - Planned airspeed profile
            - Wind direction and magnitude
            - Wind direction and magnitude
          - Projected duration of traffic delay(s) along planned route
            - Projected areas of traffic congestion
            - Projected periods of traffic congestion
      - Acceptable schedule margin

- Flight's strategic position in airline arrival bank
- Value of customer satisfaction relative to other priorities

- *Is projected ride quality acceptable?*
  - Safety requirements
  - Value of passenger comfort relative to other priorities
  - Severity of projected turbulence along planned route (2.4.4)

- *Is projected fuel usage acceptable?*
  - Assess fuel sufficiency (1.1.3)
  - Value of efficiency relative to other priorities
    - Projected schedule criticality
    - Projected ride comfort

1.1.2.2 Assess lateral flight path

- *Does the estimated time of arrival meet schedule requirements?*
  - Projected deviation from schedule
    - Scheduled time of arrival
    - Estimated time of arrival
      - Estimated time of departure
      - Estimated time en route
        - Distance along planned route
        - Projected ground speed along planned route
          - Planned airspeed profile
          - Forecast wind direction and magnitude
          - Forecast wind direction and magnitude
        - Projected duration of traffic delay(s) along route
          - Projected areas of traffic congestion
          - Projected periods of traffic congestion

- *Does the lateral flight path provide acceptable ride comfort?*
  - Projected turbulence along planned route (2.4.4)

- *Does the lateral flight path optimize fuel usage?*
  - Deviation between optimal fuel usage and fuel usage on planned path

- Fuel required to destination airport via planned lateral route (1.1.3)
    - Planned lateral route
        - Temperature profile along route
        - Wind direction and magnitude along route
- Fuel required to destination airport via fuel-optimal lateral route
    - Fuel-optimal lateral route
        - Temperature profile along route
        - Wind direction and magnitude along route

1.1.2.3 Assess vertical flight profile

- *Is this profile safe and legal?*
- *Can aircraft achieve this profile?*
- *Does this profile provide the best fuel efficiency over route?*
    - Deviation between planned profile and optimal profile
    - Deviation between planned profile and safety/legal requirements
    - Deviation between planned profile and aircraft capabilities
    - Deviation between planned profile and ATC requirements

1.1.2.3.1 Assess climb profile

- *Is this a safe and legal departure plan?*
  - Deviation between departure plan and safety/legal requirements
    - Departure plan
    - Safety/legal requirements
      - Noise abatement requirements
        - Means of measuring noise emission at airport
        - Degree of enforcement of noise abatement policy
      - Standard Instrument Departure (SID) requirements
      - ATC restrictions
      - Aircraft performance restrictions
      - Avoid obstacles and terrain (1.1.1.1)
        - Minimum climb rate to clear obstacle
      - Avoid hazardous weather (1.1.1.3)
- *Can aircraft achieve planned climb profile?*
  - Deviation between planned climb profile and aircraft capabilities
    - Planned climb profile
    - Aircraft capabilities
      - Achievable climb rate
        - Best achievable angle of climb
        - Best achievable rate of climb
          - Aircraft/engine type
          - Gross weight
          - Temperature/icing conditions
          - Altitude during climb profile

- *Is this the most fuel-efficient climb profile available?*
  - Deviation in fuel usage between planned climb profile and optimal profile
    - Projected fuel usage for planned climb profile
      - Projected fuel burn rate for climb profile
        - Aircraft/engine type
        - Gross weight
        - Temperature/icing conditions
        - Airspeed
        - Configuration
      - Estimated time in climb
        - Planned cruise altitude
        - Planned vertical speed
          - Forecast wind direction and magnitude
    - Projected fuel usage for optimal climb profile
    - Expedited climb profile availability
      - VFR conditions

- *Does the estimated time of arrival meet schedule requirements?*
  - Projected deviation from arrival schedule
    - Scheduled time of arrival at destination
    - Estimated time of arrival at destination
      - Estimated time of departure from origin
      - Estimated time en route
        - Distance along planned route
        - Projected ground speed along planned route
          - Planned airspeed profile
          - Forecast wind direction and magnitude
        - Projected duration of traffic delay(s) along route
        - Projected duration of traffic delay(s) along route
          - Projected areas of traffic congestion
          - Projected periods of traffic congestion

1.1.2.3.2 Assess cruise altitude profile

- *Does cruise altitude comply with ATC restrictions for direction of flight?*
    - Deviation between planned cruise altitude and ATC requirements
        - Planned cruise altitude
        - ATC restrictions for direction of flight
- *Can aircraft achieve planned cruise altitude?*
    - Time to reach planned cruise altitude
    - Deviation between planned cruise altitude and aircraft capabilities
        - Planned cruise altitude
        - Achievable cruise altitude
            - Planned cruise airspeed
            - Gross weight
            - Temperature/icing conditions
            - Maintenance aircraft limitations
        - Planned climb rate
        - Achievable climb rate
            - Aircraft/engine type
            - Gross weight
            - Temperature
            - Maintenance aircraft limitations
        - Stall margin

- *Is this the most fuel-efficient altitude available?*
    - Deviation between planned cruise altitude and optimal fuel usage
        - Projected fuel usage at planned cruise altitude
            - Projected fuel burn rate at planned cruise altitude
                - Aircraft/engine type
                - Gross weight
                - Temperature/icing conditions
                - Airspeed
            - Estimated time in cruise
                - Planned distance in cruise
                - Planned ground speed in cruise
                    - Planned cruise speed
                    - Forecast winds aloft (direction and magnitude)
        - Projected fuel usage at optimal cruise altitude
- *Does the planned cruise altitude avoid traffic congestion?*
    - Projected traffic congestion at planned cruise altitude
        - Areas of traffic congestion at planned cruise altitude
        - Periods of traffic congestion at planned cruise altitude
- *Does the planned cruise altitude provide acceptable ride comfort?*
    - Projected turbulence at planned cruise altitude (2.4.4)
- *Does the planned cruise altitude incorporate an acceptable escape route for mountainous terrain?*
    - Acceptable cruise altitudes
    - Potential escape routes
        - Planned cruise altitude
        - Drift-down rate
        - Single engine performance at altitude
        - Single engine performance at altitude
        - Planned lateral path
        - Height of terrain
        - Location of suitable alternate airports

1.1.2.3.3 Assess descent profile

- *Is this a safe and legal arrival plan?*
    - Deviation between arrival plan and safety/legal requirements

- Arrival plan
- Noise abatement requirements
    - Means of measuring noise emission at airport
    - Degree of enforcement of noise abatement policy
- Standard Terminal Arrival Route (STAR) requirements
- ATC restrictions
- Aircraft performance restrictions
- Obstacles and terrain (1.1.1.1)
- Hazardous weather (1.1.1.3)

- *Can aircraft achieve planned descent profile?*
    - Deviation between planned descent profile and aircraft capabilities
        - Planned descent profile
        - ATC descent restrictions
        - Achievable descent rate
            - Best achievable angle of descent
            - Best achievable rate of descent
                - Aircraft type
                - Gross weight
                - Configuration
                - Temperature/icing conditions
                - Altitude during descent profile
                - Engine performance limitations
            - Distance to touchdown point
- *Is this the most fuel-efficient descent profile available?*
    - Deviation between planned descent profile and optimal
        - Projected fuel usage in planned descent profile
            - Projected fuel burn rate for planned descent profile
                - Aircraft/engine type
                - Gross weight
                - Temperature/icing conditions
                - Airspeed
                - Configuration
                    - Thrust setting
                    - Spoiler setting
            - Estimated time in descent
                - Planned cruise altitude

- Planned vertical speed
  - Forecast wind direction and magnitude
- Projected fuel usage in optimal descent profile

- *Does the estimated time of arrival meet schedule requirements?*
  - Projected deviation from arrival schedule
    - Scheduled time of arrival at destination
    - Estimated time of arrival at destination
      - Estimated time of departure from origin
      - Estimated time en route
        - Distance along planned route
        - Projected ground speed along planned route
          - Planned airspeed profile
          - Forecast wind direction and magnitude
        - Projected duration of traffic delay(s) along route
        - Projected duration of traffic delay(s) along route
          - Projected areas of traffic congestion
          - Projected periods of traffic congestion

1.1.2.3.4 Assess speed profile

- *Does speed profile comply with ATC restrictions?*
  - Deviation between speed profile and safety/legal requirements
    - Planned cruise airspeed
    - ATC airspeed restrictions
      - Distance to traffic ahead
      - Areas of turbulence
      - Intensity of turbulence
- *Does speed profile minimize in-flight delays?*
  - Projected airborne delay at destination airport
    - Traffic ahead
    - Anticipated holding
- *Can aircraft achieve planned cruise airspeed?*
  - Deviation between planned speed profile and aircraft capabilities

- Planned cruise airspeed
- Achievable airspeed
    - Planned cruise altitude
    - Aircraft/engine type
    - Temperature/icing conditions
    - Turbulence
    - Fuel temperature

- *Does the estimated time of arrival meet schedule requirements?*
    - Projected deviation from arrival schedule
        - Scheduled time of arrival at destination
        - Estimated time of arrival at destination
            - Estimated time of departure from origin
            - Estimated time of departure from origin
            - Estimated time en route
                - Distance along planned route
                - Projected ground speed along planned route
                    - Planned airspeed profile
                    - Forecast wind direction and magnitude
                - Projected duration of traffic delay(s) along route
                    - Projected areas of traffic congestion
                    - Projected periods of traffic congestion

- *Is this the most fuel-efficient speed profile available?*
    - Deviation between speed profile and optimal
        - Projected fuel usage in cruise
            - Projected fuel burn rate at planned cruise airspeed
                - Aircraft/engine type
                - Gross weight
                - Temperature/icing conditions
                - Altitude
            - Estimated time in cruise
                - Planned distance in cruise
                - Planned ground speed in cruise
                    - Planned cruise speed
                    - Forecast winds aloft (direction and magnitude)

- Projected fuel usage at optimal cruise speed
- *Does the planned cruise airspeed provide acceptable ride comfort and safety of flight?*
  - Projected ride comfort and safety
    - Projected turbulence at planned cruise altitude (2.4.4)
    - Turbulence penetration speed

1.1.2.4 Assess anticipated instrument arrival route and approach

- *Does path conform to legal requirements?*
  - Special procedures for terrain avoidance
  - ATC clearance requirements
- *Is change needed for efficiency?*
  - Impact on fuel usage
  - Impact on schedule
  - Impact on ride quality

1.1.2.5 Assess taxi route and runway

- *Is assigned runway acceptable?*
- *Which runway should we use?*
  - Deviation between assigned runway and aircraft requirements
  - Deviation between assigned runway and desired runway
    - Assigned runway
    - Desired runway
      - Wind direction and magnitude
      - Direction of flight to destination
      - Suitability of runways
        - Runway availability
        - Designated "active" runway(s)
        - Length
        - Weight restrictions
        - Surface conditions
        - Runway heading
        - Closures
        - Departure delays
        - Length/weight requirements for aircraft
      - Runway congestion
      - Time to runway
      - Parallel approach
  - Landing configuration and runway conditions
  - Landing configuration and runway conditions

- Flap setting
- Autobrake setting
- Auto speedbrake availability
- Runway breaking action
- Runway length
- Prior landing traffic
- Wake turbulence
- Crosswind corrections
- Runway slope
- Runway width
- Visibility
- Lighting
- Pilot landing
- Runway procedures
    - Exits
    - Time available
    - Hold short
    - Following traffic
    - Aircraft on taxiways
- Abnormal systems

- *Is assigned taxi route acceptable?*
- *Which taxiway should we use?*
    - Deviation between assigned taxi route and aircraft requirements
    - Deviation between assigned taxi route and desired taxi route
        - Taxi clearance
            - Assigned taxiways
        - Desired taxi route
            - Selected runway
            - Taxiway suitability
                - Weight restrictions
                - Surface conditions
                - Surface conditions
                - Closures
                - Departure delays
                - Taxiway width/weight requirements for aircraft
- *Does runway/taxi route clearance make sense?*
    - Deviation between clearance and aircraft route requirements
        - Call sign

- Conformance of clearance with desired runway
- Sequence in flow to runway
- ATC taxi clearance

1.1.2.6 Assess departure plan

1.1.2.6.1 Assess aircraft weight & balance

- *Is aircraft weight and balance within limits?*
  - Deviation between aircraft weight/balance and limitations
    - Aircraft weight and balance data
      - Taxi weight
      - Takeoff weight
      - Center of gravity
      - Takeoff roll distance
        - Temperature
        - Wind direction and magnitude
        - Altimeter setting
        - Runway surface conditions
    - Weight limitations
      - Taxiway weight limitations
      - Runway weight limitations
      - Runway length
    - Center of gravity limitations

1.1.2.6.2 Assess takeoff plan

- *Can aircraft safely perform takeoff?*
  - Deviation between takeoff plan and aircraft capabilities
    - Planned gross weight
      - Number of passengers
      - Cargo load
      - Empty weight
    - Actual gross weight
    - Aircraft settings
      - Thrust settings
      - Calculated takeoff speeds
        - V_1
        - V_r
        - V_2
      - Max takeoff weight
      - Aircraft climb performance
      - Flap setting
      - Stabilizer trim
    - Weather
      - Temperature
      - Wind direction and magnitude
      - Altimeter setting
    - Runway suitability
      - Active runway
      - Runway length
      - Runway weight limitations
    - Takeoff settings for runway
      - Icing
      - Temperature
      - Wind direction and magnitude
      - Air conditioning (packs)

1.1.3 Assess fuel sufficiency

- *Is fuel sufficient to reach destination with reserves?*
- *Is more fuel needed?*
  - Deviation between current fuel load and fuel requirements (with reserves)
    - Current fuel quantity
    - Desired fuel reserve
    - Fuel requirements

- Fuel required to destination airport
    - Distance to destination airport via planned route
    - Aircraft engine fuel burn rate
        - Planned altitude profile
        - Planned airspeed profile
        - Configuration
            - Thrust settings
            - Flap settings
            - Aircraft and engine type
        - Temperature/icing
        - Gross weight
    - Takeoff performance requirements
        - Thrust requirements
            - Required climb rate
            - Noise abatement procedure
    - Expected ground delays
        - Projected time awaiting takeoff
            - Runways in use
            - Traffic delays on ground
            - Waiting time for de-ice
    - Expected in-flight delays and conditions
        - Projected traffic load en route
        - Projected congestion at destination airport
        - Projected weather delays en route
            - Storm cells
            - Storm cells
                - Location
                - Intensity
            - Forecast winds aloft
                - Direction
                - Magnitude
- Fuel required to alternate airport
    - Distance to alternate airport via planned route
    - Aircraft engine fuel burn rate
        - Planned altitude profile
        - Planned airspeed profile
        - Configuration
            - Thrust settings
            - Flap settings

- Aircraft and engine type
- Temperature/icing
- Gross weight
- Expected ground delays
  - Projected time awaiting takeoff
    - Runways in use
    - Traffic delays on ground
    - Waiting time for de-ice
- Expected in-flight delays and conditions
  - Projected traffic load en route
  - Projected congestion at destination airport
  - Projected weather delays en route
    - Storm cells
      - Location
      - Intensity
    - Forecast winds aloft
      - Direction
      - Magnitude
      - Magnitude
- Legal minimum fuel requirements
  - Fuel reserve requirement
  - Arrival fuel requirement

1.1.4 Determine impact of damaged, degraded or inoperable systems

- *What modifications to flight path, operational parameters or procedures are required?*
  - Impact of degrades/outages on desired flight path, operational parameters and procedures
    - Systems affected
    - Severity of degrade
    - Associated penalties, restrictions and/or abnormal operations

1.2 Determine changes to flight plan

1.2.1 Assess costs and benefits of change

- *Is a change worthwhile?*
  - Benefit(s) of change in flight path and/or speed
    - Impact on safety
      - Assess current flight plan (1.1)
      - Assess flight plan change (1.1)

- Impact on legality
  - Assess current flight plan (1.1)
  - Assess flight plan change (1.1)
- Impact on schedule
  - Assess current flight plan (1.1)
  - Assess flight plan change (1.1)
- Impact on fuel usage
  - Assess current flight plan (1.1)
  - Assess flight plan change (1.1)
- Impact on ride quality
  - Assess current flight plan (1.1)
  - Assess current flight plan (1.1)
  - Assess flight plan change (1.1)

- Workload required to execute change
  - Number of changes required
  - Difficulty of changes required
- Flight crew fatigue level

1.2.2 Assess viability of potential flight path

- *Is potential flight path available?*
  - Probability of ATC granting clearance for change
    - ATC restrictions in effect
    - Success rate of other aircraft requesting new clearances
    - Traffic volume
      - Time of day
  - Probability of staying reliably on route (potential)
    - Operational status of aircraft navigation system
    - Operational status of navaids en route (potential)

1.3 Replan flight path

1.3.1 Determine need for replan

- Costs and benefits of change (1.2.1)

1.3.2 Change destination

- *Is diversion to new airport needed?*
  - Severity of event
  - Impact of event on flight safety
    - Fuel reserves at/below minimum
    - Systems failures (3.3)
    - Airport closure

- Passenger emergency (2.5.11)

- *To which airport should we divert?*
  - Ability to reach airport
    - Weather en route and at alternate airport (1.1.1.3)
    - Weather en route and at alternate airport (1.1.1.3)
    - Fuel requirements of route (1.1.3)
    - Distance to alternate
    - Time to alternate
  - *Is the airport suitable?*
    - Facilities and runway length
    - Approach available at alternate
    - Traffic at alternate
    - Familiarity of alternate
    - Airport open to commercial traffic?
    - Airport served by airline?
    - Passenger accommodations
      - Customs
      - Stairs or jetway
      - Medical facilities

1.3.3 Change route

1.3.3.1 <u>Change lateral flight path</u>

- Costs and benefits of change (1.2.1)

1.3.3.2 <u>Change vertical flight profile</u>

- Costs and benefits of change (1.2.1)

1.3.3.3 <u>Change runway and/or departure route</u>

- Costs and benefits of change (1.2.1)

1.3.3.4 <u>Change arrival route and/or runway</u>

- Costs and benefits of change (1.2.1)

1.3.4 Change speed profile

- Costs and benefits of change (1.2.1)

2. Execute desired flight path safely, efficiently and with ride comfort

2.1 Evaluate and execute plan

2.1.1 Push back from gate

- Engine area clear
- Engine start procedure
- Clearance received
- Agent salute received

2.1.2 Reassess departure plan (1.1.2.6)

2.1.3 Reassess taxi route and takeoff runway (1.1.2.5)

2.1.4 Takeoff

- *Should we change our original takeoff plan?*
    - Impact of changes on safety of flight
        - Wind direction and magnitude
        - Impact of weather on takeoff conditions
            - Icing (2.4.2)
            - Low visibility (2.4.8)
            - Wind shear/microburst (2.4.3)
            - Thunderstorms (2.4.5)
            - Heavy rain/snow (2.4.6)
        - Aircraft configuration
- *Is it safe to take the runway?*
    - Impact of traffic on safety of flight
    - Conformance with ATC clearance
        - Position and hold clearance
        - Runway clear of traffic
        - Final approach path clear of conflicting traffic
- *Are systems functioning okay?*
    - Impact of system functionality on safety of flight
        - Checklist complete
        - Engines spooled evenly
            - Engine indications
            - Engine indications
        - Rate of acceleration
- *Do indications agree with plan?*
    - Deviation between observed indications and planned settings
        - Observed indications
            - Thrust indications
            - Airspeed indications
            - Configuration indications
        - Planned settings
            - Planned thrust setting
            - Planned airspeed

- Planned configuration
- Impact of deviation on safety of flight

- *Should we abort the takeoff?*
  - Impact of problem on safety of flight
  - Severity of problem
    - Warning or failure
      - Effect of degraded system (3.3)
        - Degraded system
    - Ability to climbout safely
      - Available climb thrust
    - Ability to stop safely
      - Airspeed relative to V_1
        - V_1
        - Indicated airspeed
      - Available braking force/reverse thrust
      - Aircraft weight
        - Passenger load
      - Runway remaining
      - Obstacles on runway
      - Impact of malfunction on stopping ability
      - Hazard potential from stopping
      - Hazard potential from stopping
        - Wheel brake fire
        - Blown tire
        - Hydraulic failure
        - Fire
        - Structural damage
        - Skid/slipping
        - Passenger evacuation
        - Passenger injury
- *Are we in compliance with departure regulations?*
  - Conformance with ATC regulations
    - Standard instrument departure procedure
    - Noise abatement procedure
      - Means of measuring noise emission
      - Enforcement of noise abatement policy
    - ATC instructions
- *Is aircraft appropriately configured?*
  - Impact of configuration on safety of flight/aircraft performance

- Landing gear
- Flaps/slats
- Thrust setting
- Autopilot engagement
- Anti-ice

2.1.5 Climbout

- *Are we performing to plan?*
  - Deviation between current climb profile and planned climb profile
    - Current climb profile
    - Planned climb profile (1.1.2.3.1)
- *Are my initial assumptions still valid?*
  - Deviation between current weather conditions and projected weather conditions
    - Current weather conditions (1.1.1.3)
    - Projected weather conditions (1.1.1.3)

2.1.6 Cruise

- *Are we performing to plan?*
  - Deviation between current cruise profile and planned cruise profile
    - Actual cruise profile
    - Planned cruise profile (1.1.2.3.2, 1.1.2.3.4)
- *Are my initial assumptions still valid?*
  - Deviation between current weather conditions and projected weather conditions
    - Current weather conditions (1.1.1.3)
    - Projected weather conditions (1.1.1.3)
  - Deviation between current gross weight and assumed gross weight
    - Current gross weight
    - Planned gross weight

2.1.7 Descent

- *Does the planned descent profile need to be modified?*
  - Impact of current conditions on planned descent profile
    - Wind direction and magnitude
    - Crossing restrictions
    - Passenger sensitivity to descent rate

2.1.8 Hold

- *How long can we continue to hold?*
  - Impact of hold on safety of flight

- Expect Further Clearance (EFC) time
- Weather in holding area
- Minimum acceptable fuel level
    - Fuel sufficiency (1.1.3)

- *Are these safe conditions in which to hold?*
    - Impact of conditions on safety of flight
        - Weather (1.1.1.3)
        - Traffic (2.3.3)

- *Are we adhering to the holding pattern?*
    - Conformance with ATC clearance
        - ATC holding clearance
        - Current track
            - Wind direction and magnitude
            - Leg timing
        - Altitude
        - Speed

2.1.9 Approach

- *What approach path should we take?*
    - Impact of approach path on safety, schedule and efficiency
        - Current field conditions
            - Wind direction and magnitude
            - Visibility
            - Ceiling
            - Runway visual range
            - Runway conditions
            - Altimeter setting
            - Temperature/dewpoint
            - Runway(s) in use
            - Approach in use
            - Special obstacles, procedures, limitations, etc.
            - Parallel approach
        - Approach clearance
        - Standard instrument arrival
            - Approach category
                - Navigation system data
                    - Navaid frequency
                    - Navaid identifier
                    - Navaid availability
                    - Navaid availability
                    - Course to navaid
            - Initial approach altitude
            - Marker crossing altitude or final approach fix altitude
            - Minimum decision height or minimum descent altitude
            - Missed approach point
            - Minimum safe altitudes (MORA/MEA/MOCA/MUA)
        - Aircraft ahead landing or going around

- Speed
  - Approach reference speed
    - Gross weight
    - Flap setting
  - Speed adjustments
    - Gusts
    - Wind shear advisories
      - Airspeed gain/loss of aircraft ahead
  - ATC restrictions or instructions
- Flap extension schedule
  - Gross weight
  - Type of approach
  - Runway length

- *Is spacing to next aircraft safe?*
  - Current aircraft spacing
    - Type of aircraft following
    - Speed of aircraft
    - Aircraft spacing on final

2.1.10 Landing and rollout

- *Are systems set for landing?*
    - Deviation between current system settings and planned landing settings
        - Status of checklist items
    - Impact of deviation on safety of flight
    - Conformance with ATC clearance
        - Landing clearance
        - Taxi route
        - Active runways
- *What control adjustments are required?*
    - Deviation between current aircraft profile and planned profile
    - Impact of conditions on safety of flight
        - Wind direction and magnitude
        - Descent rate
            - Thrust level
        - Runway length
        - Runway conditions
        - Braking action report
        - Autobraking functioning
        - Rate of deceleration
        - Ground speed
        - Airspeed
        - Flap setting
        - Directional control
            - Ground speed
        - Desired taxiway
            - Terminal/Gate assignment

2.1.11 Taxi to gate

- Assess taxi route and runway (1.1.2.5)
- Door for deplaning

2.1.12 Go-around

- *Should we go around?*
    - Impact of conditions on safety of flight
    - Conformance with ATC clearance/restrictions
        - Traffic conflict
        - Weather
            - Low visibility (2.4.8)
            - Wind shear/microburst (2.4.3)
            - Thunderstorms (2.4.5)
        - Unstabilized approach
        - ATC clearance
        - Navaid failure (3.3, 3.3.2)
        - Inoperative/degraded aircraft system (3.3, 3.3.1)
        - Available thrust
        - Fuel sufficiency (1.1.3)
        - Airport landing curfew
- *What is the go-around procedure?*
    - Conformance with ATC clearance/restrictions
        - Published procedure
        - ATC-directed special procedure
        - Pilot-requested non-standard procedure

2.1.13 Shutdown

- *When should each engine be shut down?*
    - Impact of engine shutdown on safety, comfort and efficiency
        - Ramp maneuvering requirements
        - Uphill taxiways
        - Ramp/taxiway conditions
        - Inoperative component on one engine
        - Cabin temperature
        - Gate availability
        - Fuel savings

2.2 Operate the aircraft to execute the plan

2.2.1 Determine appropriate level of automation

- *What level of automation is appropriate?*
    - Impact of automation on safety of flight
    - Impact of automation on crew workload/time
        - Time and effort to program and monitor automation
            - Time available
            - Cost (workload) to set up and execute automation
        - Time and effort to operate manually
        - Trust in the automation
            - Accuracy of information provided by automation
            - Reliability of the automation
        - Risk and cost of error committed by automation (3.6.7, 3.6.8, 3.6.9)
        - Utility of the automation
    - Impact of automation on crew skills

2.2.2 Program navigation systems

- *Is the system correctly programmed?*
    - Projected deviation between system program and planned flight profile
    - Flight plan
        - Lateral route
            - Waypoints
            - Bearing
            - Discontinuities
        - Vertical profile
            - Waypoints
        - Speed profile

2.2.3 Maneuver aircraft within flight envelope for given configuration

- *Is this maneuver safe/desirable?*
    - Impact of maneuver on safety of flight
    - Impact of maneuver on passenger comfort
    - Impact of maneuver on fuel efficiency
        - Aircraft performance limitations
            - Heading, altitude, airspeed corrections
                - Control inputs (pitch, roll, yaw, thrust, configuration)

2.2.4 Maintain desired flight path

- *Am I on path (within an acceptable tolerance)?*
    - Deviation from desired path
        - Heading deviation
        - Altitude deviation
        - Airspeed deviation
    - Deviation from desired schedule
        - Current flight path (position, altitude and time)
        - Desired flight path (position, altitude and time)
    - Acceptable tolerance
- *Change needed to recapture desired flight path?*
    - Heading correction
    - Altitude correction
    - Airspeed correction

2.3 Avoid conflicts

2.3.1 Avoid obstacles and terrain (1.1.1.1)

2.3.2 Avoid restricted and special-use airspace (1.1.1.2)

2.3.3 Avoid other aircraft (maintain separation)

2.3.3.1 Conform to ATC clearance and instructions

- *Are we in communication with the appropriate ATC organization?*
    - Deviation from ATC requirements
        - Appropriate ATC organization/frequency
        - Current frequency
- *Are we in conformance with ATC clearance and requirements?*
    - Deviation from ATC clearance/requirements
        - ATC clearance
            - Pushback clearance
            - Departure clearance
            - Taxi clearance
            - Takeoff clearance
            - Descent clearance
            - Approach clearance
            - Landing clearance
        - Current flight path parameters
            - Position
            - Altitude
            - Airspeed
            - Heading
- *Is a change needed to meet ATC clearance?*
    - Projected deviation from ATC clearance
    - Current deviation from ATC clearance and requirements
        - Deviation from assigned heading/vector
            - Current heading/vector
            - Assigned heading/vector
            - Heading rate of change
            - Heading rate of change
        - Deviation from assigned altitude
            - Current altitude
            - Assigned altitude
            - Altitude rate of change
        - Deviation from time-to-fix restrictions
            - Estimated time of arrival at fix

- Assigned time of arrival at fix
- Deviation from spacing restrictions
  - Current separation from neighboring aircraft
  - Assigned/legal separation from neighboring aircraft
- Deviation from airspeed assignment
  - Current airspeed
  - Assigned airspeed
  - Airspeed rate of change
- Time available in which to meet clearance

2.3.3.2 Identify potential intruders

- *Is a conflict imminent?*
- *Is maneuver needed?*
  - Projected distance between intruder's expected trajectory and own planned trajectory
    - Aircraft relative locations
      - Own location
      - Intruder's location
        - Location of wake turbulence
    - Projected relative trajectories of own aircraft and intruder
      - Planned trajectory and airspeed of own aircraft
        - Flight plan
      - Projected trajectory and airspeed of intruder
        - Aircraft type
          - Aircraft performance capability
          - Aircraft performance capability
          - Airspeed
        - Intent of intruder aircraft
          - Flight plan
        - Confidence in predicted flight plan
          - Competency and reliability of intruder aircraft's crew

2.3.3.3 Resolve traffic conflict

- *Which aircraft will perform avoidance maneuver?*
  - Aircraft to maneuver
    - ATC clearance
    - TCAS instructions
    - Aircraft type/ID

- Communications present
- *When is maneuver needed?*
  - Time until maneuver is required
    - ATC clearance
    - TCAS instructions
    - Aircraft separation
    - Closure rate
    - Own aircraft type
      - Performance capabilities/limitations
- *What type of maneuver is needed?*
  - Maneuver providing acceptable distance from other aircraft
  - Maneuver requiring minimum deviation from flight plan
    - Possible maneuvers
      - TCAS instructions
      - ATC instructions
      - Vertical space to maneuver
        - Separation from neighboring aircraft
          - Location of neighboring aircraft
          - Location of neighboring aircraft
      - Lateral space to maneuver
        - Separation from neighboring aircraft
          - Location of neighboring aircraft
      - Time required to perform maneuver
      - Time available before conflict
      - Projected separation with maneuver
      - Projected deviation with maneuver

2.4 Avoid hazardous weather and minimize impact of weather encounters

2.4.1 Avoid hazardous weather (1.1.1.3)

2.4.2 Icing

- *Do icing conditions exist?*
- *Are current icing systems sufficient?*
  - Present ice build-up
  - Accumulation rate
  - Anti-ice system functioning
- *How critical is the situation?*
  - Deviation between expected ground hold time and safe hold time
    - Length of time aircraft can safely remain in present/anticipated conditions

- Holdover time
- Present ice buildup
- Accumulation rate
    - Temperature
- Effectiveness of anti-ice/de-ice measures
    - De-ice fluid: type and mix ratio
    - Use of engine anti-ice
- Expected time of release from ground hold

2.4.3 Wind Shear / Microburst

- *Is an escape maneuver required?*
    - Impact on aircraft safety/performance
        - Severity of wind shear/microburst conditions
        - Effect of wind shear/microburst on aircraft performance
            - Deviation from target airspeed
            - Deviation from intended flight path
- *Is the aircraft performing an optimal wind shear escape maneuver?*
    - Deviation between optimal escape maneuver and current maneuver
        - Current thrust level
        - Current configuration
            - Flaps
            - Landing gear
            - Speed brake
        - Aircraft pitch
        - Stall margin
            - Stall warning
            - Airspeed
            - Angle of attack
        - Radio altitude
        - Vertical speed

2.4.4 Severe turbulence

- *What is the impact of the current turbulence?*
    - Impact on aircraft safety/performance/comfort
        - Effect on aircraft performance
            - Airspeed relative to turbulence penetration speed
                - Current airspeed
                - Turbulence penetration airspeed
        - Effect on passenger/crew comfort and safety
            - Turbulence severity
- *How can we minimize these effects and/or their impact on the flight?*
    - Path of minimum exposure
        - Alternate routes/altitudes
            - Availability of alternate routes/altitudes
        - Aircraft attitude
    - Cabin status
        - Flight attendants and passengers seated
        - Carts stowed

2.4.5 Thunderstorms and hail

- *What is the impact of the current thunderstorms/hail?*
    - Effect on aircraft safety and performance
- *How can we minimize these effects and/or their impact on the flight?*
    - Path of minimum exposure
        - Alternate routes/altitudes
            - Availability of alternate routes/altitudes
    - Cabin status
        - Flight attendants and passengers seated
        - Carts stowed

2.4.6 Heavy rain/snow

- *What is the impact of the current rain/snow?*
    - Effect on aircraft safety/performance and functionality
        - Rate of precipitation
        - Icing (2.4.2)
        - Static discharge (2.4.7)
    - Effect on flight plan
        - Accumulation at destination

2.4.7 Lightning strike or static discharge

- *What is the impact of the current lightning conditions?*
    - Effect on aircraft safety and aircraft systems
        - System(s) affected (3.3.1)
        - Impact of degrade (3.3)
    - Effect on passenger comfort
        - Provide passenger service (4.2)
- *How can we minimize these effects and/or their impact on the flight?*
    - Alternate routes/altitudes
        - Proximity to convective activity
        - Availability of alternate routes/altitudes

2.4.8 Low visibility

- *What is the impact of the impaired visibility?*
    - Effect on safety and legality of flight
        - Minimums
            - Takeoff minimums
            - Landing minimums
        - CAT II/III status of approaches
        - CAT II/III status of aircraft
        - CAT II/III status of crew
        - Status of aircraft navigation systems (3.6.3)
        - Runway visual range
        - Wind limitations
        - Runway limitations
- *How can we minimize these effects and/or their impact on the flight?*
    - Risk and benefit of diverting (1.2)
        - Availability of suitable alternate airport (1.3.2)
    - Risk and benefit of holding
        - Likelihood of having an opportunity to land at given airport
            - Forecast changes in visibility
            - Forecast changes in visibility
            - Number of aircraft holding ahead
            - Minimum fuel level
                - Fuel sufficiency (1.1.3)

2.4.9 Cold weather operations

- *What is the impact of the cold weather?*
    - Impact on safety of flight
        - Effect on fuel system

- Current temperature
- Minimum fuel temperature

- Potential for icing (2.4.2)

- *How can we best contend with these conditions?*
  - Alternate speed/altitudes
    - Ability to descend to warmer altitude
    - Ability to speed up
    - Availability of alternate speed/altitudes

2.5 Minimize impact of abnormal situations

2.5.1 Bird strike

- *What is the impact?*
  - Impact on aircraft safety/performance/functionality
    - Areas damaged
    - Extent of damage in each area
    - Effect on propulsion system
      - Thrust level
      - Airspeed decay
    - Effect on flight control systems
      - Attitude
      - Control feel
- *How can I minimize the impact of this problem?*
  - Applicable checklist

2.5.2 Airplane off end/edge of runway/taxiway

- *How critical is the situation?*
    - Impact on safety/performance
        - Condition of aircraft
            - Landing gear
            - Risk of fire/other hazard
        - Condition of passengers
            - Injuries
            - Emergencies
- *Is evacuation necessary?*
    - Evacuation (2.5.9)

2.5.3 Fuel mismanagement

- *Is this a real problem or an erroneous indication?*
    - Validity of fuel quantity indication
        - System functionality
        - Engine fuel flow/fuel used history
- *Do we need to divert?*
    - Change destination (1.3.2)

2.5.4 Unusual attitude

- *What is the current state of the aircraft?*
    - Severity of attitude deviation
        - Airspeed
        - Attitude
        - Proximity to ground
- *What is the appropriate corrective action?*
    - Proximity to ground
    - Recovery maneuver
        - Aircraft attitude
        - Recovery procedure
- *How can we prevent the reoccurrence of this situation?*
    - Preventive actions
        - Cause(s) of situation
            - Autoflight
            - Systems status
            - Crew error

2.5.5 Stall

- *Is this a real problem or an erroneous indication?*
    - Validity of stall indication
        - Airspeed
        - Thrust setting
        - Aircraft attitude
- *What is the appropriate corrective action?*
    - Recovery maneuver
        - Aircraft attitude
        - Recovery procedure

2.5.6 Overspeed

- *Is this a real problem or an erroneous indication?*
    - Validity of airspeed indication
        - Climb rate
        - Thrust setting
    - Maximum operating mach airspeed
- *What is the appropriate corrective action?*
- *How can we prevent the reoccurrence of this situation?*
    - Preventive actions
        - Cause(s) of situation

2.5.7 CG Mismanagement

- *Does CG offset exist?*
    - Trim setting
    - Tail strike
    - Pitch control feel
    - Fuel leak
- *What is the appropriate corrective action?*
    - Available re-balance options
        - Weight distribution
        - Fuel distribution
- *How can we prevent the reoccurrence of this situation?*
    - Preventive actions
        - Cause(s) of situation
            - Preflight weight and balance computations (1.1.2.6.1)
            - Condition of fuel system
            - Condition of cargo hold

2.5.8 Off-airport landing

- *Is an evacuation required?*
    - Evacuation (2.5.9)

2.5.9 Evacuation

- *Is an evacuation required/possible?*
    - Impact on passenger/crew safety
        - Risk due to evacuation vs. risk due to staying on board
            - Fire
            - Potential for fire
            - Injuries onboard
- *Which exits are unsafe?*
    - Unsafe exits
        - Location of fire/damage
        - Location of exits

2.5.10 Passenger disruption

- *Is a diversion necessary?*
    - Impact on passenger/crew safety
        - Crew's ability to contain/defuse situation (3.1.1)
- *Are other passengers at risk?*
    - Impact on passenger/crew safety
        - Crew's ability to restrain offenders

2.5.11 In-flight medical emergency

- *Is a diversion necessary?*
    - Impact of emergency on passenger/crew safety
        - Urgency of situation
            - Condition of passenger(s)
            - Availability of adequate medical care
                - Medical personnel on board
                - Medical equipment on board
- *To which airport should we divert?*
    - Change destination (1.3.2)
    - Time delays at airport for medical help

2.5.12 Hijacking

- *How urgent is the situation?*
    - Impact on passenger/crew safety
    - Impact on safety of flight
        - Level of threat
            - Condition of passengers
            - Hijacker profile
            - Number of hijackers
            - Presence of weapons/incendiary devices
        - Ability to meet demands

2.5.13 Other abnormal events

- *What is the impact?*
    - Impact on aircraft safety/performance/functionality
        - Status of systems
        - Status of aircraft flight parameters
        - Status of passengers/crew
- *What is the effect of procedures?*
    - Impact of procedures on aircraft safety/performance/functionality

- Status of systems
- Status of aircraft flight parameters
- Status of passengers/crew
- Appropriate procedures carried out

- *What additional actions are needed?*
  - Change flight plan (1.3)
  - Execute go-around (2.1.12)
  - Evacuation (2.5.9)

2.6 Minimize impact of abnormal ATC situations

2.6.1 ATC outage

- *What is the impact?*
  - Impact of ATC outage on aircraft safety/separation
    - Potential intruders (2.3.3.2)
    - Traffic conflict resolutions (2.3.3.3)

2.6.2 Loss of communication with ATC

- *What is the impact?*
  - Impact of communication loss on aircraft safety/separation
    - *Is there an alternate means of communication available?*
      - Alternate means of communication
        - Alternate radio frequencies
        - Alternate communication systems

- *What standard procedures govern this situation?*
    - Standard procedures for loss of communication
        - Flight rules (VFR vs. IFR)
    - Previous clearance

2.6.3 Busted clearance

- *What is the impact on aircraft safety/separation?*
    - Impact on aircraft safety/separation
        - Magnitude of deviation from clearance relative to separation margin
            - Conform to ATC clearance and instructions (2.3.3.1)

2.6.4 Controller busy

- *How urgently must I communicate with ATC?*
    - Time until ATC communication is required
        - ATC communication requirements
- *How can I communicate most efficiently?*
    - Controller's information needs regarding your clearance/intent
        - Shared understanding of clearance/intent

2.6.5 Other aircraft in distress

- *How can we assist?*
    - Proximity of aircraft
    - Nature of problem

3. Manage resources effectively

3.1 Tailor operations according to colleagues' competency and reliability

- *To what extent do I need to modify our plans/operations to accommodate the strengths and weaknesses of my colleagues?*

3.1.1 Determine colleagues' competency and reliability

- *How likely are crewmembers to assist or interfere with the successful completion of our goals?*
    - Impact of crewmember proficiency/reliability
        - Flight crew and own proficiency/reliability
            - Experience in aircraft
            - Experience in crew position
            - Currency in aircraft
            - Familiarity with route and airport
            - Workload
            - Correctness of tasks executed
        - Cabin attendants
            - Number
            - Experience (seniority)
            - Time on duty
            - Workload
            - Correctness of tasks executed
- *Is crewmember physically/mentally fit to perform at a satisfactory level?*
    - Impact of crewmember and own physical/mental fitness
        - Mental and physical condition
            - Fatigue
            - Stress
            - Attitude
            - Alertness
            - Time on duty
            - Physical comfort
                - Temperature
                - Ambient noise
                - Ambient noise
            - Workload allocation
- *How vigilant do I need to be with regard to the actions of crew and colleagues?*
    - Dependability of crew and colleagues
        - Self
        - Flight crew
        - Cabin attendants

- Dispatcher
- ATC
- Ground grew
- Gate agents

3.1.2 Determine impact of colleagues' competency and reliability

- *How should our plans and operations be adjusted?*
  - Areas of team strength
  - Areas of team weakness
- *What is the likelihood that I can get what I want?*
  - ATC competence/awareness/authoritativeness
    - ATC facility
    - Delays/indecisiveness in responses
    - Number of transmissions
    - Stress/workload
    - Flexibility
    - Crispness of instructions

3.2 Keep everyone informed at appropriate level

3.2.1 Advise cabin crew of schedule and safety issues (cabin readiness)

- Estimated time en route (1.1.2.2)
- Weather en route (1.1.1.3)
- Inoperable systems (3.3.1)
- Procedures
- Type of service

3.2.2 Communicate with maintenance

- *Is maintenance aware of our pending needs on arrival?*
    - Maintenance awareness of service needs on arrival
        - Maintenance needs of aircraft
        - Communication channel to maintenance at destination airport

3.2.3 Coordinate with dispatch

- *Do we have concurrence with dispatch on routing?*
    - Dispatch concurrence
        - Proposed flight plan
        - Communication channel to dispatch

3.2.4 Manage crew resources

- *Are all pilots briefed and ready?*
    - Departure briefing
    - Approach/descent briefing

3.2.5 Inform ATC

- *Is ATC aware of our situation/intent?*
    - Emergencies

3.3 Tailor operations according to the status and reliability of the aircraft systems and airspace infrastructure

- *To what extent do I need to modify plans/operations to account for degrades and/or failures within the system?*
    - Impact of degrades/failures on flight safety/performance
    - Impact of possible modifications to plans/procedures
        - Systems affected
        - Severity of degrade
        - Associated penalties, restrictions and/or abnormal operations

3.3.1 Determine aircraft condition and equipment functionality

- *Are aircraft systems operational?*
- *Does system status/indications agree with expectations?*
    - Deviation between system status and expectations
        - Expected status of aircraft systems
        - Operational status of aircraft systems
            - System indications
                - Pneumatic
                    - Air conditioning
                    - Pressurization
                    - Thrust reversers
                - Hydraulic
                - Flight control
                    - Flaps, slats
                    - Control surfaces
                - Fuel
                - Electrical
                - Landing gear, brakes, anti-skid and nose-wheel steering
                - Navigation and instrumentation
                    - Altimeter setting
                    - Navigation system alignment
                    - FMS programming
                    - INS
                    - GPS
                    - ACARS
                - Powerplant
                    - Engines
                    - APU
                - Autoflight
                    - Autopilot
                    - FMS
                    - FMS
                    - INS
                    - GPS
                    - ACARS
                - Anti-ice
                - Fire protection
                - Audio panel, communications systems

- Miscellaneous
  - Emergency systems and equipment
    - Oxygen
  - Doors
  - Lights
  - Warning systems
  - Cockpit voice recorder
  - Log book
  - Manuals
  - Rain repellant

3.3.2 Determine condition and functionality of air transportation system infrastructure

- *Are systems/facilities external to the aircraft operational?*
- *Do system indications agree with expectations?*
  - Deviation between expected and actual condition of airport/airspace facilities/systems
    - Expected condition of airport/airspace infrastructure
    - Actual condition of airport/airspace infrastructure
      - Origin airport malfunctions or degrades
        - Navigation aids
        - Communication systems
        - Airport/runway availability
        - Airport/runway/taxiway lighting
      - National airspace malfunctions or degrades en route
        - Navigation aids
        - Navigation aids
        - Communication systems
        - Command center flow management computer
      - Destination airport malfunctions or degrades
        - Navigation aids
        - Communication systems
        - Airport/runway availability
        - Airport/runway/taxiway lighting

3.4 Configure aircraft and determine system settings for phase of flight

3.4.1 Determine optimal engine start sequence

- *When should each engine be started?*
  - Most economical use of fuel subject to thrust and passenger comfort constraints

- *How much thrust is needed?*
    - Required thrust
        - Condition of taxiway
        - Availability of tug
        - Gross weight
    - Location of ground equipment and personnel
- *Are the passengers safe and comfortable?*
    - Impact on passenger safety/comfort
        - Cabin temperature
        - Electrical power demands
            - Darkness
- *How much fuel could be saved?*
    - Impact on fuel usage
        - Runway location
        - Distance to taxi
        - Path to taxiway
        - Warm-up time

3.4.2 Set configuration and system parameters for optimal takeoff performance

- *What is the appropriate aircraft configuration?*
    - Impact on flight safety/performance
        - Flap setting
        - Slats setting
        - Landing gear position
        - Speed brake deployment
        - Elevator trim
- *What are the appropriate system settings?*
    - Aircraft system settings (3.3)
- *Can we perform a derated takeoff?*
    - Impact on safety of flight
    - Impact on noise abatement compliance
        - Noise abatement requirements
            - Means of measuring noise emission at airport
            - Degree of enforcement of noise abatement policy
    - Impact on fuel usage
        - Conditions for derated takeoff
        - Current conditions
            - Gross weight
            - Temperature

- Runway surface conditions
- Weather conditions
    - Icing (2.4.2)
    - Tailwinds
- Aircraft system status

3.4.3 Set configuration and system parameters for optimal climb performance

- *What is the appropriate aircraft configuration?*
    - Impact on flight safety/performance
        - Flap setting
        - Slats setting
        - Landing gear position
        - Elevator trim
- *What are the appropriate system settings?*
    - Aircraft system settings (3.3)

3.4.4 Set configuration and system parameters for optimal cruise performance

- *What is the appropriate aircraft configuration?*
    - Impact on flight safety/performance
        - Slats setting
        - Elevator trim
- *What are the appropriate system settings?*
    - Aircraft system settings (3.3)

3.4.5 Set configuration and system parameters for optimal descent performance

- *What is the appropriate aircraft configuration?*
    - Impact on flight safety/performance
        - Flap setting
        - Slats setting
        - Speed brake deployment
        - Elevator trim
- *What are the appropriate system settings?*
    - Aircraft system settings (3.3)

3.4.6 Set configuration and system parameters for optimal approach performance

- *What is the appropriate aircraft configuration?*
    - Impact on flight safety/performance
        - Flap setting
        - Slats setting
        - Landing gear position
        - Speed brake deployment
        - Elevator trim
- *What are the appropriate system settings?*
    - Aircraft system settings (3.3)

3.4.7 Set configuration and system parameters for optimal landing performance

- *What is the appropriate aircraft configuration?*
    - Impact on flight safety/performance
        - Flap setting
        - Slats setting
        - Landing gear position
        - Speed brake deployment
        - Elevator trim
- *What are the appropriate system settings?*
    - Aircraft system settings (3.3)

3.4.8 Set configuration and system parameters for optimal taxi performance

- *What is the appropriate aircraft configuration?*
    - Impact on flight safety/performance
        - Flap setting
        - Slats setting
- *What are the appropriate system settings?*
    - Aircraft system settings (3.3)

3.4.9 Set configuration and system parameters for aircraft shutdown

- *What is the appropriate aircraft configuration?*
    - Impact on flight safety/performance
        - Aircraft configuration
- *What are the appropriate system settings?*
    - Impact on flight safety/performance
        - Aircraft system settings (3.3)

3.5 Configure aircraft and determine system settings for current weather and terrain

- *Do I need to modify aircraft configuration or system parameters to account for weather and/or terrain?*
    - Impact on flight safety/performance
        - Aircraft configuration
        - Aircraft system settings (3.3)
- *What configuration modifications are needed?*
    - Impact on flight safety/performance
        - Flap setting
        - Slats setting
        - Landing gear position
        - Speed brake deployment
        - Elevator trim
- *What modifications are needed for the system settings?*
    - Impact on flight safety/performance
        - Aircraft systems (3.3)

3.6 Minimize impact of system abnormalities

- *How severe is the problem?*
- *What is the impact of the problem?*
    - Impact on flight safety/performance
- *How can the impact be minimized?*
    - Type/severity of abnormal situation

3.6.1 Engine malfunction/fire

- *How can the impact be minimized?*
    - Impact on flight safety/performance
        - Phase of flight
        - Local terrain
        - Applicable checklist
    - Severity of problem

- Engine usable
- Time to restart

3.6.2 Smoke in cabin

- *Can we effectively combat the source?*
  - Impact on flight safety/performance
  - Impact on passenger/crew safety/performance
    - Source of smoke
    - Crew member available to combat source
    - Presence of fire

3.6.3 System malfunction

- *How can the impact be minimized?*
  - Impact on flight safety/performance
    - Failed components
    - Alternate components

3.6.4 Cabin depressurization/emergency descent

- *How urgent is the situation?*
  - Impact on passenger safety
    - Oxygen supply
      - Altitude
      - Oxygen system status

- *What actions will safely provide relief?*
    - Impact on passenger safety
        - Safe path to acceptable altitude
            - Traffic below
        - Applicable checklist

3.6.5 Structural damage

- *How urgent is the situation?*
- *Is the aircraft still controllable?*
    - Impact on passenger safety
        - Extent of damage
            - Aircraft stability
            - Aircraft response to controls
            - Aircraft performance

3.6.6 Flight control/surface failure

- *Is the aircraft still controllable?*
    - Impact on flight safety/performance
        - Aircraft stability
        - Aircraft response to controls
        - Aircraft performance

3.6.7 FMS malfunction

- *What is the impact?*
    - Impact on flight safety/performance
        - Alternate means of navigation
        - Over-water legal?

3.6.8 Autoflight malfunction

- *What is the impact?*
    - Impact on flight safety/performance
    - Impact on aircraft route/destination
        - Ability to safely land at destination
            - Destination approach category
                - Destination weather

3.6.9 Flight instrument/control contamination

- *What is the impact?*
    - Impact on flight safety/performance
        - Extent of contamination
            - Aircraft stability
            - Aircraft response to controls
            - Aircraft performance
        - Accuracy of cockpit indications

4. Satisfy the customer

4.1 Provide for the safety and security of passengers

- *Are there any passenger emergency situations?*
    - Impact on passenger safety
        - Passenger disruption (2.5.10)
        - Passenger health condition (2.5.11)
    - Impact on flight safety
- *Should we accept/refuse shipment of any cargo?*
    - Impact on flight safety
    - Special procedures needed
        - Dangerous goods
        - Hazardous materials
        - Human organs
- *Is intervention needed?*
    - Impact on passenger/crew safety
        - Threat to passengers
        - Threat to crew
        - Disruption to passengers

4.2 Provide customer service

- *Are passengers informed?*
    - Impact on passenger comfort/satisfaction
        - Flight progress
        - Schedule changes
        - Safety considerations
        - Special procedures and limitations
- *Are passengers comfortable?*
    - Impact on passenger comfort/satisfaction
        - Cabin temperature
        - Aircraft provision status
            - Meals
            - Meals
            - Beverages
            - Pillows/blankets
            - Communications equipment (phones, computer ports)
- *Are passengers entertained?*
    - Impact on passenger satisfaction
        - Movie

- Points of interest
- Time of day/night