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16. ABSTRACT

Implementation of NextGen improvements will require shifts in the roles and responsibilities of flightdeck, ATC and FOC personnel and that these changes will require the development of new flightdeck-ATC-FOC collaborative systems within the context of advanced automation and new procedures. In order to design and implement systems that will realize safety and efficiency benefits without introducing human factors problems or exceeding human performance limitations, research was needed to provide a framework for assessing future NextGen collaborative systems. These types of assessments would need to consider the human factors issues related to the various ways in which roles and responsibilities can be redistributed between collaborators including automated systems. The overall goal of performing such assessments is to ensure that the appropriate and effective collaborative arrangements are identified for implementation.

This report provides a comprehensive review of current roles and responsibilities related to the interaction between flight deck, air traffic control (ATC) and flight operations center (FOC) and a framework for assessing future collaborative systems with the increased use of automation and technologies under NextGen operations. The framework for assessing changes in the roles and responsibilities of flightdeck, ATC, FOC and automation was developed from:

1. Literature and state-of-the-practice reviews. The focus is current interactions between flightdeck, ATC, FOC and automation as well as projected collaborations in NextGen applications. Product: Comprehensive Bibliography (Section 2 and Appendix F).
2. Analysis of roles and responsibilities of flight deck, ATC and FOC in current operations and their interaction/collaboration points. Included detailed task listings for each group (flightdeck, ATC, FOC). These task listings were synchronized to identify points of interaction, coordination and communication between groups. The final matrix of interactions was then used as a baseline for comparison with projected collaborations required in NextGen. Product: Flight deck-ATC-FOC Interaction Matrix (Section 3 and Appendix E).
3. Identification of key elements and human factors considerations in the transition from current to NextGen operations.

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Collaborative Systems Assessment: Flightdeck, Air Traffic Control, Flight Operations Center and Automation

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Acronyms

AAC	Advanced Airspace Concept
AC	Advisory Circular
ACARS	Aircraft Communications Addressing and Reporting System
AFM	Aircraft Flight Manual
AFP	Airspace Flow Program
AOC	Airline Operations Center (see FOC)
AOP	Autonomous Operations Planner
APP	Approach control sector
AQP	Advanced Qualification Program
ASA	Airborne Surveillance Applications
ASAS	Airborne Separation Assurance acronym
ASIA	Approach Spacing for Instrument Approaches
ATC	Air Traffic Control
ATCT	Airport Traffic Control Tower
ATFM	Air Traffic Flow Management
BEBS	Best Equipped, Best Served
CATFM	Collaborative Air Traffic Flow Management
CATM	Collaborative Air Traffic Management
CAVS	CDTI Assisted Visual Separation
CC	Air Traffic Control System Command Center
CD/FD	Clearance Delivery / Flight Data
CDA	Continuous Descent Arrivals
CDM	Collaborative Decision Making
CDR	Coded Departure Routes
CDTI	Cockpit Display of Traffic Information
CDU	Control Display Unit
CFR	Code of Federal Regulations
CO-ATM	Co-Operative Air Traffic Management
CPDLC	Controller Pilot Data Link Communications
CRM	Crew Resource Management
CSA	Collaborative System Assessment
DAG-TM	Distributed Air-Ground Traffic Management
DDR	Dynamic Departure Routing
DEP	Departure control sector
DISP	Dispatchers (flight or ATC coordinator)
ERAM	En Route Automation Modernization
FDMS	Flight Deck-based Merging and Spacing
FMS	Flight Management System
FOC	Flight Operations Center
FOM	Flight Operations Manual
FSS	Flight Service Station
GC	Tower Ground Controller
GDP	Ground Delay Program
GOC	Global Operations Control (see FOC)
IFR	Instrument Flight Rules
ISM	Integrated Surface Management
ITP	In-Trail Procedure
LC	Tower Local Controller
LOA	Letter of Agreement
M&S	Merging and Spacing
MOC	Maintenance Operations Control

NAS	National Airspace System
NOTAM	Notice for Airman
OITF	Oceanic In-Trail Follow
OTA	Oceanic Tailored Arrivals
PDC	Pre-Departure Clearance
PIREP	Pilot Report
PVD	Plan View Display
R	Radar Controller
RA	Radar Assistant
RNAV	Area Navigation
RNP	Required Navigation Performance
RTA	Required Time of Arrival
S&M	Sequencing and Merging
Satcom	Satellite based telecommunication
SIDs	Standard Instrument Departures
SOP	Standard Operating Procedure
STARs	Standard Terminal Arrival Routes
STM	Surface Traffic Management
Sup	Air Traffic Control Sector Supervisor
TACAN	Tactical Air Navigation
TACEC	Terminal Area Capacity Enhancing Concept
TBO	Trajectory Based Operations
TCA	Tactical Customer Advocate
TCAS	Traffic Alert and Collision Avoidance System
Telcon	Teleconference
TFM	Traffic Flow Management
TFMS	Traffic Flow Management System
TICR	Tactical Intent-based Conflict Resolution
TMA	Traffic Management Advisor
TMI	Traffic Management Initiative
TMU	Traffic Management Unit
TOD	Top of Descent
TOPS	Trajectory Operations
TRACON	Terminal Radar Approach Control
URET	User Request and Evaluation Tool
VFR	Visual Flight Rules
VOR	VHF Omnidirectional Range

1.0 Introduction

This research supports the FAA vision for the Next Generation Air Transportation System (NextGen) whose goal it is “to provide new capabilities that make air transportation safer and more reliable, improve the capacity of the National Airspace System (NAS) and reduce aviation’s impact on our environment” (FAA NGIP 2010, p. 5). One segment of the FAA research and development effort is the NextGen Flight Deck Human Factors program which manages civil aviation human factors research supporting NextGen capabilities and operational improvements. The objective of the human factors program is to develop and implement human factors policies, regulations, programs, and procedures which promote the safety and productivity of the NAS.

This report is the FY11 FAA task 05-04 / AJP61SSP-0050 deliverable submitted to the Human Factors Research and Engineering Group (AJP-61), sponsor of flightdeck human factors projects supporting the Air Traffic Organization (ATO), NextGen and Operations Planning, Research and Technology Development. This research project provides a comprehensive review of current roles and responsibilities related to the interaction between flightdeck, air traffic control (ATC) and flight operations center (FOC) and a framework for assessing future collaborative systems with the increased use of automation and technologies under NextGen operations.

1.1 Background

It is anticipated that the implementation of NextGen improvements will require shifts in the roles and responsibilities of flightdeck, ATC and FOC personnel and that these changes will require the development of new flightdeck-ATC-FOC collaborative systems within the context of advanced automation and new procedures. In order to design and implement systems that will realize safety and efficiency benefits without introducing human factors problems or exceeding human performance limitations, research was needed to provide a framework for assessing future NextGen collaborative systems. These types of assessments would need to consider the human factors issues related to the various ways in which roles and responsibilities can be re-distributed between collaborators including automated systems. The overall goal of performing such assessments is to ensure that the appropriate and effective collaborative arrangements are identified for implementation. The research reported here is an initial step toward outlining a framework that highlights key elements and human factors considerations to identify the main benefits and risks of particular collaborative systems.

1.2 Project and products

As one project among many in a program with complex objectives but many common goals, it was important to have a relatively flexible project plan, yet one that carefully defined its assumptions, approach and final products as discussed below.

<u>Assumptions</u>. In the planning stages of the project, it became evident that several assumptions needed to be specified. First, it was assumed that this research should be procedure and technology neutral. That is, the framework for assessing potential NextGen collaborative systems should be used for any NextGen application. In the latter part of this report, some specific NextGen applications are discussed. These are examples only, and do not preclude generic applicability. Second, the assumption was made that the research products should incorporate basic operational considerations such as phase of flight, and nominal and off-nominal conditions. The phases of flight should be addressed as well as common off-nominal events such as deviations due to weather. Where automation and technologies are involved, failures and emergency responses should be considered as well.

Third, assumptions pertained to the transition from current to NextGen operations. It was assumed that the actual implementations of applications could evolve over time with a range of new technologies, hybrid systems, and mixed equipage. Not all operators and facilities may be able to implement new procedures and technologies at the same time, thus complicating their integration in the NAS. These assumptions were additional factors to keep in mind when considering benefits and risks associated with NextGen implementation.

Tasks and Products. The development of a framework for assessing changes in the roles and responsibilities of flightdeck, ATC, FOC and automation was completed by conducting and integrating the results of the following three tasks and their associated products:

1. Conduct literature and state-of-the-practice reviews. This task focused on current interactions between flightdeck, ATC, FOC and automation as well as projected collaborations in NextGen applications.
   Product: Comprehensive Bibliography (see Section 2 of this Report and Appendix F).

2. Delineate roles and responsibilities of flightdeck, ATC and FOC in current operations and identify interaction/collaboration points. This resulted in detailed task listings for each group (flightdeck, ATC, FOC). These task listings were synchronized to identify points of interaction, coordination and communication between groups. The final matrix of interactions was then used as a baseline for comparison to projected NextGen collaborations.
   Product: Flightdeck-ATC-FOC Interaction Matrix (see Section 3 of this Report and Appendix E).

3. Identify the key elements and human factors to be considered in the transition from current to NextGen operations by analyzing reviews (separating those pertaining to current as opposed to proposed NextGen applications) and by examining a specific NextGen procedure (trajectory based operations) as an example. These analyses resulted in a framework that identifies key parameters to conduct a collaborative system assessment.
   Product: *Collaborative Systems Assessment: Flightdeck, Air Traffic Control, Flight Operations Center and Automation* (this Report).

1.3 Relationship to other NextGen research areas

The NextGen Human Factors Program consists of three main topic areas:

- Human interaction with NextGen technologies (Communication, Automation/Roles and Responsibilities, Risk and Error Management, Decision Support and Decision Making)
- Human factors in NextGen implementation (Instrument Procedures, Training and Personnel Qualification, Single Pilot Operations)
- Human factors in NextGen operations: (Separation Assurance & Collision Avoidance, Oceanic In-Trail, Closely Spaced Parallel Operations, Merging & Spacing, Ground Operations and Trajectory Based Operations).

Research both within and across these areas influence each other because they pertain to the same system and because research progress in one area may change the context for other research. Concepts and assumptions must be explicit and consistent if findings are to be integrated and build upon each other. The research described in this report comes from the topic area: Automation/Roles and Responsibilities which has overlapping relevance with other projects in every topic area. Like many of these projects, levels of automation as well as the role of automation in specific NextGen procedures are important issues. This research also shares human factors concepts with other projects, such as those focusing on decision making and risk management. There should be consistency in definitions of concepts and measures pertaining to collaboration, workload and situation awareness so that findings can relate directly to each other.

Job and task analyses would be necessary to specify the assumptions about interactions and responsibilities of individuals and groups of operators. Thus to ensure a compatibility across research projects a common, yet specific set of analyses would need to be coordinated. With this perspective in mind, this research has provided descriptions of the current responsibilities for the flightdeck, ATC and FOC with an emphasis on tasks or procedures that involve interactions between these groups. The reviews in this research showed that most existing job or task analyses contained minimal detail about collaborative activities. If such analyses are to be used across research projects, collaborative activities should be included and specified at a finer level of detail.

The assessment of collaborative systems is based on the analysis of collaborative procedures or scenarios that must specify their basic assumptions. When this project entered the phase that transitioned from current interactions to potential NextGen collaborations, it needed to address common assumptions with other projects focusing on Human Factors in Implementation and Operations (e.g., Instrument Procedures, Trajectory Based Operations). It became necessary to know what technologies were required, how these technologies were integrated into the aircraft system as a whole, and how new procedures would be integrated into the existing operational flow. In the absence of a common set of assumptions, this research made several general assumptions about systems requirements to account for increased collaboration, while leaving the option for specifying required technologies up to the individual conducting the assessment.

In summary, since many projects in the FAA Human Factors research portfolio are directly relevant to each other, there must be clear definitions of operational factors and consistent measures and metrics. Researchers working on specific NextGen procedures can help identify common scenarios of interest as well as draw attention to particular human factors risks that may lead to degraded performance. Formal or informal review meetings of related projects could help to establish common concepts, measures, assumptions and scenarios. In addition, consultations with FAA stakeholders could identify key scenarios of interest from a developer's concern to design human-centric system improvements within the constraints and priorities established by the decision makers.

1.4 Organization of the report

This report describes how the three tasks were performed and shows how the first two tasks led to the identification of key elements of the third task, the development of a framework for assessing collaborative systems. Section 1 introduces the research with a short description of the FAA NextGen Flight Deck Program Plan objectives and the structure of its portfolio of projects. This provides a context for this research within the larger program and describes how it relates to other projects.

Section 2 introduces collaboration between flightdeck, ATC, FOC and automation by considering the nature of collaboration, some important dimensions and how it relates to roles and responsibilities. The literature review covers a wide range of published papers ranging from conceptual discussions to experiments that place collaborative activity within the context of the NAS. It differentiates between group from within group collaboration in order to reinforce the between group focus of this research. State-of-the practice reviews look at flightdeck, ATC and FOC separately in order to establish each of their current baseline functions and responsibilities. These reviews were based on a variety of sources including operational documents as well as interviews and surveys. Section 2 ends with a consideration of current interactions between flightdeck, ATC, FOC and automation. Section 3 represents the culmination of the information and data described in Section 2. It takes each group's basic task listings and integrates them within a single timeline that indicates the phases of flight, information media, groups involved and the nature of the interactions. The final product is captured in a matrix that is described in Section 3 and presented in Appendix E.

Section 3 details interactions between the flightdeck, ATC and FOC and describes the somewhat limited collaboration and minimal amount of advanced automation found in current operations. Section 4 describes the transition from the current baseline to future NextGen collaboration that offers a number of opportunities for NAS improvement. It presents NextGen collaborators, including automation, and their responsibilities, functions and procedures, human factors considerations and required technologies. Among many possible changes, this section considers increasing collaboration primarily by improving FOC and automation responsibilities and the collaboration between the flightdeck and ATC. Section 4 concludes with an example of considerations based on trajectory based operations.

Section 5 represents the culmination of Sections 2 through 4 by addressing the important considerations in the transition from current operations to NextGen collaboration. It lays out the information needed to be able to conduct a collaborative system assessment based on a very general scenario as well as a relatively specific NextGen procedure. The outputs of the assessment present human factors considerations as they relate to general benefits and risk and detailed performance tradeoffs for specific collaborative procedures. Section 5 concludes with an example of how this framework for conducting collaborative systems assessments can be represented as a tool to help in the development of concepts of operation.

2.0 Collaboration Between Flightdeck, ATC, FOC and Automation

This review of collaboration was conducted to identify methods of current and possible future collaboration between the flightdeck, ATC, FOC and automation. The transition from current forms of collaboration to more efficient and flexible forms under NextGen requires a detailed understanding of the points of interaction between these three NAS organizations and automation. Following that, the state-of-the-practice review provides a high level summary of current collaborative roles and responsibilities as specified in FAA orders and operational manuals.

Although the primary focus is on collaboration between flightdeck, ATC, and FOC, the fourth collaborator that will be playing a greater role under NextGen, is automation. Automation is presented here in the context of multiple agents concentrating on those areas of automation that may ultimately be assigned responsibilities that are currently assumed by human operators. There are two ways to look at automation in collaboration, one along the line of within group collaboration and the other along the line of between group collaboration. The within group approach addresses automation as an agent within each of the three collaborators. The between group approach, the approach taken in this research, looks at automation as the fourth agent that may collaborate with the flightdeck, ATC, and FOC.

2.1 Literature review of collaboration

For the literature review, collaboration was conceptualized as an activity that takes place when stakeholders of a problem domain engage in an interactive process, using shared rules, norms, and structures to act or decide on issues related to that domain (Wood & Gray, 1991). This section starts by presenting some aspects of collaboration culled from studies related to groupware, both inside and outside air traffic management. The results from this review were analyzed and used to determine which aspects are both central to air traffic collaboration and can be used to assess NextGen collaborations. The state-of-the-practice review then presents the current interactions between flightdeck, ATC and FOC.

2.1.1 Collaboration's dimensions of time and space

In this review, some of the higher level aspects of collaboration are first presented first Drury (2009) used a taxonomy to organize case studies and technologies relevant to aviation security based on the temporal and spatial dimensions that Smith and Billings (2009) used to characterize Collaborative Air Traffic Management (CATM). Drury (2009) identified one of the sources of the time-space framework based on Ellis, Gibbs and Rein (1991) whose time-space framework was originally used in the classification of groupware back in the late 1980's and early 1990's. Time was used to distinguish those systems that could facilitate collaboration taking place at: 1) Asynchronous or different times, as distinct from 2) Synchronous or time critical interactions. This distinction is important in the traffic management environment where there is a substantial difference between collaboration during the flight planning phase and that taking place during flight events. Groupware was divided into two spatial categories: 1) Distributed systems for collaborations that take place over many locations and 2) Face-to-face systems of group interaction. This is a significant distinction within aviation operations because instances of collaboration between flightdeck, ATC and FOC can fall in all four categories.

Ellis, Gibbs and Rein (1991) combined the time and space dimensions into a two by two matrix classifying groupware into four categories:

* Same time face-to-face interaction
* Same time distributed interaction
* Same place asynchronous interaction
* Asynchronous distributed interaction.

More recently, Bafoutsou and Mentzas (2002) referenced the time and space dimensions as a starting point for a collaborative systems framework. Such a framework specifies two basic dimensions and key distinctions in the management of air traffic. The time dimension highlights the distinction between asynchronous collaboration typified by the planning process and the synchronous collaboration typified by time critical negotiations between the flightdeck and ATC. The space dimension differentiates within group from between group collaboration. As shown in Figure 2.1, collaboration within groups is exemplified by pilots communicating with each other on the flightdeck, and collaboration between groups is exemplified by collaborations that take place between the flightdeck and ATC or the flightdeck and FOC.

	Collaboration Within Flightdeck, ATC or FOC	**Collaboration Between Flightdeck and ATC or FOC**
Asynchronous Collaboration	Flight Planning within the Flightdeck, ATC or FOC	Flight Planning between Flightdeck, ATC and FOC
Synchronous Collaboration	Clearance management on the Flightdeck and within ATC	Clearance/route/trajectory management between Flightdeck, ATC and FOC

Figure 2.1: Operational View of the Time-Space Framework

The time-space dimensions provide a solid foundation that can be extended in different ways. For example, Bolstad and Endsley (2003) conducted an evaluation of collaborative tools based on a collaboration framework for the assessment of both military and commercially available tools. The authors found that there was a large number of collaborative tools but a limited number of the types of collaboration techniques being utilized. They categorized collaboration based on the following high level dimensions:

* Time: synchronous or asynchronous
* Place: co-located or distributed
* Predictability of collaboration
* Degree of interaction.

Given Bolstad and Endsley's (2003) objective of developing a collaborative tool taxonomy, groupware tools were key to their framework. Their list of tools reflects those available at the turn of the century from telephone based technology to some of the earlier Internet technologies such as email and instant messaging. Their framework evaluates 13 types of collaborative tools or technologies based on the type of collaboration, tool characteristics, information types and processes or functions. This last category, functions, plays a key role in air traffic management collaboration.

From the time and space perspective, three of Bolstad and Endsley’s (2003) functions are highly relevant to air traffic management. The first two, planning and scheduling, are integral functions of the between flightdeck, ATC and FOC flight planning (see Figure 2.1). The authors indicated that these two functions require substantial interaction, so that when they are conducted in distributed space, as it is the case between the flightdeck, ATC and FOC, dedicated domain specific tools are best suited for these types of planning and scheduling. The third function relevant to traffic management is the general one of building and maintaining shared situation assessment. This general function underlies many of the traffic management functions, with an emphasis on the more synchronous functions of managing separation, spacing and trajectories. The authors indicated that maintaining shared situation awareness involves communication or representing common data about the situation as well as the task status. They explained that when substantial amounts of data are required, domain specific tools with substantial bandwidth are best suited to facilitate collaboration.

Bolstad and Endsley (2003) concluded that there are different types of collaboration, and that developing a successful system requires a detailed analysis of the processes and conditions within the environment of interest. The time and space dimensions along with the functions are particularly helpful in determining a basic structure for the design as well as for the assessment of air traffic collaborative systems. Technology is also significant in this type of assessment, but they would play a secondary role to that of the human operators.

2.1.2 Collaboration and responsibilities

With the implementation of NextGen operations, current roles and responsibilities of flightdeck, ATC, FOC and automation are likely to change. This section specifies what roles and responsibilities mean for collaborators. Their collaborations need to solve at least two problems: 1) How to divide work and 2) How to coordinate that work (Mintzberg, 1983). Division of work involves breaking down tasks and assigning responsibilities to carry out the tasks. Coordination involves the management of the interdependence of the tasks, so that throughput is optimal (Malone & Crowstone, 1994). Clarity of roles and responsibilities are crucial to avoid poor throughput and accidents (Rizzo, House & Lirtzman, 1970). To help anticipate needs and optimize productivity in large organizations, coordination is often formalized by creating top-down hierarchies, bottom-up reporting system (van Aart & Oomes, 2008), and standardization of products and service (Mintzerg, 1983). Direct supervision is one of the first coordination mechanisms large groups collaborating together use to organize, assign responsibilities, issue instructions and monitor actions (Mintzberg, 1983). With standardization, the work process and outputs become prescribed activities relying on procedures (Mintzberg, 1983, van Aart & Oomes, 2008). Standardization also leads to highly specialized professionals, which in turn ensure that individuals or group of individuals are able to assume their responsibilities. This is the case for controllers, where the FAA's Air Traffic policy Order JO 7110.65T specifies that controllers need to be familiar with their operational responsibilities as well as exercise best judgment when required.

In aviation, crew coordination has been shown to enhance group performance. Coordination can be improved by explicit leadership (Orasanu, 1993), clearly defined tasking and effective communication (Kanki, Lozito & Foushee, 1989; Kanki & Palmer, 1993). Procedures help group coordination even when they have conflicting interests and are required to negotiate common resources. For instance, ATC's objective may be flow control, and an airline's objective may be saving time and fuel. In the NAS today, there are few shared responsibilities between groups, such as flightdeck and ATC. The controllers' responsibilities are to ensure the safety of the airspace through direct supervision of operations, and compliance to standardized procedures. Pilots also follow standardized procedures and have responsibilities to safely carry out the flight operations. They must comply with the controllers' authority in the use of airspace and airport surfaces.

With regard to collaboration, there have been some successes involving shared responsibilities in collaborative decisions in the NAS. FedEx ramp collaborates with Memphis airport controllers to allocate dynamic departure slots during their heavy push of departing traffic. The same allocation of departure slots has been taking place at JFK (Borgman Fernandez & Smith, 2011). Ramp control tower coordinates with airlines who want to participate on the time of the push back so they can meet the time window that has been reserved for their departure. Ramp control tower provides a time slot to optimize flow on the surface, thus reducing fuel burn. Borgman Fernandez and Smith (2011) showed that such departure metering has helped both the airlines and controllers. A distribution of responsibilities requires that individuals communicate their intentions and that decision support tools provide adequate coordination of these individual intentions. Roles and responsibilities are determined by how tasks are divided and how these tasks are coordinated. Coordination relies on clearly defined tasks, communication, leadership and procedures.

2.1.3 NAS collaboration issues

Currently, flightdeck, ATC and FOC interact, but as mentioned earlier, those interactions involve limited collaboration; a prime example is Collaborative Decision Making (CDM). Experimental work on CDM was started in the early 1990's demonstrating that traffic management could be improved when FOCs supplied operational information to the FAA (Ball, Hoffman, Knorr, Wetherly & Wambsganss, 2000). The overarching goal was to improve traffic management by improving information exchange, procedures, and tools for shared situation awareness and decision making between ATC and FOC. However, the early focus of CDM was on Ground Delay Programs (GDPs) with FOCs continually updating Air Traffic Control Systems Command Center (CC) with flight delay, cancellation and newly created flight information. While FOCs were able to monitor the GDP results, they did not have the ability to alter those programs.

Later, CDM become a set of collaborative procedures between ATC and FOC as FOC involvement in decision making increased over the years. CDM now includes greater data exchanges with shared tools being used by both groups. But in spite of increased collaboration between ATC and FOC and the inclusion of FOC preferences, CDM was still primarily based on air traffic manager decisions (Idris, Evans, Vivona, Krozel & Bilimoria, 2006). It became evident that further expansion of CDM would be required including more complete information such as combined airspace and airport constraints and more complete cancellation, delay and rerouting information (Berge, Carter, Haraldsdottir & Repetto, 2007).

Air Traffic Flow Management (ATFM) is another area with limited collaboration (Wolfe, Jarvis, Enomoto, Sierhuis & van Putten, 2009). Their field observations of ATFM found issues in the collaboration due to the limited sharing of information between the FAA and FOC. This resulted in FOC planning without accurate information about the current situation and priorities (Wolfe et al., 2009). Under ATFM, most of the planning was done by the FAA creating workload issues and limiting the number of solutions that could be considered. Another set of problems was due to the differences in air traffic management goals between ATC and FOC. Beyond safety, the FAA aims to reduce NAS flow problems while keeping ATC workload at a reasonable level. FOCs are guided by their business model that may include customer convenience and cost containment. These issues combine to create ATFM bottlenecks where collaboration between the FAA and FOCs decrease as problems become more severe resulting in little collaboration when it is most needed (Wolfe et al., 2009).

In addition, current air traffic management does not fully account for FOC flight planning preferences because of the lack of electronic data and limited opportunities for FOC and ATC negotiations (Sheth, Gutierrez-Nolasco, Courtney & Smith, 2010). This results in ATC making changes to flight plans that do not address FOC preferences because those preferences are proprietary and often unique to a specific operator. User preferences are based on ten factors, led by schedule integrity and flight connectivity (Sheth et al., 2010).

Lack of accurate and current information and appropriate means of communication have constrained collaboration between ATC and FOC, but this has changed over the recent past. That limited information has been rapidly transformed into large datasets with dynamic updates that can overwhelm operators (Billings, Smith & Spencer, 2007). Thus, under the transition to NextGen, the past problems of too little current information will become one of too much data with the concomitant challenges of how to represent and display that information to the different collaborators, whether flightdeck, ATC or FOC. Smith and Billings (2009) enumerated some of the key collaborative issues in their discussion of CATM. Under NextGen, collaboration will spread to additional areas within these three primary groups. These researchers indicated that CATM will present a new set of human factors issues including how to distribute the responsibilities between the different groups, operators and technologies. Along with this issue of responsibilities, Smith and Billings (2009) focus on three areas essential to the current research:

- Identification of possible collaborative concepts or procedures
- Assignment or distribution of responsibilities
- Analysis of human factors of those procedures.

In addition to these core areas, there are two related concerns. The first concern is the human factors issues related to the technologies required by different NextGen collaborative procedures. Although some of those required technologies may not provide the primary means of collaboration, they are still required to make the procedure possible. For example, Data Comm, with its many human factors issues, has been recognized as both a required and primary means for certain NextGen collaborative procedures. On the other hand, some of the flightdeck or ATC displays may not be a primary part of the collaboration, but they may be required to implement the procedure. The second concern, that is an essential part of many NextGen collaborative procedures, is that of automation and levels of automation. In their evaluation of ATFM, Wolfe et al. (2009) found that utilizing FOC preferences led to better traffic flow management (TFM) solutions but increased FOC involvement did not reduce FAA workload. They concluded that it is more likely that automation, and not collaboration, that will help reduce workload. Smith and Billings (2009) point out that the success of CATM is dependent upon the ability of NAS service providers and airspace users to collaborate effectively to make use of advanced technologies within a new approach to air traffic management.

2.1.4 Collaboration between versus within groups

Collaboration can be assessed at a very detailed level starting with individual utterances all the way up to higher organizational structures. This research focuses on collaborations between teams or groups and in this context, collaborators are groups of operators from the same organization (flightdeck, ATC or FOC). Thus, two controllers across sectors and across facilities are considered as belonging to the same ATC group, and a captain and first officer are considered as a crew from the flightdeck.

In much of the earlier research, the notions of cooperation, coordination and communication are not distinct from each other. For example, cooperation has been highlighted in the context of ATC activities by Bellorini and Vanderhaegen (1995). These authors specified two different types of ATC activities; those that are individual and those that are cooperative. Individual activities were performed by a single controller and include functions such as separation management and control of departure and arrivals. Cooperative activities involved more than one controller and included the management of landing sequences and transfer of aircraft control. They further distinguished two types of cooperation that fit with the dimensions of collaborative space. One type is based on face-to-face communication where the space is collocated, and the other type requires remote communication where space is distributed.

Communication between the flightdeck and ATC has been researched over the last thirty years. Among the relatively fewer studies of within ATC facility communication Peterson, Bailey, and Willems (2001) studied controller to controller communication and coordination. In the en route environment, controllers work as teams consisting of a radar side and a data side. These teams emphasize team communication in planning and monitoring traffic particularly in situations that require attention or immediate action. The analysis showed that traffic was the single greatest topic of communication. In turn, within team activities may impact the coordination with other sectors and with other groups, such as flightdecks and FOC. For instance, controllers of a sector may agree to start holding aircrafts, and thus, this within coordination will momentarily impact the communication with incoming aircrafts.

Between group collaboration may also impact within group collaboration, such as a flightdeck requesting ATC to change the routing of their flight plan while in flight. Controllers at the sector may then have to coordinate the change in the flight plan, as well as the crew may have to coordinate the changes of the flight plan in the Flight Management System. Though beyond the scope of this research effort, the impact of within and between group changes should be kept in mind with respect to the implementation of long term changes with NextGen collaboration, which may influence the distribution of workload as well as situation awareness within and between groups.

The current research effort maintains a narrow focus on between group collaboration in order to develop a framework that can be used to efficiently and successfully assess NextGen collaborative systems between flightdeck, ATC and FOC in the context of advanced automation. The literature review provided direction in determining which dimensions of collaboration should form the basis for an assessment that would be useful to those designing and evaluating collaborative procedures and systems. Starting with the time dimension, an assessment should focus on the distinction of the synchronous and asynchronous collaboration to ensure that collaborative planning is distinguished from time critical and time sensitive separation, spacing and trajectory management. In the space dimension, the focus should be on between group collaboration though it is recognized that between group and within group activities have an effect on each other.

In summary, the literature review brought to light a wide range of research approaches to collaboration. The CDM research showed the direction where NextGen collaboration may evolve. An extension and expansion of CDM could change the responsibilities between ATC and FOC as it improves air traffic flow management. It is also evident that collaboration between ATC and flightdeck with spacing, separation and trajectory management will be required to address increased air traffic density. Increases in collaboration will be accompanied by shifts in collaborator responsibilities as the NAS moves from the current centralized air traffic control to a more decentralized air traffic management. Smith and Billings (2009) emphasized the need to identify the NextGen procedures over the next decade as well as the human factors issues related to the technologies required by those procedures. Other research suggested the need to focus on specific functions, like planning and separation management as well as the human factors considerations such as workload and shared situation awareness (Bolstad & Endsley, 2003). Finally, the review has pointed out the need to clarify the definitions of concepts like cooperation, communication as distinct from collaboration.

2.2 State-of-the-practice review

This following section is a state-of-the-practice review of flightdeck, ATC and FOC tasks and responsibilities based on regulatory and advisory documents. This review concentrates on those responsibilities that involve an interaction between any two of the three groups. Although most of these interactions are not termed collaboration, they point to areas of possible collaboration in the transition to NextGen. The review first presents the responsibilities of each collaborator followed by a more detailed discussion of points of interaction based on operating manuals and additional data collection.

2.2.1 Current flightdeck responsibilities

This first section of the state-of-the-practice review summarizes the higher level flightdeck roles and responsibilities based on regulatory and advisory documents. The more detailed flightdeck responsibilities related to collaboration are described in Section 2.3.1. This state-of-the-practice review starts with 14 CFR Part 91, General Operating and Flight Rules that contains two subparts, Subparts A and B, addressing responsibilities related to the interaction between the flightdeck and ATC. Under Subpart A, General, the captain of an aircraft "is directly responsible for, and is the final authority as to, the operation of that aircraft" (91.3 Responsibility and authority of the captain). This is a general responsibility that gives the captain final authority. In addition, during an inflight emergency that requires immediate action, the captain may deviate from the flight rules in order to address that emergency.

14 CFR Part 91. Subpart B, specifies the flight rules. Before beginning a flight, the captain will become familiar with all available information concerning that flight including any known traffic delays advised by ATC. Subpart B also specifies the responsibility of those on the flightdeck to avoid other aircraft and to give right of way to an aircraft that is in distress or is landing. It is the responsibility of the captain to adhere to ATC clearances: "When an ATC clearance has been obtained, no captain may deviate from that clearance unless an amended clearance is obtained, an emergency exists, or the deviation is in response to a traffic alert and collision avoidance system resolution advisory" (91.123 Compliance with ATC clearances and instructions). Any captain that deviates from ATC instructions in response to an emergency or to TCAS advisory is responsible to notify ATC as soon as possible. In addition, if a pilot is uncertain of an ATC clearance, it is the flightdeck's responsibility to request clarification from ATC. Further, no one may operate an aircraft opposite to ATC instructions where ATC is exercised except in an emergency.

Subpart B, also specifies the rules of operation for the different types of airspace. Class A airspace, that from 18,000 to 60,000 feet, and Class B airspace, that which encompasses the major or busiest US airports, are of main concern to US operators, § 91.135 Operations in Class A airspace. For Class A airspace, the flightdeck is responsible to conduct operations: 1) Under instrument flight rules (IFR), 2) only under an ATC clearance received prior to entering the airspace, 3) equipped with a two-way radio capable of communicating with ATC on a frequency assigned by ATC, and 4) maintaining two-way radio communications with ATC while operating in Class A airspace. In addition, there are provisions for deviating from the above rules if the operator has authorization issued by the ATC facility having jurisdiction of the airspace concerned.

When operating in Class B airspace, an operator must receive an ATC clearance from the ATC facility having jurisdiction for that area before operating an aircraft in that area. The aircraft must be equipped with an operable VOR or TACAN receiver or an operable and suitable RNAV system; and an operable two-way radio capable of communications with ATC on appropriate frequencies for that Class B airspace area. In addition, for aircraft arriving or on a flight through

Class B airspace, two-way radio communications with the ATC facility must be established prior to entering that airspace and thereafter maintain those communications while within that airspace. For flights departing the primary airport in Class B airspace with an operating control tower must establish and maintain two-way radio communications with the control tower, and thereafter as instructed by ATC. As with Class A airspace, there are provisions for deviating from the above rules if the operator has authorization issued by the ATC facility having jurisdiction of the airspace concerned.

Subpart B, also specifies Visual Flight Rules (VFR) and Instrument Flight Rules (IFR). The IFRs are most pertinent to commercial aviation, especially in Class A and B airspace. §91.173, ATC clearance and flight plan required, sets the general flightdeck responsibilities under IFRs. First, an aircraft operated in controlled airspace under IFR must have filed an IFR flight plan. Second, it must have received an appropriate ATC clearance. Flightdeck communication responsibilities under IFR include ensuring continuous monitoring of the appropriate ATC frequency. Also, the flightdeck is responsible for reporting time and altitude of passing designated reporting points. When the aircraft is under radar control, the flightdeck need report only those reporting points specifically requested by ATC. In addition, the flightdeck is responsible for reporting when they encounter unexpected weather and any other information related to the safety of flight.

FAA S-8081-12B. This standards document, Commercial Pilot Practical Test Standards for Airplane, provides a structure for understanding the flightdeck roles and responsibilities when interacting with ATC and FOC. Crew Resource Management (CRM) is at the heart of that structure. CRM includes human, systems and information resources with the emphasis here on the human side. Human resources are made up of the groups that interact with the flightdeck on decisions regarding the safety of flight. Those groups include ATC and FOC. FAA S-8081-12B goes on to indicate that CRM is not a specific task. Rather, it is a set of skills that apply to all tasks assessed under the practical tests standards. Although CRM does not pinpoint the specific areas where collaboration is most critical, this structure suggests the need to search all tasks involving the interaction of the flightdeck with ATC and FOC. As discussed in Section 2.1.4, the lower level group collaborative actions of communication, cooperation and coordination need to be addressed in future research efforts.

In discussing CRM, FAA S-8081-12B test standards directly reference dispatch, or FOC but they include a number of indirect references to ATC. It divides its test standards into areas of operation that can be used to identify when the flightdeck is more likely to interact with ATC. The first area of operation that specifies flightdeck interaction with ATC is during taxi operations. Specifically, during taxiing, the flightdeck interacts with ATC by complying with clearances and instructions. The next area of operation involving flightdeck interaction with ATC is in the airport area. The test standards assess the commercial pilot's ability to:

- Exhibit knowledge of the aspects related to radio communications and ATC light signals
- Select appropriate frequencies
- Transmit using recommended phraseology
- Acknowledge radio communications and comply with instructions.

FAA S-8081-12B indicates additional areas of operation that involve flightdeck interaction with ATC. Those areas include navigation and tasks related to navigation systems, radar services, diversions and lost procedures. They also include emergency operations with the tasks of emergency descent, engine failure and systems and equipment malfunctions. A third set of tasks involve an engine failure during flight and approach with one engine inoperative under multiengine operations. Although these test standards do not strictly conform to commercial aviation operations categories, they do point to the critical interactions between flightdeck and

ATC during off-nominal and conditional operations. Overall, FAA S-8081-12B test standards highlight the flightdeck responsibility for good CRM during all phases of flight with an increased need during off-nominal operations.

<u>Advisory circulars</u>. In addition to the flightdeck specific regulatory documents, a number of FAA Advisory Circulars (ACs) were reviewed for general guidance on flightdeck responsibilities. The review concentrated on ACs related to pilot activities and flightdeck systems used in the collaborative process. Two specific areas were identified as related to flightdeck collaboration with ATC and FOC: 1) CRM, and 2) Use of Data Comm or data link communications. As previousy discussed, FAA S-8081-12B identifies CRM as a core concept in the flightdeck's use of external resources such as ATC and FOC. Advisory Circular 120-51E, Crew Resource Management Training, although focusing on within flightdeck coordination, provides general guidance for the broader collaboration between the flightdeck, cabin crew, dispatchers, maintenance and ATC.

AC 120-51E divides the topic of communication into internal and external influences. The internal influences include speaking and listening skills, decisionmaking and conflict resolution skills. External influences include potential barriers due to age, gender and rank as well as organizational factors and procedures, such as Standard Operating Procedures (SOP). AC 120-51E advises that CRM training on communication and decisionmaking emphasize clear and unambiguous communication between flightdeck, cabin crew and FOC. For this state-of-the-practice review, the emphasis is on the external factors, especially those factors that may facilitate collaboration between groups. Although internal factors, such as individual skills, are very important, they are at too low a level of detail in developing a framework for the assessment of collaboration between flightdeck, ATC, FOC and automation.

A second Advisory Circular, FAA AC 120-70A, Operational Authorization Process for use of Data Link Communication System, provides guidance related to a communication technology that is playing an increasing role in the communication and collaboration between the flightdeck and ATC. Under data link communications operational use, AC 120-70A lists the following flight crew responsibilities:

- Prompt initiation of messages where needed
- Prompt response to messages where appropriate
- Appropriate crew coordination so that each crewmember receives needed information
- Appropriate retention of messages (archive) requiring later action
- Appropriate resolution of message uncertainty
- Appropriate use of data link and voice where circumstances or operations dictate
- If ATC data link clearance contradicts a voice clearance, comply with voice clearance.

At a general, regulatory level, flightdeck interaction with ATC and FOC can take place during most phases of flight. During nominal operations, that interaction is relatively proceduralized, often ATC controlled and less likely to involve active collaboration. During off-nominal operations collaboration can play a larger role with the captain having authority to deviate from flight rules under certain inflight emergencies. Although the flightdeck regulatory documents reviewed do not directly address collaboration or negotiation, they do indicate that CRM provides a structure for interacting with other human resources such as ATC or FOC. The flightdeck has responsibility for using good CRM skills during all phases of flight especially during off-nominal operations.

In summary, the FAA documents reviewed indicated the following general captain responsibilities that affect the interaction between the flightdeck and ATC:

- Captain has the final authority regarding aircraft operations
- Captain may deviate from the flight rules to address an inflight emergency requiring immediate action
- Captain is responsible to adhere to ATC clearances
- Captain that deviates from ATC instructions is responsible to notify ATC as soon as possible
- Captain may deviate from a clearance if an amended clearance is obtained, an emergency exists, or the deviation is in response to a TCAS resolution advisory.

The more general responsibilities in Class A airspace include that the flightdeck operates:

- Under instrument flight rules (IFR)
- Under an ATC clearance received prior to entering the airspace
- Equipped with a two-way radio capable of communicating with ATC on a frequency assigned by ATC
- Maintaining two-way radio communications with ATC.

When in Class B airspace, a flightdeck responsibilities involving ATC interaction include that they:

- Receive an ATC clearance from the ATC facility having jurisdiction for that area before operating an aircraft in that area.
- Are equipped with an operable VOR or TACAN receiver or an operable and suitable RNAV system and an operable two-way radio capable of communications with ATC on appropriate frequencies for that Class B airspace area.
- Establish two-way radio communication with ATC when arriving or on a flight through Class B airspace
- Establish and maintain two-way radio communications with the control tower, and thereafter as instructed by ATC when departing the primary airport in Class B airspace.

In conclusion, the FAA documents emphasize that in the current ATC environment, the flightdeck establishes and maintains communication with the appropriate controller entities and that they adhere to ATC clearances and instructions. The flightdeck has the important responsibility for collision avoidance and it has more leeway under certain off-nominal conditions and is encouraged to use good CRM skills whenever interacting with ATC or FOC.

2.2.2 Current ATC roles and responsibilities

Current ATC performs two separate functions; one that provides service to users (Traffic Control) and one that manages traffic (Traffic Management). These functions are different and so are their roles and responsibilities.

Traffic Control. Roles and responsibilities for controllers are found in Section 10 ‘Team Position Responsibilities’ of chapter 2 from the FAA Order JO 7110.65T. Each type of facility, En Route, Terminal Radar, and Tower, has their own set of positions. Supervisor responsibilities are also indicated in various parts of orders JO 7110.65T and JO 7210.3W. All the positions in each facility have a list of responsibilities, though for each position it is clearly stipulated that:

> "1. There are no absolute divisions of responsibilities regarding position operations. The tasks to be completed remain the same whether one, two, or three people are working positions within a facility/sector. The team, as a whole, has responsibility for the safe and efficient operation of that facility/sector." (FAA JO 7110.65T, 2-10).

The concept of team responsibility provides service to the customers independently of staffing variations and controllers can be assigned to all of the positions to which they have been certified. The more certification controllers acquire, the more positions they can fill in. For instance, in a Tower facility, Local Controllers can accomplish the tasks of Ground Controllers, Clearance Delivery, and Flight Data positions. At a Terminal or En Route Sector, Radar Controllers can assume the responsibilities of Radar Associate.

A comparison of Radar Controller positions across the three types of facilities indicate that they share responsibilities in the following order: 1) Ensure separation, 2) Initiate control instructions, 3) Monitor and operate radio (or equipment at tower), 4) Accept and initiate automated handoffs (not at Tower), 5) Assist Radar Associate with non-automated handoffs, 6) Assist Associate with coordination 7) Scan radar display and correlate with flight strips or flight data, 8) Ensure computer entries, or strip markings, are completed on instructions or clearances issued or received, 9) Process and forward flight plan information (Tower only).

The first four responsibilities represent the main activity of a radar position. Radar Controllers ensure separation and clear pilots through air-ground communication. They also hand off control to the next controller, by means of Plan View Display (PVD). They help coordinate with the RA, when present, in non-automated handoffs which include ground-ground communication between sectors or facilities. They make sure data reflect accurately the position and clearances of aircrafts (data coordination) either on flight strips or in their computer system. The Tower Controller doesn't handoff control, but transfer flight data, by scanning or phone prior to departure. There is no handoff for approaching aircrafts either. Handoff is assumed automatic seven miles prior to runways, after aircraft are cleared for approach and requested to contact Tower. This coordination is standardized in letter of agreements.

Radar Associate Controllers share responsibilities across facilities in the following order: 1) Ensure separation; 2) Use User Request and Evaluation Tool (URET) data to plan, organize, and expedite flow of traffic; 3) Initiate control instructions (not at Tower); 4) Operate interphones; 5) Accept and initiate automated handoffs (at En Route and Terminal) / assist Tower position by accepting and initiating coordination for the smooth operation of the tower cab (at Tower); 6) Assist Radar Associate with non-automated handoffs; 7) Coordinate including pointouts (not Tower); 8) Monitor radio, scan flight strips/data and correlate with radar (En Route only); 9) Manage flight strips/data; and 10) Enter computer entries/ strip marking, or ensure those are completed on instructions or clearances issued or received.

The first four responsibilities represent the main activity of a Radar Associate. These controllers assist in ensuring separation and clearing pilots through air-ground communication. Though when the two positions are staffed, their main activity is focused on ground-ground communication. They handle handoffs (automated and non-automated) and pointouts, and coordinate with other sectors/facilities. They also assist in making sure data reflects accurately the position and clearances of aircraft (data coordination) either on flight strips or in their computer system. At the Tower, Radar Associates have a less influential role. Usually a Local Controller and a Ground Controller will handle most of the activity, including strip marking and updating data.

The three Radar Coordinators positions share the exact same responsibilities across the facilities: 1) Perform interfacility/intrafacility/sector position coordination of traffic actions; 2) Advise the radar position and the Radar Associate of sector actions required; and 3) Perform any of the functions of the sector team. Their function is to help coordinate when sectors are in high demand of traffic. The Radar Controller will keep issuing instructions and clearing aircrafts, and the Radar Associate will handle handoffs and data. The coordinators are usually more experienced controllers. They will primary anticipate the needs to maintain separation of the traffic and provide instructions for the Radar Controller and coordinate traffic with other sectors.

Flight Data Controllers share a similar order of responsibilities as well: 1) Operate interphone; 2) Receive and disseminate weather NOTAMs, NAS status, traffic management and other status messages; 3) Assist RA in managing flight strips, receive, prepare and distribute flight strips (En Route only); 4) Enter/process and forward flight data into computer; 5) Issue clearance and ensure accuracy of pilot read back (only Tower); and 6) Assist facility/sector.

The three Flight Data positions mainly work on a ground-ground communication and are in contact with other facilities or operators (Flightdeck or FOC). They control the accuracy of flight data, and if the facility is working with flight strips, they will prepare the strips according to the needs of the controllers at the sectors. They also update information available for operators (e.g., weather, NOTAMS).

Based on the above description, the position's primary functions are the following. At En Route and the TRACON facilities:

- Radar position focuses on monitoring and clearing traffic (air-ground communication)
- Radar Associate focuses on transfer of control (handoffs) and verifying flight data (ground-ground communication)
- Radar Coordinator focuses on planning separation and coordinating flow of traffic
- Flight Data focuses on controlling and updating flight data, and updating information for operators.

At Tower facilities:

- Tower position focuses on monitoring and clearing traffic (Ground Control for taxiing, and Local Control for runway departure and landing)
- Tower Associate focuses on transfer of control of traffic
- Tower Cab Coordinator focuses on planning clearances and transfer of control
- Flight Data, often combined with Clearance Delivery, focuses on controlling and updating flight data, and updating information for operators.

The primary positions across all ATC facilities are Radar positions, followed by Associates and Coordinators, which are staffed to support the Radar activity at a given sector, depending on the traffic activity. The Flight Data positions may support several sectors.

Overall, the main responsibilities among all positions and facilities fulfill the mission of Air Traffic Control: Ensure separation and efficient flow of traffic. This requires the control of separation of traffic, the transfer of control and the accuracy of flight data. Radar Controllers can be responsible for all of these, if they are the only position staffed at a sector, or Tower. When Radar Associates are staffed, they will typically handle the transfer of control and data, whereas Flight Data will verify accuracy and transfer of data.

The main mission of ATC is to ensure separation as well as an efficient flow of traffic. For all controllers, ensuring separation means protecting space between aircraft and prevent loss of minimal separation. It requires controllers to monitor flights' positions and intentions, anticipate conflicts, and organize the flow of traffic. For Tower Controllers, it means organizing ground movements, runway arrival and departure. For Terminal Controllers it means sequencing and merging of traffic for runway approaches, as well as controlling departures and climb until reaching an En Route Sector. For En Route Controllers it means monitoring and clearing all airborne operations. En Route Controllers manage traffic in cruise, in climb, in descent and approach. They separate, vector, sequence, and merge traffic. They also coordinate military requests.

Roles and responsibilities are central to the organization and efficiency of the ATC. Several means of coordination used by the controllers include: shared flight data, communication devices, such as radio and Controller Pilot Data Link Communications (CPDLC), standardization of sectors, Letters Of Agreement (LOAs) and SOPs.

Flight data. To support the smooth and efficient control of traffic, controllers coordinate flight data with customers (flightdeck and FOC) and with other facilities. Tower Controllers make sure departure clearances are up to date, and activate flight data at takeoff. Terminal and En Route Controllers are also responsible to control the accuracy of flight plans and may clear departures, depending on equipage and agreement with the airport tower. Amendment to flight plans and departure clearances can be made by the Flight Data position, Flow Control, Terminal or En Route Controllers. Inter-facility coordination on flight data amendments can take place between facilities, often for flow control purpose, but it always need to be coordinated with the flightdeck or the FOC. Terminal and En Route Controllers transfer control between sectors by handing off the flight data to the next sector. This is generally done automatically by activating a request for transfer, and by accepting this transfer on a keyboard. When necessary, controllers will issue control instructions prior to accepting a handoff from other controllers.

Communication devices. Controllers provide instructions and clearances to pilots almost exclusively by voice via VHF radio. There are few exceptions though. Controllers can send pre-departure clearances by text via ACARS and CPDLC clearances over Oceanic are currently undertaken.

Standardization. Controllers rely on standardization of airspace, fix points, routes, approach, departure, runway configuration, separation, and procedures. Within sectors, Standard Operating Procedures prescribe particular operations in given sectors, for instance, description of airspace, frequencies, military operations, flow of traffic, additional responsibilities and tasks for controllers, as well as procedures for departures, arrival, holding, handoff and pointouts. Between interdependent ATC facilities, Letters of Agreements regulate the configuration of airspace, approaches, delay standard, procedures in several situation or location, altitude and speed requirement for handoffs or for runway approaches. These prescribed rules constitute a means of coordinatio which allow for predictability and mutual expectations between controllers.

Controllers' job descriptions have been under the lens of other researchers. Broach (2009) coined similar controllers' responsibilities as domain skills. He identified separation and coordination as the primary domain that requires controllers to provide vertical and horizontal separation, as well as perform handoffs/pointouts, and update flight route on flight progress strips. Additional domains were identified including method of control, use of equipment and compliance with communication rules.

Willems and Koros (2007) reviewed six ATC task analyses. They aggregated 33 core tasks and grouped them under the following six core tasks:

- Maintain situation awareness of the traffic in the sector
- Develop and receive sector control plan (anticipate action, process flight data, manage traffic)
- Make decision for control actions
- Solve aircraft conflicts (provide separation and prevent conflicts)
- Provide tactical Air Traffic Management (e.g., provide instructions, coordinate pointouts and handoffs, manage arrivals & departures, relay information, manage emergencies, handle communications, handle flight data)
- Update working knowledge or supervise.

These high level core tasks are central to ATC activities. They are expected skills, but are also functions that allow collaborations with flightdeck and FOC to be efficient in the current configuration. They must maintain situation awareness and manage workload while engaging in tactical and strategic decisions to manage and control traffic.

The cognitive path of controllers' activity is assumed to follow three steps: situation awareness, decision process and action performance (Willems & Koros, 2007). The most common activities identified by Dittmann, Kallus and Van Damme (2000) are in the following order of priority:

1) Take over a position, build a mental picture of traffic
2) Prioritize scanning and switch attention
3) Monitor aircrafts progress, update mental picture and maintain situation awareness
    a. Identify traffic conflicts
4) Solve traffic conflicts
    a. Issue control instructions to flightdeck
5) Manage air traffic sequences
6) Assess weather impact
7) Manage workload and resources
8) Respond to system/equipment degradation.

As Willems and Koros (2007) pointed out, controllers typically monitor traffic, identify conflicts, solve them, and issue control instructions. With the increase of traffic and NextGen anticipated changes, the way controllers maintain situation awareness, their decisionmaking and overall performance will be influenced by the introduction of new technologies, including automation, new procedures, and eventually new roles and responsibilities.

<u>Traffic Management</u>. The second organization within ATC, Traffic Management encompasses the Air Traffic Control System Command Center (CC) and its network of Traffic Management Units (TMUs) located across En Route Centers, TRACON and important airport towers. The CC assesses traffic situations to avoid traffic demand exceeding capacity of the NAS, generates plans to mitigate delays and coordinates the implementation of plans with ATC facilities and NAS users. The CC plays an important role in monitoring traffic and adverse conditions. The CC initiates reroute of traffic and delay programs (e.g., Ground Delay Programs). Strategic planning is the main goal of the CC. It relies on its network of weather specialists and severe weather unit; its network of traffic managers, its planning team and its tactical customer advocate position. In addition, the CC has positions filled by the National Business Aviation Association and the Airline Transportation Association that can provide information on air traffic demands and constraints during the process of planning decisions. They also relay strategic information back to their members (Idris et al., 2006).

The CC runs telephone conferences every two hours, from 6:00 AM to 8:00 PM EST. These telephone conferences inform about the current situation in the NAS and any delays and decisions implemented by the CC. ATC facilities and airline dispatchers can participate. First the CC will report the current situation in the NAS, in terms of traffic and adverse conditions through the NAS. They will update about any delays and their intentions. ATC facilities may add additional information such as a runway configuration. Then dispatchers may ask questions or make requests of the CC or ATC facilities. The CC also publishes NAS Status advisories on its website, as well as NOTAMS on runway closures, malfunctions of navigational aids, or changes in airport arrival and departure procedures. The timing of those advisories is synchronized with the telephone conferences.

The TMUs are responsible for traffic flow management, and the coordination with the Traffic service and the users. Their primary responsibilities are to maintain safe and efficient operations for en route traffic, and for arrival and departure flows. Other functions are: monitor traffic, relay information to supervisors of emerging problems, post flight restrictions, set reroutes in the system, approve departure release during En Route Spacing Programs (ESPs), and communicate with other local TMUs across En Route, TRACON and Tower.

In summary, there are two organizations within ATC. On one hand, there are controllers located at ATC facilities who provide traffic service, mainly to flightdecks. They control aircraft, execute traffic management initiatives, and maintain safe separation of traffic. On the other hand, there are traffic managers located at the CC and TMUs who control the flow of traffic, monitor weather and other constraints in the NAS, initiate delay programs, and coordinate customer demands mainly with dispatchers. Both Traffic Control and Traffic Management provide safe and efficient flow of traffic. Controllers operate more in real-time. They mainly monitor and issue control instructions, based on flight data, flightdecks' intentions and traffic constraints. Controllers also update and transfer flight data to other controllers. Traffic managers operate more in a planning mode. They rely on flight data and airspace constraints to plan traffic flows across the NAS and initiate delay programs. They also gather and transfer information with controlling facilities, and inform, sometime negotiate with, customers about strategic decisions.

2.2.3 Current FOC responsibilities

The higher level roles and responsibilities of dispatchers, or generally those of FOC, were identified starting with several regulatory documents (FAA S-8081-10C, FAA 8900.1 and FAA AC 121-32A). The FAA S-8081-10C, Aircraft Dispatcher Practical Test Standards, provides a general understanding the FOC roles and responsibilities in relation to the flightdeck and ATC.

The Code of Federal Regulations 14 CFR Part 121 provides requirements for operational control system, also known as dispatch system (FAA 8900.1). Operators must have a sufficient number of dispatch centers and must employ enough certified dispatchers to control all their flight operations. Operators must have a General Operation Manual that contains policies and procedures to release and monitor flights that are available for each dispatcher while they perofrm their duties. Operators need to ensure they have enough personnel to cover fluctuations in workload and to ensure that dispatchers are not overloaded. Typically, dispatchers are assigned to geographical areas and a limited number of flights, for the duration of a shift. More dispatchers may be assigned during non-routine conditions, such as difficult weather. Dispatchers must be familiar with all essential procedures for their operations, and dispatchers not yet qualified need to be supervised by qualified dispatchers. Dispatchers must maintain communication with all their flights.

Dispatchers both dispatch (including signing a dispatch release) and monitor flights. 14 CFR requires both the dispatcher and the captain of a flight to sign the dispatch release. Both certify that, to the best of their judgment, the flight can be made safely as planned. Most of the time, dispatchers and captains are not able to sign on the same form. Dispatchers sign a duty roster at the beginning of their shift, and each of their releases contains their name and a date and time. Releases thus can be considered as signed. Captains sign a paper or an electronic release they receive locally. Dispatchers may have to re-release a flight, while the given flight is already airborne. This can be done in print or orally. Captains can accept re-releases by reading back the release message, recording the message, noting the date and time, and signing the entry.

Before releasing flights, dispatchers must be familiar with current and forecast weather conditions, and the status of navigation and airport facilities. Dispatchers are required to provide a preflight briefing on these conditions (verbally or in writing) to the captain. The purpose is that dispatchers and captains have identical information about the conditions and its effect on flight planning. Dispatchers must also monitor the progress of each flight until the flight has landed, the flight has passed the dispatcher’s area of control, or until the dispatcher is relieved by another dispatcher. Dispatchers monitor fuel state, remaining time of flight, weather trends (en route and at destination), and airport status. Dispatchers are required to report to pilots in command (by voice or text) any information that could affect the safety of the flight. Rapid and reliable two-way radio communication is required between dispatchers and flights, independently of any government systems.

Dispatchers who release flights under 14 CFR Part 121 domestic rules need to include specific information in writing. It should have at minimum: aircraft identification number, flight number, departure airport, intermediate stops, destination airports and alternate airports, IFR or VFR operation, minimum required fuel. Plus dispatchers need to attach, or include in the release, weather reports and forecasts for the destination as well as intermediate stops and alternate airports. Dispatchers need to note planned re-releases as well as alternate routings that flights can’t legally take. Currently, dispatchers from commercial airlines and business private jets companies typically transmit flight releases electronically to pilots and to the ATC host system.

An amendment of dispatch release for an alternate destination must follow the same requirements for the original release. It needs to be jointly approved by the dispatcher and the captain and both need to be informed about the weather. The destination airport must be above the forecast weather minimum and the aircraft must have enough fuel on board at the time of the amendment. The amendment information and its receipt must be recorded.

Re-release or redispatch is sometimes planned for extended range flights to save fuel. International flights are required to carry an extra 10% of fuel of en route time. To save fuel, dispatchers can release a flight to an intermediate destination, a redispatch point, and re-release when aircraft reaches the intermediate point. This needs to be indicated in the original release althought the re-release is a new dispatch. Both the dispatcher and the captain must record the release and amendement information and the receipt of the release.

Additional requirements include weather where dispatchers cannot release a flight for VFR operation unless the ceiling and visibility en route and at destination fulfill the VFR minima. Dispatchers cannot release a flight when the weather condition is lower than the takeoff minima or lower than the destination airport (Cat 1). When the destination airport does not meet the minimal criteria, an alternate airport where the weather exceeds the minimum requirements must be set. A second airport may be designed as alternate, when both the destination and alternate weather are considered marginal. Further, dispatchers may not let flights takeoff unless theu are carrying enough fuel for each increment: en route fuel, alternate fuel, routing, domestic reserve fuel (added 45 min of flight time), contingency fuel (compensation for delays), and additional increments for start-up, and taxi and pre-departure delay. The dispatch release must display the necessary amount of fuel for the flight at engine start prior to takeoff.

Also, dispatchers must know what actions should be taken when flight crews are not responding. When either the dispatcher or the captain believes the continuation of a flight to its destination is unsafe, a captain must obtain a concurrence of new course of actions from the dispatcher and amend the dispatch release. That process should address ATC requirements to re-assign altitudes, reroute flights or delay them.

Typically a dispatcher is assigned to a region and is given a series of flights to plan and file for and monitor. Similarl to controllers, dispatchers hand over responsibility for the set of flights during a shift break or turn over. Commercial airline Flight Operations Centers operate 24 hours a day. When a dispatcher takes over a position, there may be flights to monitor and flight plans to file. The typical tasks include: monitor regional and local weather and ATC information, such as NOTAMS and advisories, search flight and aircraft information, assess weather, runway performances, build flight route, compute fuel requirements, coordinate with pilots, release flights, monitor flights progress, and provide support during emergency or rerouting.

Flight Operations Centers also employ dispatchers who coordinate information with ATC facilities. These ATC coordinators track all status information and change in the NAS. The main source of information comes from the Command Center (CC) advisories and NOTAMs on its website. ATC coordinators also participate in telephone conferences every two hours to share information about the current NAS situation and any delays and decisions implemented by the CC. ATC coordinators monitor ATC and CC information including local and regional weather, delay programs, traffic rerouting and runway conditions. ATC coordinators also relay information to regional dispatchers and relay strategic needs to the CC to reduce arrival delays.

In sum, the main responsibilities for dispatchers are filing flight plans that fulfill the obligations of captains to fly aircraft according to weather, performance, fuel restrictions, as well as flight plans that take into account delay constraints and optimize fuel spending for the air transport company. Dispatchers are also responsible to monitor and assist flight crews when needed in case of emergencies or rerouting. The dispatchers who act as ATC coordinators have no legal responsibilities, but play a critical role for the company in coordinating the airline needs with strategic plans in the NAS, supporting delay reductions and in relaying information to regional dispatchers.

2.3 Current interactions between flightdeck, ATC, FOC and automation

The previous section 2.2 provides a description of current operator responsibilities as presented by a review of regulatory and advisory documents. This following section adds to that description by presenting the data collected within each of the organizations: Flightdeck, ATC, and FOC. Data was collected from operating documents and personnel from operations in each of the groups to provide a more in-depth understanding of how they currently work together.

2.3.1 Flightdeck current interaction

<u>First step</u>. Starting with the general responsibilities discussed in Section 2.2.1, a more detailed listing of flightdeck interactions was developed. The listing was based on current operating documents that described pilot tasks or procedures. This detailed listing included those tasks or procedures by phase of flight that likely involved flightdeck interaction, communication or coordination with ATC or FOC. The following eight terms were used to search two Aircraft Flight Manuals (AFMs) of the most widely used domestic aircraft types, the A320 series and the B737, as well as a current Flight Operations Manual (FOM):

- Advisory
- ATC/Air Traffic Control
- ATIS/Automatic Terminal Information Service)
- Clearance
- Communicate/Communication
- Dispatch
- Responsibility
- Voice.

Each of the search results were evaluated for inclusion in an interaction task listing. Only those results that related to pilot initiated communication to ATC or FOC were included. The preliminary results netted 51 procedures or tasks under nominal operations and 121 under off-nominal or conditional operations. Those results were further analyzed to ensure there were no duplicates. The most frequent types of flightdeck to ATC communication actions during nominal operations were to advise, notify, report and request. The most frequently used flightdeck to FOC communication actions during nominal operations were to contact, coordinate and notify. The wording of some of the interactions between flightdeck and FOC during nominal operations implied a greater degree of collaboration. In addition, the flightdeck had several communication actions with FOC that included concur and conference.

The off-nominal listing showed a wider range of interactions that implied some level of collaboration. Table 2.1 lists some of the interactions between the flightdeck and ATC under off-nominal conditions. It must be remembered that these interactions are taken primarily from flight operations manuals without specific reference to how often they might occur.

Table 2.1: Examples of Off-Nominal Flightdeck Interactions with ATC

Flight Phase	Communication Interaction
Preflight	1. Advise ATC (If anything affects the RVSM status or ability to maintain flight level within 150 feet)
Preflight	2. Advise ATC of the failure (If radar failure)
Preflight	3. Contact ATC (If an FMC, FMGC, GPS/IRS fails inflight)
Preflight	4. Contact ATC & request authority to continue operating at cleared flight level (If transponder fails)
Preflight	5. Contact ATC or OCC for PIREPS and other information (If radar attenuation)
Taxi	6. Notify ATC (If loss of All GPS/IRS and FMC procedures)
Inflight	7. Notify ATC (If RNP-10 minimum equipment is not available)
Inflight	8. Report to ATC (If loss of VOR, ADF, complete/partial loss of ILS receiver capability)
Inflight	9. Report to ATC a degrade in the aircraft's navigational capability as soon as possible
Inflight	10. Request new clearance (If any RVSM system fails)
Inflight	11. Contact ATC if transponder fails
Inflight	12. Revert to voice procedures If any question about clearance received via datalink
Inflight	13. Contact ATC by voice If no reply within 15 minutes of datalink request for clearance
Inflight	14. Verify clearance by voice If clearance confirmed message not receive within 5 minutes of sending CLA
Inflight	15. Ask ATC for assistance (If need to quickly, locate an off-line diversion airport to accommodate the aircraft)
Inflight	16. Coordinate with ATC to determine the best course of action (If fuel crossfeed valve fails in closed position)
Inflight	17. Coordinate with ATC and other aircraft (If wake turbulence is encountered or anticipated)
Inflight	18. Coordinate with ATC (If one engine inoperative)
Approach	19. Coordinate with ATC (If navigation system failure)
Approach	20. Coordinate with ATC prior to applying any corrections (If Cold Temperature Approach Altitude Corrections)
Approach	21. Receive advisory information from the controller (If deviation from glideslope)

Many of the interactions with ATC under off-nominal conditions include the actions of contacting, notifying and reporting. Table 2.1 lists six interactions that could imply some level of collaboration. These include the action "Ask ATC for assistance" if the flightdeck needs to locate an off-line diversion airport (Interaction #15 in Table 2.1). The other five are instances of "Coordinate with ATC" (Interactions #16 through #20) under various environmental conditions and aircraft system failures. The number and range of these types of failures and conditions will become more significant with regard to collaboration under NextGen with its increasing dependence on automation, communication and navigation systems.

The interactions under off-nominal conditions between the flightdeck and FOC in Table 2.2 suggest that collaboration during preflight generally address the flight plan (Interaction #1 through #4) and during inflight it addresses several company critical issues such as emergencies, pilot incapacitation or criminal acts (Interactions #5 through #10). Under off-nominal conditions, operating manuals list a greater number of possible collaborative interactions, especially with ATC.

Table 2.2: Examples of Off-Nominal Flightdeck Interactions with FOC

Flight Phase	Communication Interaction
Preflight	1. Captain and dispatch assessment will determine if pair is acceptable (If there is a SPAR condition/ procedure pair)
Preflight	2. Concur with dispatch whether operations can continue (If precipitation accumulation on runway more than .5 inch)
Preflight	3. Confer with dispatch when necessary (If clearance differs from the Flight Release routing)
Preflight	4. Coordinated with dispatch (If discrepancy in FDML at non-maintenance station)
Inflight	5. Captain and dispatch exercise teamwork, initiative, and good judgment with ultimate responsibility with the captain (If emergency)
Inflight	6. Consult dispatch (If criminal acts)
Inflight	7. Contact dispatch to obtain new flight plan (If prior to ETOPS entry, significant ATC reroute)
Inflight	8. Coordinate with dispatch (If after ETOPS entry, alternate forecast is revised below limits)
Inflight	9. Coordinate with dispatch (If pilot incapacitation)
Inflight	10. Determine nearest suitable airport with dispatch (If FAA does not define suitable airport for emergency landing)

Second step. As a second step in the data collection, a listing of flightdeck interaction tasks was presented to pilots in order to identify the most frequent and critical interactions between the flightdeck ATC and FOC. Pilots were asked to first rate communications taking place under nominal conditions. They were instructed to rate Frequency based on the how often the specific communication takes place across all nominal operations. They were given the following rating guideline and were asked to circle just one level of Frequency for each type of communication:

VL - Very Low (Less than 5 percent of all operations - very infrequent)

L - Low (Less than 25 percent of all operations - infrequent)

M - Medium (More than 25 percent and less than 75 percent of all operations)

H - High (More than 75 percent of operations - something that usually occurs)

For off-nominal conditions, participants were asked to rate Frequency strictly based on their frequency within all off-nominal operations. They were also asked to rate each nominal, as well as off-nominal interaction for Criticality, using the following rating guideline by circling just one level for each task or procedure:

L - Low (Little risk to the safety of the flight)

M - Medium (Moderate risk to the safety of the flight)

H - High (High risk to the safety of the flight)

A total of 11 pilots completed the two-page rating form (see Appendix A). They were all type rated commercial pilots from a single operator. Respondents had an average of 23 years with their current operator and a mean of 13,500 total flight hours based on a range from 4,500 to 18,000 hours. Table 2.3 shows the most frequent flightdeck interactions with ATC and FOC under nominal conditions. These are the interactions rated a 2 or higher based on a 4-point scale where 1 indicated a Very Low Frequency and 4 indicated a High Frequency. During preflight, flightdeck communicates with ATC most often to request the Pre-Departure Clearance (PDC) and to inform them of the ATIS identifier they have reviewed. Neither of these ATC interactions would involve collaboration, but the preflight interaction with FOC could. The most frequent preflight interaction with FOC is to get the preflight briefings that may involve more than just a one-way communication.

Table 2.3: Most Frequent Interactions Under Nominal Conditions by Phase of Flight

Flight Phase	**INTERACTION SORTED BY FREQUENCY > 2** *(where 1= Very Low and 4=High)*
Preflight	Request PDC via ACARS
Preflight	Inform ATC on initial contact of the ATIS identifier they have reviewed
Preflight	Call dispatch when at the gate to get preflight briefings
Taxi	Obtain taxi clearance from ATC prior to taxiing onto a movement area
Taxi	Acknowledge any hold short instructions to ATC
Taxi/takeoff	Request ATC clearance prior to operating an aircraft on a runway or taxiway or taking off
Inflight	Report vacating any previously assigned altitude or flight level for a newly assigned level.
Inflight	Acknowledge receipt of traffic advisories
Inflight	Inform ATC if traffic in sight
Inflight	Advise ATC prior to any altitude change to ensure the exchange of accurate traffic information
Inflight	Confirm clearance paying attention those received in areas of high terrain, or include a change to heading, route/waypoints, altitude, or involve instructions for holding short of a runway

During taxi and inflight, the flightdeck communicates most frequently with ATC under nominal conditions. The communications during taxi are designed to improve runway and taxiway safety. This inflight communication deals with traffic, altitude changes, and clearances. Under off-nominal conditions during preflight, most of the frequent communications are with FOC. Several of these can involve some level of collaboration. The Systems Performance Adjustments Reference (SPAR) procedures deals with adjustments to takeoff or landing performance based on weight, speed, runway length, or altitude. It involves a number of codes and conditions that can require some discussion and coordination between the captain and FOC. The two frequent inflight interactions (see Table 2.4) are with ATC, and they both involve deviations. In the case of a deviation greater than 10 nautical miles, there is some level of involvement as the flightdeck keeps ATC advised of intentions and ATC provides the flightdeck with traffic information.

Table 2.4: Most Frequent Interactions Under Off-Nominal Conditions by Phase of Flight

Flight Phase	**INTERACTIONS SORTED BY FREQUENCY > 2** *(where 1= Very Low and 4=High)*
Preflight	Communicate mechanical delays to dispatch
Preflight	Notify dispatch if FOB exceeds release fuel (If weight restricted flight)
Preflight	Contact dispatch (If performance limitations or inflight restrictions preclude operations)
Preflight	Captain and dispatch will determine if pair is acceptable (If SPAR condition/procedure pair)
Preflight	Obtain clearance from ATC prior to starting engines and/ or taxiing out of any de/anti-icing area
Inflight	Contact ATC as early as possible for deviations (If hazardous weather)
Inflight	Keep ATC advised of intentions and obtain traffic information (If deviation greater than 10 NM)

Table 2.5: Most Critical Interactions Under Nominal Conditions by Phase of Flight

Flight Phase	INTERACTIONS SORTED BY CRITICALITY YELLOW > 2.5 *(where 1= Very Low and 3=High)*
Preflight	Request PDC via ACARS
Taxi	Advise ATC if either pilot is uncertain of airport orientation of location on runway
Taxi	Obtain taxi clearance from ATC prior to taxiing onto a movement area
Taxi	Acknowledge any hold short instructions to ATC
Taxi	Contact ATC if holding in position for more than 90 seconds or upon seeing a potential conflict
Taxi/takeoff	Request ATC clearance prior to operating an aircraft on a runway or taxiway or taking off
Inflight	Request clarification from ATC if uncertain of an ATC clearance
Inflight	Make en route position reports for traffic control purpose at all compulsory points and at additional points as requested by FAA
Inflight	Advise ATC if unable to maintain visual separation
Inflight	Confirm clearance paying attention those received in areas of high terrain, or include a change to heading, route/waypoints, altitude, or involve instructions for holding short of a runway

Some of the more frequent forms of flightdeck communication are also the most critical for the safety of the flight under nominal conditions. These include requesting the PDC and some of the communications during taxi that have been implemented to reduce runway incursions such as the flightdeck's acknowledgement of any hold short instructions. The main difference between frequency and criticality under off-nominal conditions is that the most frequent communications are during preflight while the most critical interactions are inflight. Most of the critical inflight interactions deal with deviations and emergencies.

Table 2.6: Most Critical Interactions Under Off-Nominal Conditions by Phase of Flight

Flight Phase	INTERACTIONS SORTED BY CRITICALITY YELLOW > 2.5 *(where 1= Very Low and 3=High)*
Taxi	Contact dispatch (If discrepancy prior to takeoff)
Inflight	Obtain ATC clearance (If diverting)
Inflight	Declare emergency fuel status (If emergency fuel advisory)
Inflight	Determine nearest suitable airport with dispatch (If emergency landing)
Inflight	Notify dispatch (If landing at unauthorized airport)
Inflight	Contact ATC and dispatch once aircraft is under control (If emergency)
Inflight	Contact ATC as early as possible for deviations (If hazardous weather)

Although the operating documents do list a number of possible collaborative interactions, "mostly under off-nominal conditions," none of those collaborative interactions were rated as very frequent or high in criticality to the safety of flight. Overall, this review shows that there are more opportunities for collaboration between the flightdeck and FOC with some limited collaboration between the flightdeck and ATC under off-nominal conditions. When looking specifically at the frequency of these more collaborative interactions, very few are rated as having a medium to high degree of frequency.

In conclusion, there is not a substantial amount of collaboration between the flightdeck and ATC or FOC under current operations. Most interactions involve acknowledging, contacting, obtaining or requesting information with little indication of negotiations or collaboration. This review highlights the fact that there are a large number of possible communication and navigation system failures. These include different types of failures of the FMC, GPS, IRS, VOR, ADS, and ILS receivers. With NextGen requiring more new systems, greater precision along with automation, the possible interaction of multiple failures and recovery procedures could overwhelm the flightdeck.

2.3.2 ATC current interaction

ATC interactions were described using process charting (i.e., Operation Sequence Diagram) which is based on a task analysis (Stanton, Salmon, Walker, Baber & Jenkin, 2005). Process charts were developed to depict steps, sequential flow of tasks, and points of interactions between collaborators.

First, interviews were conducted with three Subject Matter Experts (SME). The SMEs were recently retired radar and local controllers from En Route, TRACON and Tower facilities. They described their activities, their work environment, technologies used, and interactions across positions and with flightdecks and FOC. Important topics were discussed, such as, emergencies, change of runway configuration, weather, transfer of control and separation of traffic. The most frequent controlling activities were identified. These frequent activities represented common traffic demands and covered the generic control for Tower, Terminal and En Route. The following activities were identified for Tower and Terminal facilities:

- Departure
- Approach
- Missed approach.

The following activities were identified for En Route facilities:

- Cruise
- Climb
- Descent and approach with handoff to TRACON with and without sequencing
- Descent, approach and landing to airport with and without Tower.

Second, these activities were described in detail by SMEs. Each activity was decomposed into sub-activities following a step-by-step process (task list). Steps were defined by the purpose and result of the interactions. Physical movements were not described.

Third, activities were depicted in a process chart (See Appendix B). Microsoft Visio software was used to draw the charts. Symbols were taken from the AMSE standards (AMSE, 1972). Fourth, SMEs reviewed process charts and corrections were made.

The process charts indicate the most common interactions points between ATC and between ATC and flightdecks or FOC, for all types of facilities and sectors, and thus, for all phases of flights. The interactions with flightdeck and FOC are in Table 2.7 (nominal), and 2.8 (off-nominal). The top interactions are handled by all facilities. Both within and between ATC interactions are shown (including specific ATC positions) in Appendix C.

Off-nominal events require more coordination both with flightdeck, other controllers and dispatchers. For fairly frequent events, such as holding and missed approaches, standard operating procedures are in use (e.g., published holding points, heading and altitude for missed approach for each runway). There are no specific procedures for rare and unpredictable events except to give priority to the flightdeck and provide all needed assistance. For nominal operations, many interactions serve to verify contact, information, intentions, and operations with flightdecks. Other interactions serve to coordinate data, control, flow of traffic and constraints with other controllers.

Table 2.7: Examples of ATC Interactions Under Nominal Conditions

Interactions with Flightdeck
By En Route, TRACON and Tower Controllers
Initial contact with pilots
Request pilots to contact other controller onto a new frequency
Read back communication from pilots
Request pilots to report identification, position, altitude, or information
Check with pilots if STAR or ATIS (if applicable) statuses are current
Relay ATIS information to pilots
Advise pilots to get new ATIS information
Relay PIREPs to other pilots
Inform pilots about adverse conditions
Advise pilots for traffic
Receive traffic in sight advisories by pilots
Caution pilots for wake turbulence
Control flight data accuracy with pilots
By En Route and TRACON Controllers
Receive pilots' intentions (altitude, heading, speed, route, deviation, destination, approach, runway)
Receive pilots' report of change of altitude, heading, or passing location
Provide control instructions and clearances to pilots regarding their heading, altitude, speed, fix point, via radio (as filed, to allow a shortcut or to delay (vectoring, sequencing)
Clear pilots for change of altitude, heading, speed, approach.
Communicate altimeter at or under 17'000ft to pilots
Clear pilots for a different approach than filled or advised (e.g. visual instead of ILS)
Verify identity and altitude leaving and assigned + provide additional instructions to pilots, if needed.
By Tower Controllers
Receive pilots' intentions (Pre-Departure, pushback, star engines, taxi, runway, de-icing, departure time, takeoff, gate)
Receive pilots' report of position
Receive a Pre-Departure Clearance (flight plan) request from pilots, digitally (ACARS) or by voice (radio)
Amend Pre-Departure Clearance (flight plan), digitally (ACARS) or by voice (radio), (based on weather, traffic constraints)
Clear Pre-Departure Clearance (flight plan) to pilots
Issue delay/flow restrictions to departing aircraft
Coordinate delay/flow restrictions with departing aircraft
Clear pilots for pushback, taxi route, crossing taxiway and runway
Clear pilots for takeoff, landing, exit point of runway
Abort takeoff
Issue a clearance limit to pilots (fix point, hold short point)
Coordinate pilots position and movements requests prior to departure
Clear approach to runway to pilots
Inform pilots of wind, runway condition, breaking actions
Interactions with FOC (by any controller)
Receive flight data in the system from dispatch
Relay information between dispatch and pilots (when needed)
Coordinate customers questions (most often dispatch, about weather, runway or approach condition and configuration, restricted airspace)
Coordinate alternative flight destinations with dispatch (when needed)

Table 2.8: Examples of ATC Interactions Under Off-Nominal Conditions

Holding by En Route Controllers
Warn pilots of holding instruction at least 5 minutes before reaching holding fix point
Provide control instructions to pilots for holding procedures as published or else
Clear pilots to go on holding or to continue as filed
Coordinate with pilots for an alternative destination if minimum fuel, when holding
Missed approach by TRACON or Tower Controllers
Initiate go-around (missed approach) + plus give instruction for altitude and heading to pilots
Relay control instructions from departure sector to pilots (missed approach)
Emergency (medical or mechanical) by En Route, TRACON or Tower Controllers
Declare emergency to pilots
Coordinate with pilots emergency declaration
Request the pilots to state the number of souls on board, remaining fuel and cause of emergency
Coordinate with pilots how ATC can help, during emergency
Coordinate with dispatch in case of emergency
Coordinate ATC help to pilots during emergency
Inform pilots of off-nominal mechanical issues (gears problem, fire)

In summary, the interactions between controllers and the flightdeck or FOC are based on the way controllers perform their tasks. A controller's interactions between organizations are affected by five tasks that could occur almost simultaneously involving communication within ATC as well as between ATC and the flightdeck or FOC.

First, controllers manage the identity of each flight, its current position and intentions. A flight's identity is established when contact is made with the aircraft. A flight’s current position and intentions also need to be communicated to controllers. Identity, position and intentions are also corroborated with flight's datablock which is transferred across sectors. Controllers immediately check if the given flight will conflict with other traffic.

Second, controllers prioritize clearance. Each clearance needs at least two exchanges and an update of the datablock when applicable. Often clearances require some control of adequate information or procedure from flightdecks. For instance, controllers make sure flightdecks have the right ATIS information, Standard Instrument Departures (SIDs) and Standard Terminal Arrival Routes (STARs). The same constraints can apply between controllers, for instance, when departure controllers amend flight plan, departure time (flow control), which then needs to be ensured by local controller and relayed to flightdecks.

Third, controllers handle multiple tasks at the same time managing competing demands. But each interaction only deals with a specific need of one specific aircraft such as providing a clearance. Controllers constantly shift attention from the most critical operations to other operations.

Fourth, transfers of control between controllers can imply a simple or complex coordination. The simple coordination consists of sending and accepting a full datablock (PVD), by the click of a button. The more complex coordination consists of a request from the receiving sector to the feeding sector to relay instruction to flightdecks before they enter the receiving sector. Transfer of control can also happen before a flight has left the feeding sector. During pointouts, a controller of a sector does not need to control flights that remain under the control of another; they can let the other controller maintain contact with the flightdecks.

Fifth, flight data is updated and transferred separately from the control of traffic. It is a key part of planning the separation of traffic. It allows controllers to anticipate the demand and constraints from incoming traffic. Controllers forward a datablock of incoming traffic to subsequent sectors by means of the PVD to indicate incoming traffic into their sectors. The datablocks will change appearance. This facilitates planning traffic flow in sectors where traffic is heavy. This is often the case at sectors that are merging traffic at En Route or at Terminal facilities. Though if flight data is handled separately, controllers always make sure it corroborates actual operator's position and intention.

2.3.3 FOC current interactions

Interview and observations of dispatchers were conducted at a domestic operator. An interview was conducted with the dispatcher senior manager and series of observations were made during two shifts at the operator's FOC. The initial interview with the senior manager provided a perspective of the organization of the operational center, as well as a general overview of dispatchers' activities. Observations conducted at the FOC focused on domestic flights. Two persons observed two full shifts. Dispatchers who participated were briefed before the shifts about the purpose of the observations. They signed consent forms that granted anonymity and freedom to withdraw from their participation. All questions were answered and contact information was exchanged.

The first set of observations started at 2:00 PM and ended at 11:00 PM, during the swing shift. The second set of observation started at 10:00 PM and ended at 7:00 AM. A North-East region and the ATC Coordinator desk were observed during the swing shift, and a South-West region and a Mid-Atlantic region desks were observed during the mid-shift. Each observer sat near a dispatcher and logged in all new activities without interrupting the dispatchers. Occasionally dispatchers spoke with the observers and provided them with background information. The two observers logged a total of 815 entries in observation forms over the 32 hours of observations. Entries described new or ongoing actions undertaken by a dispatcher. Tasks usually involved obtaining, updating, entering or sending information either on a computer, on paper, or with another person who was either co-present or remote.

An analysis of the observation entries show that fifty-two percent of all recorded actions involved communication with another person. The two most frequent interactions were with flightdecks and other dispatchers. The less frequent interactions involved controllers, ramp or scheduling. The two most frequent media of communication used were the telephone (25%) and face-to-face interactions (18%). The other media were text based (ACARS, emails, and other message systems).

The most frequent topics of interactions related to weather, runways, delays, routing, fuel, maintenance and MEL. The most frequent tasks without interaction related to flight release, gathering information about weather, delays or maintenance. Dispatchers who are responsible for flights pull a lot of information prior to the release of a flight plan. They need information on the weather from ATC, company and from national service as well as runway configurations and current or possible delays from ATC. Dispatchers also need information on aircraft performance capacity, the crew and the payload from the company along with any other information that may affect performance or may delay flights. Once dispatchers have the needed information, they build a flight route, compute the needed fuel, and establish a flight plan that meets all regulatory requirements. Dispatchers may prepare alternative or amended flight plans. Once the captain and dispatcher have agreed to co-sign the flight plan, the dispatcher releases the flight plan to ATC. The dispatcher may have to address possible overfuel, maintenance and delay issues with the flightdeck prior to a flight's departure. Once a flight is airborne, dispatchers have the responsibility to monitor the flight until it lands. Dispatchers are required to communicate with each flight they are monitoring every two hours.

During off-nominal events, dispatchers are in close contact with flightdecks. Off-nominal events are critical. They can be related to passenger threats, medical emergency, mechanical emergency, diversion, significant rerouting, missed approach, holding. In most cases, flightdecks notify dispatchers of the situation, and dispatchers will provide assistance to the flightdecks. In some cases, rerouting, diversion, or holds, dispatchers will also collaborate with ATC to agree on alternative routes, destinations, or assess delays. Those are mainly related to safety issues, which translate into delays, fuel cost, and possibly changing the destination of the flights. In the destination is changed, passengers and cargo have to be redispatched to their final destination.

FOC also has dispatchers working as ATC Coordinators monitoring ATC activities, information about weather and airport capacities. They discuss adverse conditions such as delay programs (arrival/departure rates, traffic rerouting), weather, and reduced operations with the CC and other ATC facilities. They transfer relevant information to flight dispatchers about decisions that ATC has made, and the best way to improve the company's operations. During critical situations such as a bad weather near a company hub, the coordinators will try to push the company's agenda with ATC.

FOC interactions ratings. Dispatchers' interactions were also rated by the four observed dispatchers. The methodology was similar to the one used for the flightdeck survey in section 2.3.1. The interactions between pilots and dispatch in the flightdeck survey were reworded to be centered on dispatch. Additional interactions were searched in regulatory documents (FAA AC121-32A, CFR Part 65, and 8081-10C). Interactions with ATC were searched in controllers' procedures (FAA JO 7110.65T) as well as in the task listing collected in section 2.3.2. Thirty-six interactions related to the flightdeck, and twenty-one to ATC, among them, half were in off-nominal conditions. The interactions were rated for frequency and criticality. The scales were identical to the pilots' questionnaire: Frequency (1 = Very Low, 2 = Low, 3 = Medium, 4 = High) and criticality (1 = Low, 2 = Medium, 3 = High) using the same scales in the pilots' survey. A sample form is in Appendix D.

The following tables list the most critical (above 2.5, Medium-High) and most frequent (above 2, Low-Medium) interactions with the flightdeck and ATC under nominal condition (Table 2.9) and off-nominal conditions (Table 2.10). The interactions are grouped by ratings, first by Criticality and then by Frequency. Empty cells indicate that the rating was under the threshold of criticality (2.5) and frequency (2). The small sample of responders should be kept in mind when reading the following results.

Table 2.9: FOC Interactions Under Nominal Operations with Highest Ratings for Criticality and Frequency.

Flight Phase	Interactions	Criticality Med-High > 2.5 High = 3	Frequency Low-Med > 2 Medium => 3
Nominal Interactions with Flightdeck			
Taxi	To obtain departure clearance with applicable void time	High	Medium
Preflight	When hold fuel is to be reduced or eliminated	High	Low-Med
Preflight	When there are cold weather/icing conditions	High	Low-Med
Inflight	When fuel consumption greater than planned	High	Low-Med
Inflight	When route changes significantly	High	Low-Med
Inflight	When unplanned holding or delaying vectors	High	Low-Med
Preflight	When there are any changes to the release	Med-High	Medium
Inflight	When flightdecks are given a clearance change (reclearance)	Med-High	Medium
Preflight	When route clearance differs from flight release IFR routing	Med-High	Low-Med
Preflight	When a change in either route or altitude is desired	Med-High	Low-Med
Preflight	To get preflight briefings		Medium
Taxi	When there are flight delays		Medium
Inflight	When ground delay programs are implemented		Medium
Inflight	To establish voice communication		Low-Med
Nominal Interactions with ATC			
Preflight	When flight data is not correct on flight plan, prior to the Flight release clearance	High	
Inflight	To enquire about runway condition (braking actions) at airport of destination	High	
Inflight	When ground delay programs are being implemented	Med-High	Medium
Inflight	When ground stops are being implemented	Med-High	Medium
Preflight	To require changes on Flight plan prior to the Flight release clearance	Med-High	Low-Med
Preflight	To enquire about runway condition	Med-High	Low-Med
Inflight	To enquire about approach configuration at airport of destination	Med-High	Low-Med
Inflight	To enquire about weather impact		Low-Med

Under nominal conditions, highly critical interactions with the flightdeck addressed concern for the safety and the operation of the flight. Those relate to fuel issues, cold weather, departure void time, significant route change and delays. They are also moderately frequent. Medium to highly critical interactions deal with changes to the flight data. Interactions that are not critical but fairly frequent are delays and the need to communicate (preflight briefing, establish voice communication).

Highly critical interactions with ATC deal with errors in the flight data and to enquire about braking actions at the destination. Those are not frequent. Medium to highly critical interactions relate to delay programs, runway condition at departure and approach at destination. Interactions about delays seem more frequent than interactions on runway and approach configurations. Enquiries about weather impact wasn't rated as critical but seemed fairly frequent.

Table 2.10: FOC Interactions Under Off-Nominal Operations with Highest Ratings for Criticality and Frequency.

Flight Phase	Interactions	Criticality Med-High > 2.5 High = 3	Frequency Low-Med > 2 Medium => 3
Off-Nominal Interactions with Flightdeck			
Preflight	When performance adjustment need to be made by dispatchers	High	Low-Med
Inflight	When unforecast or unreported weather conditions might affect operations	High	Low-Med
Inflight	When flightdecks are diverting	High	Low-Med
Preflight	When aircrafts performance limitations or inflight restrictions preclude operations	High	
Preflight	When FOB exceeds release fuel for weight restricted flight	High	
Preflight	When Takeoff Performance System data are not correct	High	
Preflight	When any condition prohibits acceptance of PRM clearance If departing to airports where PRM operations are authorized	High	
Preflight	When actual fuel on board exceeds gate release fuel by any amount for weight restricted or capped flight	High	
Preflight	When NIL braking action are reported	High	
Inflight	To determine nearest suitable airport if emergency landing	High	
Inflight	When flightdecks need to land at unauthorized airport	High	
Inflight	When there are emergencies	High	
Preflight	When fuel is greater or less than the Gate Release fuel	Med-High	Low-Med
Preflight	To concur with dispatch whether operations can continue, if precipitation accumulation on runway more than .5 inch	Med-High	
Preflight	When aircrafts have mechanical delays		Medium
Preflight	To obtain amended release, if immediate maintenance action not required		Medium
Preflight	When flight clearance differs from the Flight Release routing taxi with flightdecks		Low-Med
Off-Nominal Interactions with ATC			
Inflight	When aircrafts are diverting	High	
Inflight	When flightdecks missed an approach	High	
Inflight	To transmit information to flightdecks, because direct communication is disabled	High	
Inflight	When landing aid components are inoperative (localizer, glideslope, VOR are unreliable)	High	
Inflight	To determine nearest suitable airport when there is an emergency landing	Med-High	
Inflight	When aircrafts are holding	Med-High	
Inflight	To determine alternative airports when aircrafts are holding	Med-High	
Inflight	When aircrafts are landing at unauthorized airports	Med-High	
Preflight	When aircrafts have mechanical delays		Low-Med
Preflight	When flights are cancelled		Low-Med
Inflight	To coordinate reroute of flights, because of adverse conditions (weather)		Low-Med

Under off-nominal conditions, highly critical interactions with the flightdeck address important risks or situations that preclude operations, such as, weather, diversion, aircraft performance, overfuel, emergency, or unauthorized operations. Ratings show that performance adjustment, weather and diversions can be moderately frequent. Medium to highly critical interactions concern fuel and accumulation of precipitation on the runway. Not rated as critical, but fairly frequent interactions are due to mechanical delays, maintenance intervention, and differences with taxi routing clearances.

Highly critical interactions with ATC mainly pertain to the safety of operations, such as, diversion, missed approach, ground equipment malfunctions and disabled communication with the flightdeck. Medium to highly critical interactions also deal with the safety of operations. They pertain to landing issues. All of these high to medium interactions are rated as not frequent. The ones that are moderately frequent deal with mechanical delays flight cancellation and rerouting.

In sum, the observed dispatchers indicated that critical interactions between FOC and the flightdeck address issues with flight data and fuel, and weather. Off-nominal issues relate to significant adverse conditions impacting safety and delays. Critical interactions between FOC and ATC relate to issues about flight data, and weather conditions. Off-nominal conditions relate to counter-performing issues with safety risks.

2.3.4 Automation and current interaction

Current interactions between the flightdeck, ATC and FOC involve some level of interaction with automation. The current use of automation is based on a collection of systems and tools that are generally not integrated and rarely shared across collaborators such as between the flightdeck and ATC. The transition to NextGen will offer a number of opportunities for improvements in the NAS by increasing collaboration and shifting responsibilities that have traditionally been assigned to human operators to automation. The current air traffic environment has tools that perform automated sub-functions while NextGen is interested in integrated systems based on advanced automation responsible for higher level functions. This section addresses current automation and Section 4 will consider NextGen advanced automation.

There are several ways to evaluate the use of automation in air traffic collaboration. The within group approach addresses automation as tools used by the flightdeck, ATC or FOC. The between group approach looks at automation as the fourth collaborator that can interact with and share information with the flightdeck, ATC, and FOC. This section looks at current automation that is primarily within each group, and Section 4 examines the more important between group approach treating automation as the fourth collaborator.

In addition to the between and within distinction, there are two other automation elements to consider in an assessment framework. The first element is the collaborative function being automated and the second is the amount of responsibility assigned to automation. Function and amount of responsibility being automated interact and can be used to determine the significance of the role played by automation in collaboration. In current air traffic management, there are numerous examples of limited automation such as those performed by the Flight Management System (FMS). The FMS performs some navigational sub-functions, but it does not relieve the flightdeck from the responsibilities of navigating the aircraft.

Flightdeck automation. Regarding the FMS on the flightdeck, Sherry, Feary, Fennell and Polson (2009) describe how its automation helps manage navigation based on substantial crew interaction. For example, when the flightdeck is instructed to hold at a waypoint, the crew must determine which FMS sub-function to access. Once the proper FMS function is determined, in this case the lateral navigation hold function, the crew has to access the function. This involves a number of FMS entries to get to the proper display page. Once on the appropriate FMS page, the crew has to enter the appropriate hold data, or in some cases, make the correct selections.

Depending on flightdeck Standard Operating Procedure (SOP), the entries need to be cross-checked by the other crew member and then executed. Once executed, the flightdeck must monitor to ensure that the aircraft maintains the selected hold pattern, generally achieved by the FMS with greater accuracy than can be achieve through manual flight. There are several conditions that require additional flightdeck actions such as during icing, extreme wind conditions or turbulence when higher holding speeds are required. This particular task or procedure is considered a sub-function of descent and holding which is a sub-function of flightdeck navigation. This brief description of one aspect of FMS current automation demonstrates that the FMS addresses lower level functions requiring a reasonable level of flightdeck input and monitoring without relieving the flightdeck of its responsibilities to perform the hold.

This FMS example reflects the general degree of current automation available within collaborators in the current air traffic environment where the system can help execute a lower level task but requires inputs and monitoring without reliving human operators from their responsibilities. Also, the FMS data and current automation is limited to the flightdeck. Proposed changes under NextGen may see substantial changes where the FMS becomes a more active part of collaboration between the flightdeck and ATC. An example of this type of advanced automation is indicated by Becher, MacWilliams and Balakrishna (2010) in their presentation of trajectory modeling on the ground side. They suggest that aircraft intent information such as FMS predicted ETA could be transmitted to and used by ATC automation to provide more accurate trajectory management. These FMS examples show that advanced automation is fundamentally different from current automation. Although a number of flightdeck and ATC systems are considered automated, there is a substantial gap between current automation and NextGen advanced automation.

Shutte et al. (2007) describe another flightdeck automated system, Traffic Collision Avoidance System (TCAS), as the result of "piecemeal technology evolution" where individual systems or sub-functions are replaced by stand-alone computers. As Shutte et al. (2007) point out, something may appear autonomous because it operates for extended periods of time without human intervention, but the human has actually entered a sequence of commands that are then automated. Lack of integration and limited functionality restrict the current automation to individual collaborators in the way that the FMS and TCAS are limited to the flightdeck. In their cognitive task analysis, Hilburn (2007) describe TCAS as a 'last-resort' system to prevent collisions between aircraft. It works within a one minute timeframe to alert and advise the flightdeck on resolutions to avoid an imminent collision. Although a number of different proposals have been made to use the TCAS display for functions such as continuing under visual rules on approach down to the actual minimum visibility (McAnulty & Zingale, 2005), the additional authorized use of the TCAS is for oceanic in-trail climb and in-trail descent. It can be used if the trailing aircraft can see the lead aircraft on the TCAS display and there is sufficient separation at the start so that the procedure can be safely completed (Sorensen, 2000).

<u>ATC automation</u>. ATC also has a number of automated tools, but as Federal Aviation Administration (2009) points out, automation is constrained by system and data limitations. That report summarizes ATC automation as providing controllers with updated displays of aircraft identification, position, altitude, speed and whether climbing, level or descending. ATC automation can also calculate and aircraft's future position in cases where there is a loss of current aircraft data. Essential to within ATC operations, automation helps to maintain aircraft flight data throughout the flight, generates route and restricted area symbology, provides potential conflict alerts, and displays weather, navigation and flight plan information. Current ATC automation that is fully implemented shares some characteristics with that on the flightdeck. The automation is primarily within ATC and is not directly shared with the flightdeck.

The functions being automated are relatively lower level such as providing conflict alerts and resolutions, both sub-functions of separation management. Further, the ATC automation does not relieve the controllers of separation responsibilities.

Current ATC automation is further limited by the installed hardware and software and lack of system-wide data. A current program, Collaborative Decision Making (CDM) points the way to the type of systems and data that will be required for the type of advanced automation envisioned in NextGen. CDM has demonstrated that traffic management can be improved when FOCs supplied operational information to the FAA (Ball et al., 2000). It has started using some of the tools required for advanced automation such as improved information exchange, decision making and shared situation awareness between ATC and FOC. CDM has evolved into a set of collaborative procedures with increased FOC involvement in the decisionmaking process, but it is still dominated by air traffic management objectives (Idris et al., 2006). CDM provides the direction, but not the final solution, for collaborative air traffic management which will have to include the flightdeck and automation with more complete shared information about the airspace and its constraints.

FOC automation. Current FOC automation is used to manage the large amount of information that dispatchers must consider in order to release and follow flights. Before filing a flight plan, dispatchers must review NOTAMs, the proposed route of flight, fuel, runway data and conditions, specific aircraft data with its conditions and procedures, visibility, weather, winds as well as current flow control (Darr, Morello, Shay, Lemos & Jacobsen, 2009). Software used by most major U.S. operators, Flight Explorer, provides the tools to integrate much of the data required to review and manage dispatcher considerations (Wolfe et al., 2009). Flight Explorer provides an integrated display of flight, weather and essential operational information for FOC personnel. This information includes real-time flight tacking, current and forecasted weather, airport and related reports. It also includes automated alerting tools for changing aircraft, aircraft or airport conditions. As on the flightdeck and within ATC, the information used by dispatchers tends to be within FOC rather than shared systematically across the NAS. Further, the FOC functions that are automated tend to be at a lower level often involving computations and alerts.

In summary, current automation does little to support between flightdeck, ATC or FOC interactions and must evolve to a form of advanced automation that is shared between collaborators. The move to such an advanced, shared technology will likely be gradual due to a number of constraints and human factors considerations. Among those considerations is the human's confidence in the automation. Battiste et al. (2008) found out that almost a third of flightdecks had problems with automated conflict resolutions, but less that 10 percent of those same flightdecks wanted to consult with ATC when they were able to use tools to request and modify similar automated resolutions. The transition to advanced automation under NextGen will likely evolve over several technology and procedural changes from the current to the point where automation can function as the fourth collaborator.

2.4 Summary of Current Collaboration

Section 2 has reported on the review of the general concept of collaboration followed by an operational review of possible collaboration between the flightdeck, ATC, FOC as well as automation. At the conceptual level, a number of collaborative frameworks relevant to air traffic management were identified, and one was particularly useful in that it specified two basic dimensions central to collaboration between operators and controllers. Time, the first dimension, highlighted the distinction between asynchronous interactions, such as those occurring in the planning process, and the synchronous collaboration typified by time critical negotiations. Space, the second dimension emphasized two different forms of collaboration. Collaboration within groups is exemplified by that of pilots communicating with each other on the flightdeck while collaboration between groups is the very different collaboration that takes place between the flightdeck and ATC, the flightdeck and FOC or ATC and FOC.

At the operational level, currently there is substantial interaction but little collaboration between the flightdeck and ATC or FOC. Most interactions involve acknowledging, contacting, obtaining or requesting information with little indication that negotiations are taking place. The flightdeck state-of-the-practice review and data collection showed that currently there are more opportunities for collaboration between the flightdeck and FOC with some limited collaboration between the flightdeck and ATC, with most of those under off-nominal conditions. The operational review of ATC between group interactions also concluded that off-nominal events required more collaboration with flightdecks and their FOCs. From the FOC perspective, off-nominal events also indicated increased interaction with flightdecks. Generally, the flightdeck advises FOC of the situation, and FOC provides assistance and in some cases, collaborates with ATC on alternative routes or destinations.

Current interactions between the flightdeck, ATC or FOC involve limited automation based on a collection of tools that are generally not integrated and rarely shared across collaborators such as between the flightdeck and ATC. The transition to NextGen will with increasing collaboration shift responsibilities currently assigned to human operators over to automation. In reviewing the fourth possible collaborator, automation, it was determined that current automation plays a minor role in the interaction between flightdeck, ATC or FOC, and must evolve to a more advanced form before it can be considered a collaborator.

Recommendations. This set of reviews suggests that improved collaboration can lead to a better distribution of the resources under NextGen if the full range of interactions between flightdeck, ATC and FOC is considered. It is recommended that these assessments take into consideration the element of time, especially the different requirements for collaboration during planning versus time critical or time sensitive operations. Current nominal operations have only limited collaboration between the flightdeck, ATC or FOC, while off-nominal events offer more opportunities for collaboration. Therefore, it is recommended that NextGen developers give substantial consideration to the effects of off-nominal conditions. Developers also need to keep in mind that there are currently a large number of possible communication and navigation system failures including FMC, GPS, VOR and related system failures. With NextGen requiring more new systems, greater precision along with automation, the possible interaction of multiple failures and recovery procedures could overwhelm the flightdeck.

3.0 Flightdeck-ATC-FOC Interaction Matrix

The previous section reviewed current collaborators' responsibilities and their respective interactions with other groups in the NAS. The flightdeck, ATC and FOC each have a somewhat different perspective based on their responsibilities, functions and procedures. The next step in this research was to integrate individual roles and responsibilities in the current NAS operations based on the nominal events of a generic flight. The goals were threefold, to: 1) Identify and describe current interactions that are potential candidates for NextGen collaboration, 2) Provide operational context for assessing collaborative procedures, and 3) Provide a basis for assessing collaborative scenarios and procedures.

3.1 Method

The generic phases of flights and their collaborations were initially built from an existing flight involving two large US airports that would allow for weather issues, daylight flight, and access to radio frequencies in both airports. The chosen flight was a flight departing from San Francisco airport (KSFO) and arriving at John F. Kennedy (KJFK) airport. Two track logs were taken from the website www.flightaware.com which provided the time, position, direction, groundspeed, altitude and the reporting ATC facilities. On top of track logs, KSFO, and KJFK airport charts were used for departure and arrival procedures information. The following types of VHF frequencies were monitored on www.liveatc.net: Clearance, Ground, Tower, TRACON, Departure, Center, Approach and Final Approach. The track log and the radio monitoring were used for the actual flight data and information exchanged between flightdecks and ATC. In addition to actual exchanges, controllers' instructions phraseologies were cross checked with the FAA JO 7110.65T, and flightdeck requirements were cross checked with FARs and FOMs.

The sequence of the interaction points were drawn from flightdeck, ATC and FOC documentation and data collections in sections 2.2 and 2.3. Flightdeck information came from documents, such as Federal Aviation Regulations 14 CFR Part 91, Part 121, S-8081-12B, the Aeronautical Information Manual, and a Flight Operation Manual, as well as from data, such as a cognitive task analysis (proprietary) and the pilot survey reported in section 2.3. Controllers' information came from documentation gathered in JO 7110.65T, SOPs, and LOAs, as well as from data collected for the task listing and process charts in section 2.3. Dispatcher information came from regulatory documents, such as 14 CFR Part 121, S-8081-10C, 8900.1, as well as data collected during observation logs and from the dispatcher survey described in Section 2.3.3.

It should be noted that in reality, the suggested sequence may vary. Both ATC and flightdecks may address sub-tasks in various orders with unknown parameters that cannot be represented in the depiction of a single generic flight.

3.2 Matrix components

In the matrix developed (see Appendix E), the interaction points were described according to 1) Phase of flight, 2) Media, 3) Collaborators, and 4) Interactions. Each component is described in the following sections.

3.2.1 Phases of flights

The phases of flight refer to specific operations during a full commercial flight. The chosen terminology comes from the phases of flights presented in the operational concept for mid-term NextGen (JPDO, 2009). The following phases were used in the matrix: Flight planning, Push back, Taxi-out, Takeoff, Cruise, Descent, Final approach, Landing and Taxi-in.

The flight planning phase has two sub-phases: before and after flight plan release. The first sub-phase starts with the dispatcher responsibility to build a flight plan for a scheduled flight and ends by the flight plan release. This sub-phase includes dispatcher's interactions with the Command Center and with the crew to address both strategic and tactical needs (Appendix E, Table E-1). The second sub-phase starts with the crew's responsibility to prepare their flight prior pushback. This preparation takes place in the flightdeck and involves interactions with ATC, FOC and the ramp personnel (Appendix E, Table E-2).

The pushback phase starts with the crew requesting permission to push the aircraft back from the gate to the taxiway. It ends with the crew being released from guidance on the taxiways. It is a short phase, but one that has implications for the coordination of surface operations and departure. During this phase, the flightdeck starts to operate according to the flight plan, and becomes an active user that ATC has to integrate in the flow of surface operations. The crew interacts with the gate agents, the ramp and/or the ground controller and may not contact the ground controller until they are ready to taxi. It depends whether ramp has authority to push back aircraft to the active surface of operations. When ramp has no responsibility to pushback aircraft, the ground controller will clear the crew to do so (Appendix E. Table E-3).

The taxi-out phase starts with the crew requesting permission to taxi to the runway. It ends with the crew taking position for takeoff on the runway. This phase can vary in duration. At the end of the phase, the local controller has provided the last amendment of the flight plan, if any, and clears the flightdeck to position on the runway for takeoff. The crew may have contact with the dispatcher if off-nominal events occur (Appendix E, Table E-4).

The takeoff phase starts with the clearance for takeoff and ends with the crew reaching cruising altitude. The flightdeck interacts with ATC from the Local Controller (Tower), the departure sector (TRACON), and high altitude sectors (En Route). The flight becomes airborne, climbs to reach cruising altitude and follow a vector or a route (Appendix E, Table E-5).

The cruise phase starts with the flightdeck contacting a controller in a high altitude sector. It ends with the last high altitude sector controller asking the crew to contact the lower altitude sector (En Route) which will initiate the descent (Appendix E, Tables E-6 and E-8). This phase has the least amount of interaction and coordination with ATC and the dispatcher but off-nominal events can trigger more activity (Appendix E, Table E-7 and E-9).

The descent phase starts with the last En Route Sector controller clearing the flightdeck to descend and contact approach controller (TRACON). It ends with the approach controller requesting the crew to contact the final approach sector. This phase has two sub-phases: initial descent, and approach. The initial descent sub-phase is controlled by the low En Route Sector. It starts by merging traffic, may sequence or even hold traffic (Appendix E, Table E-10).

The approach sub-phase is controlled by the Approach sector at TRACON. ATC descends and further merges traffic for final approach. The crew will communicate with ATC across sectors, and may contact the dispatcher in case of off-nominal events. The ATC across sector coordinate the merging of traffic, and sequence traffic if it is heavy. The final approach phase starts with the crew contacting the final approach sector, and ends with the tower controller clearing the crew for landing. This phase is short. The controllers clear the crew's approach and sequence traffic for landing (Appendix E, Table E-11 and E12).

The landing phase is also short. It starts with the Tower controller clearing the crew for landing, and ends with the tower controller requesting the crew to contact ground to clear them to their gate. The taxi-in phase starts with the crew contacting the ground controller, and ends with the crew shutting down the aircraft's engines, after the brakes are set at the gate. This phase is composed of two sub-phases: taxi-in and at the gate. The taxi-in sub-phase involves the surface movements until the crew reaches the gate. The gate sub-phase starts when the aircraft is immobilized. The generic flight stops when the crew reaches the gate sub-phase (Appendix E, Table E-13).

3.2.2 Media

This header refers to the medium that collaborators use to communicate or interact. Type of media that differed in terms of copresence, synchronicity, and type of information that could be conveyed. In Appendix E, Media is found in column 1 of all Tables. The media are described as follows:

Face-to-face. The interactions involved two collaborators who were co-present in the same environment, and had synchronous interactions. This media is rich in content. It allows people to use, voice, gesture and artifacts to communicate.

Radio. The interactions involved two collaborators who were not co-present, but had synchronous interactions. The communication was taking place on a VHF radio frequency. This is often referred to as air-ground communication. In all cases, the collaborators were ATC and flightdecks.

Phone. The interactions involved two collaborators who were not co-present, but had synchronous interactions. The communications were using, telephone, interphones, teleconferences (telcon), or Satellite phones (Satcom). These various phones were specified in the matrix. Most of the time, it involved ground to ground communication (communication between controllers), but it could also be air-ground communication in the case of Satcom (communication between flightdecks and dispatcher).

Paper. The interaction involved two collaborators who were not co-present and had asynchronous interactions. The communications were through the use of printed documents. The type of printed document was specified in the matrix.

Computer. The interaction involved two collaborators who were not co-present, and had asynchronous interactions. The communications involved using a computer to send or receive digital information, such as electronic messages to a recipient (email), or messages destined to a large audience (internet posts, advisories or NOTAMS). The Flight Management System in the flightdeck was also considered to be a computer.

ACARS. There were two types of interactions using ACARS: The interactions that involved two collaborators, and the interactions that were completely or partially automated. Both types of interactions were distant and data exchange was asynchronous. The interactions that involved two collaborators used ACARS to send messages and data. Those took place between flightdecks and ATC (clearance delivery) and FOC. The interactions that involved partial automation were when the dispatcher retrieved information from the aircraft via ACARS. The interactions that involved a complete automation were those that reported data from the aircraft computer to the FOC without any humans involved. Those automated interactions happened only in the case of the Out Off On In (OOOI) progress report. The OOOI reports are generated when aircraft reach certain points in the flight progress. Those points are Out of the gate, Wheels Off the ground, Wheels on the ground, and In the gate.

HOST, PVD and URET. HOST refers to the host system, an ATC En Route automation system used by all En Route Centers. The host system is used to file flight data and then to process flight data. Flight data is filed by airline companies who send flight plan in electronic format directly to the Host system via an Aeronautical Fixed Telecommunication Network (AFTN). The host system processes flight plans and distribute data to relative sectors where the flight is planned to fly into. The host system is also used by ATC to store and retrieve flight data.

PVD. PVD stands for Plan View Display. This tool is used by controllers to transfer datablock across sectors. HOST and PVD are part of the system baseline for all the En Route Centers. URET: URET stands for User Request Evaluation Tool. It is a tool to detect potential conflict in their airspace. URET shows controllers aircraft that are routed into their sector. URET allows controllers to check flight plans and amend them through an interface.

3.2.3 Collaborators

The Group and Position headers used in the matrix involve two entities, either human or computer, that interact together. The approach in this matrix was to describe an action by a “Subject” “Interacting with” another entity. The “Subject” refers to the entity that initiates an interaction with another entity. “Interacting with” refers to the entity the Subject is interacting with.

For each entity (“Subject” or “Interacting with”), a “Group” and a “Position” was defined. The Group could be either flightdeck (FD), ATC, FOC, or RAMP that includes the load planner as well as ground or pushback personnel. The group level shows the communication exchange between the separate organizations collaborating together to coordinate flights operations. RAMP was added to the generic flight because they are part of critical steps in the progress of the flight, and they could not be included with either ATC or FOC. "Position" in the matrix refers to the actual individual who is initiating an interaction with the other position. The positions are described below.

The flightdeck, or crew, had two positions that were named differently depending on the phases of flight. When the aircraft was on the ground, the two positions were “Captain” or “First Officer”. When the aircraft was airborne, the two positions were “Pilot Flying” or “Pilot Monitoring.” It should be noted that while airborne, the "Pilot Flying" can be either the "Captain" or "First Officer," and the same goes for the "Pilot Monitoring."

The ATC positions indicate the position of the controllers and the facility/sector where they operate. Facilities were distinguished between Air Traffic Control Tower, TRACON (Departure, Approach and Final Approach Sectors), En Route Center and Command Center. Sectors at En Route facilities were distinguished to help explain the interactions between sectors by specifying the first few and last few sectors (i.e., 1^{st} Center 1^{st} Sector, 1^{st} Center 2^{nd} Sector). Positions were also specified based on FAA Order JO 7110.65T. The following acronyms were used: CD for Clearance Delivery, GC for Ground Controller, LC for Local Controller, TMU for Traffic Management Unit, R for Radar Controller, RA for Radar Associate. The positions used in the matrix for the Air Traffic Control Tower were:

- Tower - CD
- Tower - GC
- Tower - LC
- Tower - TMU.

The positions used in the matrix for TRACON were:

- Departure - R
- Departure - RA
- Approach - R
- Approach - RA
- Approach - TMU
- Final Approach - R
- Final Approach - R.

The positions used in the matrix for En Route Control Centers were:

- 1st Center 1st Sector - R
- 1st Center 1st Sector - RA
- 1st Center 2nd Sector - R
- 1st Center 2nd Sector - RA
- 3rd to Last Center - R
- 3rd to Last Center - RA
- 2nd to Last Center - R
- 2nd to Last Center - RA
- Last Center 2nd to Last Sector - R
- Last Center 2nd to Last Sector - R
- Last Center Last Sector - R
- Last Center Last Sector - RA
- Last Center - TMU.

The position for Command Center was Traffic Management Unit (TMU). It should be noted that not all the positions may be filled the same way in between Towers and sectors, depending on traffic demand. When the traffic is low, a local controller can fill several positions in the Tower cab. A sector may be staffed with only one controller who handles both air-ground communications with flightdecks, and ground-ground communications with other sectors.

At the Flight Operation Centers, two types of dispatcher interact with other groups. ATC Coordinators are in contact with ATC facilities. Their mission is to coordinate the interests of the company with the ATC facilities. Flight Dispatchers are filing flights plans and monitoring flights.

Some of the ramp positions interact with the crew at the gates. There were few positions that were used in the matrix: Load planner, Pushback/ground personnel. The matrix reflects current interactions in the NAS. For this reason, when automation was involved in an interaction, it was allocated to a position, but assigned to a specific group (flightdeck, ATC, FOC) and not treated as a collaborator.

3.2.4 Interactions

The interactions indicate the content and purpose of the transition points in collaborations. Flightdeck and ATC terminology follow a Flight Operation Manual and the FAA Order JO 7110.65T. The following list of verbs were used to describe the different interactions between ATC, the flightdeck, FOC or RAMP: acknowledge, advise, amend, assign, call, check, clear, confirm, compute, downlink, establish, give, hand over, inform, initialize, issue, load, monitor, notify, obtain, print, read back, release, report, retrieve, request, review, run, send, state, update, uplink.

Controllers use standard phraseology to communicate with flightdecks. Those were collected, but could not be included in a generic version of a flight, because they include information that is context-specific for a particular flight. For instance, clearances are specific to a given aircraft at a certain position with specific intentions.

Some off-nominal events were incorporated in the matrix including rerouting, holding, and a missed approach because they are relatively frequent. However these events are off-nominal because they are unexpected based on the flight plan and they often indicate additional forms of interaction.

3.3 Matrix of current collaboration

A little over 300 entries were logged in the matrix in Appendix E. Those were transfers of information or data between people and/or computers. The entries were sequential based on the order tasks are normally completed under each phase of flight. In actual operations, the task order can change. For example, the flightdeck can receive information about the aircraft final weight via at the gate, after brake release or while taxiing out.

The interactions in the generic flight show how information is transferred between the three key groups in the NAS: Flightdeck, ATC and FOC. Many interaction points involve the flightdeck and ATC. There is a close interdependence between these two collaborators since the flightdeck requires ATC clearances as they progress through the flight. In the matrix, clearances started from the pre-departure clearance up to cruising altitude, and then near the end of the flight, from the start of descent until the taxiway clearance to reach the gate. To coordinate clearances and control instructions, flightdecks and ATC most often used the radio frequency to communicate. In contrast, flight data was most often transmitted digitally between controllers, or between the FOC and flightdeck, or FOC and ATC.

Clearances and control instructions are standardized, procedural interactions where just one of the participants has ultimate responsibility. This is particularly true between flightdecks and ATC where requests, clearances or transfer of information follow procedures with standard outcomes. Flightdecks need to have their operations cleared to proceed and controllers need to make sure the operations are undertaken safely and efficiently. There is little room for negotiations, but ATC does try to adapt to flightdecks' request to the extent possible (e.g. change of runway, change of approach). Flightdecks also can disagree with the controllers' requests.

Some procedural interactions could be collaborative if they included a cooperative exchange information and a common solution. For example, the FAA has implemented Collaborative Decision Making (CDM) that involves a cooperative effort between ATC and FOC to exchange information and data to make better decisions. In the concept of Integrated Collaborative Rerouting (ICR), stakeholders who are facing constraints are allowed to share Early Intents (EI) to communicate their decisions. Traffic managers then either assess if the decisions is enough to mitigate the constraints. CDM supports exchange of information, and ICR takes into account customers' intentions. In both initiatives, interactions are more collaborative, but responsibilities are not shared and the decision is ultimately made by Traffic Management.

Exchange of information and taking into account customers needs is in line with the NextGen Implementation Plan 2011: "We are laying the groundwork for the communications and information-sharing networks that will enable the FAA to collaborate with its stakeholders to align their preferences with the overall needs of the system." (page 8). Benefits should include reduction of fuel use and delays, as well as improving shared situation awareness, "Collaborative decision making will increase everyone's understanding of what others are doing." (page 20). "If a NextGen perspective of shared responsibilities were also taken into account, NAS collaboration could be defined as:

> *"A joint effort between groups to reach a common solution based on shared information, consideration for each other's needs and shared responsibilities."*

The above definition was applied to the interactions in the matrix with the goal of identifying those closest to the notion of collaboration envisioned by the FAA for the future operations regardless of whether they took place within and between groups. Table 3.1 lists those more collaborative interactions found in the generic flight nominal events. Several off-nominal interactions are also listed for Cruise and Final Approach based on some of the more frequent off-nominal events that show some conditional forms of interaction.

Table 3.1: Current Possible Collaborative Interactions

Media	Groups	Area of Interaction
	Flight Planning	
Telcon	FOC & ATC	Traffic routes & delays
Telephone	Flightdeck & FOC	Flight plan modifications
	Pilots in the flightdeck	
Radio	Flightdeck & ATC	EDCT modification (when applicable)
	Taxi-out	
Radio	Flightdeck & ATC	De-icing (off-nominal)
Face-to-Face	GC & LC (ATC)	Runway crossing
	Cruise	
Telephone	R/RA & R/RA (ATC)	Control instructions before flight enters in a new sector (when applicable)
Radio	Flightdeck & ATC	Fly direct to fix point (when applicable)
Radio	Flightdeck & ATC	Other deviations to Flight plans (when applicable)
Satcom / ACARS	Flightdeck & FOC	Rerouting flight
Off-Nominal: CC decision to reroute traffic due to weather		
Relephone	TMU at CC & En route & APP & LC (ATC)	Diversion of traffic due to RWY closure
Telcon	FOC & ATC	Strategy for rerouting flights
Satcom / ACARS	Flightdeck & FOC	Rerouting flight
Off-Nominal: Holding		
Telephone	APP & En route (ATC)	Holding flights
Satcom / ACARS	FOC & Flightdeck	Minimum fuel and alternate destination (if applicable)
Radio	Flightdeck & ATC	Alternate destination
Telephone	FOC & ATC	Alternate destination (optional)
	Descent	
Radio	Flightdeck & ATC	Alternative approach (if applicable)
	Final Approach	
Off-Nominal: Missed approach		
Telephone	LC & DEP (ATC)	Coordinate go around (altitude, heading, speed)
Telephone	DEP & APP (ATC)	Merging 'go-around' flight back into the approach flow

There are at least three areas where current interactions tend to be more collaborative. First, FOC and flightdeck, who work for the same airline and have similar needs and objectives, tend to use a more collaborative approach in reaching a solution. Second, FOC and ATC can have a collaborative approach when the issues are at a higher level, such as when the FOC interacts with CC for traffic routes and delays. Third, off-nominal events also can produce more collaborative exchanges due in part to less standardized procedures. The least collaborative interactions appear to be between ATC and the flightdeck where most are under ATC's control. There are a few exceptions where ATC may coordinate with a flightdeck on a later departure time, on a decision to deice an aircraft prior departure or on a deviation from a flight plan.

Within group coordination seem to allow more collaborative processes, such as within ATC. For example, in Table 3.1, Ground Controller and Local Controllers collaborate on runway crossings by adjusting to each others' needs. NextGen plans to introduce more collaborative interactions between ATC, the flightdeck and FOC. Information and responsibilities would be shared and each group's needs would be taken into account to arrive at a common solution.

3.4 Summary of Current Interactions

Section 3 has reported on the development of a matrix that illustrates the interactions between the flightdeck, ATC and FOC during a generic flight. The result confirmed that there is currently only limited between group collaboration. This is mainly because the most frequent interactions, such as those involving clearances and control instructions, are procedural interactions with one of the participants having dominant responsibility. This is particularly apparent between flightdecks and ATC where requests, clearances or transfer of information follow procedures with standard outcomes with little room for negotiations. The matrix can be used to identify the different interactions between the flightdeck, ATC or FOC for all phases from flight planning to taxi-in.

Some current interactions could be more collaborative if they included shared information with the objective of reaching common solutions. As discussed in Section 3.3, although CDM supports a collaborative exchange of information, responsibilities are not shared and the decision is ultimately made by ATC. This suggests the need for a new generation of collaboration based on shared information, a consideration for each other's needs, a joint effort to reach a common solution as well as shared responsibilities. The requirements were used to propose a definition of collaboration that was used to identify areas where current interactions tend to be more collaborative. One area for possible collaboration includes flightdeck interactions with FOC where the two groups have similar needs and objectives leading to a more collaborative approach in reaching a solution. A second area includes the interactions between FOC and ATC when the issues are at a higher level, such as when the FOC interacts with CC for traffic routes and delays. An important third area includes interactions during off-nominal events that can produce more collaborative exchanges due in part to less standardized procedures. The least collaborative interactions appear to be between ATC and the flightdeck where most are under ATC's control. There are a few exceptions where ATC may coordinate with a flightdeck on a later departure time, on a decision to deice an aircraft prior departure or on a deviation from a flight plan.

Recommendations. The matrix of current interactions indicates more within group collaboration, such as within ATC, but between group collaboration should provide greater benefits to the NAS when information and responsibilities are shared with each group's needs taken into account to arrive at a common solution. The matrix suggests that collaboration during preflight is more manageable on the flightdeck than collaboration during flight, especially during higher workload phases of flight. It is recommended that preflight, and more generally the planning timeline, be considered as a viable time for collaboration, especially for collaboration involving the flightdeck.

Based on the analysis of flightdeck, ATC and FOC interactions, future collaboration should include information sharing, responsibility sharing, a shared a consideration for each collaborator's needs leading to a common solution. When ConOps developers assess a collaborative procedure, it is recommended that they consider the quality of those four characteristics. Collaboration is most likely to increase in spacing and merging, separation management, departure and arrival management and trajectory management. It is recommended that collaboration build on the current procedures such as those between ATC and FOC, the flightdeck and FOC as well as between the flightdeck and ATC where limited collaboration has already been introduced. Finally, it is recommended that special consideration be given to the assessment of collaboration under off-nominal conditions where time criticality and workload issues take on a greater significance.

4.0 Transition to NextGen Collaboration

This section identified possible changes in collaboration brought on by NextGen procedures and systems and is based on a literature review of journals, reports and conference publications of research studies and reviews of future collaboration between the flightdeck, ATC, FOC and automation under NextGen. Because NextGen research covers a very large area, the review has focused on possible changes in collaboration under Trajectory Based Operations (TBO). The state-of-the-practice review in Section 2 and the matrix described in Section 3 and included in Appendix E, report on high level current areas of collaboration while this section explores future NextGen points of collaboration.

More than 500 references from the past 20 years were reviewed (see Bibliography in Appendix F) with about 100 selected for more detailed analysis. Key TBO references were selected as the core for this review (see Table 4.1). The chief criteria for this core selection was that they reported on recent flightdeck, controller and/or dispatcher collaboration research and that the research was primarily NASA or FAA sponsored. Further, priority was given to research that examined human performance more than the development of algorithms or systems models.

Much of the NextGen research prior to 2000 concentrated on specific parts of the system with the objective of increasing capacity while keeping the controllers workload at acceptable levels. More recent NextGen research suggests a shift from a controller centric view to a more distributed approach to align the objectives and situation awareness of the controllers with those of the dispatchers and flightdecks. It also attempts to more closely unify the results of flight planning with those of flight execution through the use of Trajectory Based Operations (TBO). Finally, the business model, greater fuel efficiency, sustainability, and increased safety have augmented the initial goal of greater capacity. In essence, the research has moved from better resource management of individuals, competing groups to improved resource management of the entire system (Smith & Billings, 2009).

This section presents general NextGen considerations and then provides an example based on TBO issues related to flightdeck with ATC and FOC collaboration. Operational relevance was a guiding principle of this review based in part on Piccione and Sawyer (2009) pointing out the lack of coordination between the research and operational community. They note that human factors researchers tend to identify root system causes or the need for additional research with neither of these results directly benefitting the operational community. The authors call for a better partnership between these two communities, especially during the transition from research to implementation. For this reason, the state-of-the-practice review in Section 2 was conducted to gain operational relevance. Consideration was also given to the gradual shift in NextGen from a concerted effort to increase capacity up to three times air traffic levels in the early 2000's to a balanced approach that also deals with economic, environmental and social impacts. Penhallegon and Bone (2008) indicate that the noise and environmental issues are of concern along with fuel costs which have seen record highs in the last few years. This presentation of the transition to NextGen incorporates the more current issues and concerns related to collaboration between the flightdeck, ATC, FOC and automation.

4.1 General NextGen considerations

NextGen offers a large complex of issues, even when focusing on TBO concepts or procedures. Selecting too fine a level of detail results in so many considerations it is difficult to identify the most important ones. For example, Funk (2009) proposed the identification of prospective NextGen human factors issues in the context of specific task and subtask sequences. He demonstrated the analysis of a TBO subtask, Get Traffic Information, using HSI/CDTI methodology. That approach identified more than 200 potential human failure modes from the

Get Traffic Information subtasks including operator delays, lapses, misses and slips. Although helpful in identifying possible human factors issues, this detailed analysis produces a very large set of problems making it difficult to determine where one should focus an evaluation or attempt to find solutions. Working with a more general review of NextGen considerations can help to provide a perspective that can be used to then focus on an assessment of collaborations in the context of TBO procedures. With that perspective in mind, this section introduces five key elements that will be the basis for a collaboration assessment framework:

- Collaborators
- Collaborator Responsibilities
- Functions and Procedures
- Human Factors Considerations
- Required Technologies.

4.1.1 Collaborators

The collaborators for this assessment framework are the flightdeck, ATC, FOC and automation in all possible combinations. Procedures between flightdeck, ATC, FOC and automation will change under NextGen. In the current ATC environment, the flightdeck establishes and maintains communication with the appropriate controller entities adhering to ATC clearances and instructions. The less proceduralized and more collaborative interactions between the flightdeck and ATC are more likely to occur under off-nominal situations when the flightdeck has immediate responsibility for the safety of the aircraft. There are also areas of possible collaboration between the flightdeck and FOC. The most visible form of current collaboration is that taking place under CDM between ATC and FOC, mentioned in Section 2 and 3, with the goal to improve traffic management by improving information exchange, procedures, and tools for shared situation awareness and decision making. However, the current operational environment has only limited collaboration between the flightdeck and ATC or FOC. Most interactions involve acknowledging, contacting, obtaining or requesting information with little indication of negotiations or collaboration.

Advanced automation will have a substantial effect of collaboration under NextGen. The User Request Evaluation Tool (URET) represents an early step in the transition from current limited automation to NextGen advanced automation. The URET is used by En Route Sector teams for performing strategic planning. It uses a range of data including that from flight plans, and aircraft performance track data to calculate expected trajectories so that it can predict conflicts between aircraft. The automation uses aircraft calculated trajectories to constantly check for conflicts. When a conflict is detected, the URET performs several additional calculations including time until the conflict and its probability. The system will notify within 10 to 20 minutes of the conflict. When the probability of the conflict is low and there is sufficient time prior to the conflict, URET postpones controller notification. It is not fully implemented in En Route, but it offers those centers with URET improved notification compared to the three minute alert from the older conflict alert system. For each conflict, URET classifies and displays the resulting minimum separation. This informs controllers if the conflict is predicted inside our outside the five nautical mile horizontal separation requirement.

Advanced automation will require some key technologies before it can be fully implemented. In its NextGen Implementation Plan, the Federal Aviation Administration (2010a) indicates that the NextGen foundational technologies and infrastructure will include Automatic Dependent Surveillance - Broadcast (ADS-B), Data Communications (Data Comm), NextGen Network Enabled Weather (NNEW), NAS Voice Switch (NVS) and System Wide Information Management (SWIM). These five systems will be required for the integrated automation, communication, navigation and surveillance to support the information flows that will allow better coordination resulting in improved use of airspace capacity. These five technologies, along with organizational and responsibility changes, will allow NextGen to transition from current limited automation to advanced automation.

Advanced automation will be an essential part of collaboration that should be assessed as the fourth collaborator under NextGen. Automation as a fourth collaborator will have a significant effect on responsibilities given that collaborative systems are being proposed wherein automation will assume some of the responsibilities described in Section 2 currently held by the flightdeck, ATC or FOC. Automation will also have a profound effect on human factors, especially on situation awareness and on workload. With automation playing an increasing role under NextGen, consideration will have to be given to the level of function being automated as well as the level of automation. Dwyer and Landry (2009) present different levels of automation without fully considering the role of the function being automated. They concluded that the greater the level of automation, the greater the possibility for a reduction in situation awareness. In assessing the effects of advanced automation on collaboration one should both consider the traditional levels of automation as well as the role and significance of the function being automated. These two elements must be considered jointly to understand their effects on the collaboration between flightdeck, ATC and FOC. A further consideration when promoting automation to the level of a collaborator is how the automation is implemented. Some of the researchers, in proposing the automation of certain functions currently the responsibility of the flightdeck or ATC, have suggested that new automation can be first introduced as a decision aid or tool, and when confidence and trust is developed, the aid or tool can then be assigned actual responsibility (Erzberger, Lauderdale & Chu, 2010). This evolutionary approach should be considered whenever implementing automation at the level of a collaborator.

4.1.2 Collaborator responsibilities

NextGen is expected to allocate more optimally the functions between the flightdeck, ATC and FOC in an environment with far greater information sharing (Sipe & Moore, 2009; Smith & Billings, 2009; Wing, 2005). Currently there are a few initiatives that rely on a more distributed environment. For instance, in the CDM framework, airspace users, such as the FOC, have more responsibilities. Collaborative Air Traffic Management (CATM), discussed in Section 2, is another NextGen initiative drawing on CDM where responsibilities are less centralized and more distributed. The key for CATM's success would depend largely on the ability of future ATC and FOC to collaborate effectively through distributed responsibilities where actions are interdependent and decisions are coordinated (Vossen, Hoffman & Mukherjee, 2009). Distributed responsibilities have been successful at the strategic level, for instance, between Traffic managers, and with airline dispatchers. With NextGen, responsibilities may become more distributed between collaborators during flight operations.

Considering NextGen operational improvements, Krois, Herschler, Hewitt, McCloy and Piccione (2010) point out that NextGen aims to address issues, such as the “Allocation of roles to human operators and automation support through design of displays, controls, and procedures for effective and efficient human interaction with automation” as well as “Changing controller roles from vectoring to monitoring as responsibility is delegated to pilots.” (page 6). In that regard, questions remain open as to which current technology can be leveraged by more complex operational procedures, what human-automation relationships with what roles and responsibilities should be considered in the flightdeck in NextGen operations.

<u>Distribution of responsibilities</u>. The distribution of responsibilities between ATC and flightdeck is central to NextGen requiring new technology as well as automation (JPDO, 2009). Currently, most interactions between the two pertain to separation of traffic, and accounts for much of the workload for controllers. To help the research industry, the FAA and EUROCONTROL have

produced a guideline on four levels of Airborne Separation Assurance (ASAS) in 2001 (FAA/EUROCONTROL, 2001). The four levels of increasing delegation of separation to flightdecks are: Airborne Traffic Situation Awareness, Airborne Spacing, Airborne Separation, and Airborne Self-Separation. The concept of separation and the changes of responsibilities are as follows:

- Airborne Traffic Situation Awareness: Enhancements in fight crew knowledge of surrounding surface and airborne traffic (no change of responsibilities with more information about surrounding traffic may be provided by CDTI)
- Airborne Spacing: Flight crews ensure an assigned spacing value from a designated aircraft (responsibility to achieve and maintain spacing. Separation remains under the controller's responsibility with the controller need to know which aircraft is equipped)
- Airborne Separation: Flight crews ensure separation from a designated aircraft, which relieves the controller from the responsibility for separation between these aircraft
  (controllers may delegate depending on the aircrafts' equipage)
- Airborne Self-Separation: Flight crews ensure separation of their aircraft from all surrounding traffic (controllers may delegate depending on the aircrafts' equipage).

Currently, the top-down hierarchical line from the Command Center down to the Air Traffic control facilities allows for clear decisions and distribution of information, when, how and to where it goes. If the responsibility for separation were to be delegated to the flightdeck, changes of plans would be made by the flightdeck, and there could be a potential risk of loss of situation awareness on the controller side. The same loss of situation awareness may arise if airspace sectors would become flexible. Any loss of situation awareness may require a limited responsibility to accommodate the increase of workload. Other issues may arise when both controller and flightdecks would have both similar information but are not identical (Willems & Koros, 2001). With a wider degree of shared information, it is critical to specify who is responsible for which functions.

Idris, Wing, Vivona and Garcia-Chico (2007) argued that distributed control would reduce workload, since flightdecks would be responsible for maintaining separation and would be supported by advanced sensors, communication and decision support tools. In their opinion, more traffic would mean more flightdecks responsible to make decisions and would not necessarily increase workload for controllers. Also since flightdecks would be assisted with conflict detection and resolution, it should maintain their level of workload to an acceptable level. Maintaining an acceptable level of situation awareness and workload seems dependent on shared information, through new technologies, and delegated responsibilities, in part due to the support of automation.

<u>Self-separation responsibility</u>. Self-separation is the full delegation of separation responsibility to the flightdeck and has also been referred to as free flight. Sharples et al. (2007) evaluated changes in collaboration and communication with the introduction of free flight and datalink. With free flight, responsibilities to determine the flight path would be transferred from ATC to the flightdeck. Controllers' roles would change from direct manipulation (control) to passive monitoring. Controllers would act as system managers, monitoring traffic and intervening only when a potential conflict needs to be resolved. At the same time, flightdecks would largely control the planning and the execution of their flight. The main concern with such change is that situation awareness for traffic activity would no longer be in one person's hand. This could lead to a higher risk of controllers intervening without an accurate representation of the situation.

Metzger and Parasuraman (2001) compared passive air traffic control with active control. They found that passive control in high density traffic led to worse controller conflict detection when compared to active control. When controllers are passive they take longer to detect conflicts and their situation awareness seems less accurate. The authors argued that controllers should have more responsibilities. Though, both passive and active controllers took longer to detect conflict in a high traffic density.

Delegated separation responsibility. Delegated separation responsibility to the flightdeck has been addressed in studies that evaluate the impact of automated support decision tools for conflict detection and resolutions (Ho, Martin, Bellisimo & Berson, 2009; Wing et al., 2010). In Ho et al. (2009), scenarios describe either the airside or the groundside automation as generating solutions for either the flightdeck or the controller, and responsibilities falling either on the flightdeck or the controller side. In many studies, automated decision tools help controllers delegate separation to the flightdeck while keeping the responsibility to solve conflicts (Dao et al., 2009; Prevot, Homola, Mercer, Mainini & Cabrall, 2009). Some tools are designed to assist the flightdecks in solving conflicts (Wing et al., 2010), while others assist the flightdeck to maintain spacing intervals (Bone & Marksteiner, 2007). In advanced concepts, such as Prevot et al. (2008, 2009) or Wing et al. (2010), ground automation monitors trajectories, detects conflicts, and sends new trajectories to flightdecks. There, workload was significantly reduced with clear benefits for the controllers who were able to manage two to three times the amount of current traffic. In Kopardekar, Prevot and Jastrzebski (2008), automation assisted controllers in conflict detection and in offering solutions. There, density of traffic increased controllers' workload. In a follow-up study, Kopardekar et al. (2009) showed that controllers tended to favor equipped aircrafts, as opposed to unequipped aircrafts, in dense airspace suggesting a link between density, complexity and workload.

Maintaining current responsibilities. Other studies consider the least change of responsibilities, but with the inclusion of new technology to increase shared information (Bone & Penhallegon, 2007; Moertl, Beaton, Lee, Battiste & Smith, 2007; Sorensen, 2000). For instance, in Merging and Spacing operations, the use of CDTI allows flightdecks to maintain spacing during their approach, while the responsibility to monitor separation remains with the controllers (Zingale & Willems, 2009; Bone & Penhallegon, 2007; Prevot et al., 2007). Borgman et al. (2010) tested Integrated Arrival/Departure Control (AI/DC) coupled with the Dynamic Departure Routings (DDR) and the Integrated Surface Management (ISM) procedures to help controllers manage the flow of surface, arrival and departure operations. They argued that maintaining the current definition of roles and responsibilities allow experts to keep appropriate authority to complete their tasks, and that distributed authority in decision making may create more complex decisions processes.

Ligda et al. (2010) studied the effects of varying the allocation of responsibilities. They manipulated the allocation of the primary responsibility for conflict avoidance to the flightdeck, ATC or automation. The entity with primary responsibility was accountable for 75 percent of the potential conflicts. When the effects of workload on the flightdeck were assessed, it was the lowest when the flightdeck had the primary responsibility for conflict avoidance. The hypothesis that increasing pilot responsibility for separation avoidance would increase workload was not supported. The researchers suggest that in this case, workload is affected less by the amount of responsibility and more by to the degree of situation awareness that can be gained under conditions of greater responsibility. Similarly, in a simulation study, Ruigrok and Valenti Calri (2002) also found that there was less of an increase in flightdeck workload when pilots had more time to plan ahead.

In summary, more distributed responsibilities between flightdecks and ATC under NextGen may only be possible with technology that will allow for better shared situation awareness, and possibly with the support of automated tools, which could reduce the workload of the controllers. The risk with automated tools is that awareness may be lost and thus responsibilities may be compromised.

4.1.3 Functions and procedures

The third element in the assessment framework is made up of the functions and the procedures under those functions that involve collaboration. The primary functions that will likely see an increase of collaboration under NextGen include traffic flow, spacing, separation, merging and trajectory management. The current function allocation is due in part to the lack of shared information as well as the limitation of voice communication between the flightdeck, ATC and FOC (Sipe & Moore, 2009). NextGen will provide improved digital data communication across these groups expanding the possibilities for collaboration. Sipe and Moore (2009) provide an example of how post departure rerouting may evolve under NextGen due to improved digital data communications. Under current operations, the flightdeck has limited rerouting possibilities working mostly with ATC. Under NextGen, FOC, with improved traffic and weather data, can address the longer term rerouting issues to ensure efficient operations. The sharing of common digital information allows FOC to receive changes in the weather forecast, evaluate the impact on existing flights, replan and communicate that with the flightdeck and ATC much earlier in the flight allowing for more efficient routing (Sipe & Moore, 2009). NextGen researchers and developers have been considering a number of changes in function allocation that are better understood in the context of explicit collaborative procedures.

Function allocation. When assessing the effects of different types of collaboration on air traffic functions, it is essential to consider function allocation between the various collaborators and automation. Under NextGen, it is assumed that ATC will transition from the near-term control of individual aircraft to the management of longer term flow and separation across multiple aircraft. Responsibility for near-term separation, less than three minutes to Loss of Separation (LOS), will be assigned to the flightdeck and possibly ground-based automation (Ho et al., 2009). A closer examination of NextGen separation management demonstrates the range of collaborative options and resulting complexity. Concentrating on 12 to 15 minutes to LOS, Ho et al. (2009) examined three concepts, each differing in its allocation of responsibilities based on different uses of automation and aircraft equipage. To further simplify these three concepts, the researchers assumed that one set of aircraft are equipped to operate under trajectory rules, referred to here as equipped, and a second set of aircraft are non-equipped. The three concepts were: 1) Shared Separation Assurance between ATC and Flightdeck, 2) Separation Assurance by ATC with Delegation to Ground Automation, and 3) Separation Assurance by Ground Automation.

The first concept has the responsibility for separation shared between ATC and the flightdeck where ATC is responsible for the separation between non-equipped and other non-equipped aircraft and the flightdeck is responsible for all other conditions. Under this shared separation concepts, the flightdeck automation would detect conflicts and assign responsibility. If the flightdeck is responsible for the conflict resolution, they can use automation or a route assessment tool (RAT) to generate and then review the resolution. On the ATC side, ground automation would detect the non-equipped to non-equipped aircraft conflicts and ATC could automatically or manually generate resolutions and send them to the flightdeck.

A second concept for separation assigns ATC primary responsibility providing them with the capability to delegate separation responsibility between equipped aircraft to automation (Ho et al., 2009). Under this concept, ATC is responsible for separation with the ability to delegate separation responsibility between equipped and equipped aircraft to ground-based automation. Although this option has the potential to reduce ATC workload, it can increase workload if for some reason (e.g., the need for weather avoidance) the equipped flightdeck rejects the conflict resolution. In such a case, the flightdeck would use a tool such as the RAT to generate a more acceptable resolution and would send it back to ground automation to determine if it is conflict free. If the resolution proposed by the flightdeck is not conflict free, then ATC, with or without automation, needs to propose an additional resolution.

The third separation concept assigns responsibility to ground automation. Under this concept, the ground autoresolver is responsible for resolving conflicts between equipped and other equipped aircraft as well as between equipped and non-equipped aircraft. ATC would be responsible for only resolving conflicts between non-equipped and other non-equipped aircraft. The purpose of outlining these three different function allocations is to show problems in identifying the full range of human factors considerations when concepts are proposed at a relatively abstract or simplified functional level. In example from Ho et al. (2009), they made a number of simplified assumptions about separation and its required technology across three possible concepts. In one case long term separation responsibility was shared between ATC and flightdeck, in a second it was shared between ATC and automation, and the third case it was assigned primarily to automation. If specific technologies and more detailed procedures were specified, substantially more human factors considerations could have been identified. These three concepts suggest the need to assess NextGen collaboration in greater detail that is generally provided by proposed collaborative procedures.

Procedures. Smith and Billings (2009) provided a useful perspective to frame the broad issue of collaborative procedures within NextGen. They presented CATM, referred to earlier in this section, as a critical part of NextGen that includes both flow programs as well as collaboration on procedures to shift increasing demand to alternate resources. McCoy, Smith, Billings, Chapman, and Obradovich (2001) were one of the few research groups that used the term under review, collaborative procedures. In their discussion of collaborative air traffic management, they discussed collaborative procedures as well as collaborative processes. A closer examination of how they used these two terms helped arrive at a more precise understanding of collaborative procedure. The intent of their collaborative process was to provide ATC and FOC with a means to work collaboratively in developing plans for dealing with predicted constraints in the NAS (McCoy et al., 2001). Their collaborative process was based on a set of approved alternative departure routes called Coded Departure Routes (CDRs). It was designed to provide control towers with greater flexibility when responding to changing conditions and to include FOCs at specific control centers and airports. Based on limited collaboration between ATC and FOC, two or three CDRs would be identified and communicated to FOC. The dispatchers would include that information in the flight planning process and the final decision is made, generally by the controlling tower, about which route to use.

To gain a clearer understanding of collaborative procedures, a range of NextGen procedures were reviewed that contained some level of collaboration between flightdeck, ATC and FOC with or without automation. Of the over 100 NextGen concepts or procedures analyzed, those listed in Table 4.1 seemed the most likely to be or have an aspect of a collaborative procedure.

Table 4.1: Listing of Possible NextGen Collaborative Procedures

Reference	Possible Collaborative Procedure
Ball (2008)	CDM resource allocation procedures
Becher et al. (2010)	3D Path Arrival Management
Becher et al. (2010)	Dynamic Airborne Reroute Procedures
Becher et al. (2010)	Terminal Area Required Time of Arrival
Borgman et al. (2010)	Dynamic Departure Routing
Borgman et al. (2010)	Integrated Arrival/Departure Air Traffic Control Service
Borgman et al. (2010)	Integrated Surface Management (ISM)
Cabrall et al. (2010)	De-Conflicting Air Planes procedure
Callantine et al. (2006)	Continuous Descent Arrivals
Cheng et al. (2008)	Flight-Deck Automation for Reliable Ground Operation
Cheng et al. (2008)	Ground-Operation Situation Awareness and Flow Efficiency
Colageo & DiFrancesco (2008)	In-Trail Procedure
Consiglio et al. (2008)	TCAS II procedure
Coppenbarger et al. (2009)	Oceanic Tailored Arrivals
Dao et al. (2009)	Route Assessment Tool
Doble et al. (2009)	Departure Flow Management (DFM)
Erzberger & Heere (2008)	Tactical Separation Assured Flight Environment
Erzberger & Heere (2008)	Automated Airspace Concept (AAC)
Foyle et al. (2009)	Surface Traffic Management (STM)
Foyle et al. (2009)	Tailored Departures (TD)
Hilburn (2007)	RA Downlink (RAD) operational concepts
Ho et al. (2009)	TBO Function Allocation Concepts
Idris et al. (2007)	Distributed Trajectory-Oriented Approach
Jackson et al. (2005)	Autonomous Operations Planner (AOP)
Kopardekar et al (2009)	Mixed Equipage Operations in the Same Airspace
Lester & Hansman (2007)	Oceanic In-Trail Follow (ITF)
Lester & Hansman (2007)	Self-Separation in Organized Track System (SSEP-FFT)
Ligda et al. (2010)	Conflict Avoidance Responsibility Allocation
McAnulty & Zingale (2005)	Approach Spacing for Instrument Approaches (ASIA)
McAnulty & Zingale (2005)	CDTI Assisted Visual Separation (CAVS)
McAnulty & Zingale (2005)	Enhanced Visual Approach (EVApp)
McAnulty & Zingale (2005)	Independent Closely Spaced Parallel Approaches
McAnulty & Zingale (2005)	Sequencing and Merging (S&M)
McAnulty & Zingale (2005)	Visual Separation on Approach (VSA)
Moertl et al. (2007)	Airline Based En route Sequencing and Spacing
Mohleji & Wang (2010)	Airborne Spacing- Flightdeck Interval Management (ASPA-FIM)
Penhallegon & Bone (2007)	Flight Deck-based Merging and Spacing (FDMS)
Prevot et al. (2005)	Co-Operative Air Traffic Management (CO-ATM)
Prevot et al. (2005)	Distributed Air-Ground Traffic Management (DAG-TM)
Prevot et al. (2007)	Trajectory-Oriented Operations with Limited Delegation
Prevot et al. (2008)	Ground-Based Automated Separation Assurance
Sheth et al. (2010)	equitable Credit-based User Preference System
Smith (2005)	Coded Departure Routes (CDRs)
Smith & Billings (2009)	Collaborative Air Traffic Management (CATM)
Sorensen (2000)	DAG-TM CE 11, Self Spacing for Merging and In-trail Separation
Spencer et al. (2007)	Traffic Management Initiative (TMI) procedures
Verma et al. (2008)	Terminal Area Capacity Enhancing Concept (TACEC)
Vossen et al. (2009)	Performance-Based Services
Willems & Koros (2007)	High Altitude Airspace RVSM and User-Preferred Routes
Wing et al. (2009)	Tactical Intent-based Conflict Resolution (TICR)
Wing et al. (2010)	Ground-based automated separation assurance + Airborne trajectory management with self-separation
Wolfe et al. (2009)	Collaborative Air Traffic Flow Management CATFM
Zingale & Willems (2009)	Merging and Spacing (M&S)
Zingale & Willems (2009)	Trajectory-Oriented Operations with Limited Delegation
Zingale et al. (2008)	Big Airspace (BA) concept

The range of specificity of these possible procedures mirrors the findings of the overall review that showed the term procedure used in the NextGen literature to include many different types of processes from those described in very general terms to those highly specified. An example of the more general use of the term was presented by Ball (2008) as CDM resource allocation procedures. These procedures more closely resembled a set of collaborative principles. An initial concept under CDM was that operators would provide ATC updated flight information. This could penalize those operators providing the most accurate and up to date information and could discourage FOCs from providing ATC with the updated information. The CDM resource allocation procedures were improved through a set of gaming principles based on the concept of allocation based on an inter-airline trading process. At the other end of the spectrum, a frequently mentioned part of NextGen, Area Navigation (RNAV) procedures, are route specifications for individual terminal areas. RNAV procedures provide routes that conform to local air traffic flow management needs and allows ATC to issue terminal route clearances reducing the need for vectoring. This in turn can reduce the need for flightdeck with ATC communication. Their greater precision and increased efficiency make the general concept relevant to NextGen, but the individual RNAV routes for specific airports, though considered NextGen procedures sometime are at too fine a level of detail for consideration in this research on NextGen collaborative procedures.

There are at least three areas where NextGen could substantially improve collaborative procedures. The first of those areas would be during the planning phase between FOC and ATC. FOC requires a lot of information prior to the release of a flight plan including information on the weather, runways configurations, current or possible delays, aircraft performance capacity, the payload as well as any other information that may affect performance or delay the flights. These information requirements could be met through a shared information system between ATC and FOC leading to improved shared situation awareness and flight planning collaboration. The second area is between the flightdeck, ATC and FOC especially during off-nominal events. Off-nominal events can be rare to fairly frequent, but critical. Those can be related to passenger threat, medical emergency, mechanical emergency, diversion, significant rerouting, missed approach, or prolonged holding. Currently, flightdecks notify ATC and FOC of the situation but there could be between collaboration between all three collaborators regarding alternative routings, deviations, and assess delays. The third area for substantial improvement is the collaboration of flightdeck, ATC and FOC with automation.

Some researchers use the term procedure to describe a very narrow procedure, such as RNAV routes. The current research takes the middle ground using the term, collaborative procedure, to specify NextGen concepts, processes or procedures that apply to a range of situations and conditions involving the interaction between organizations such as the flightdeck, ATC and FOC. For this study, collaborative procedures are those concepts or processes that have been defined at a sufficient level of detail so that they can be distinguished from other processes or procedures.

4.1.4 Human factors considerations

The fourth element in the assessment of collaborative systems is made up of human factors considerations. A set of human factors issues were identified, based on NextGen considerations specific to the proposed collaborative procedures. First, general human factors considerations were identified with respect to collaborator situation awareness and workload concerns, and with respect to specific collaborative procedures. They were then analyzed for related considerations taking into account their required technology. Thus, human factors considerations were analyzed both at the more general level looking at the effects of NextGen on situation awareness and workload as well as at the more detailed level looking at the specific effects that collaborative procedures and their required technology would have on human operators.

General human factors considerations. The first general category is situation awareness that considered in the context of collaborative procedures should concentrate on shared situation awareness. Based on Sheridan's (2009) outline of the main NextGen human factors considerations, shared situation awareness is described as a relatively new construct that needs to be examined in relation to the users as well as in relation to its measurement. From the user's perspective, achieving shared situation awareness can be difficult because the different users, such as flightdeck versus ATC users, have different responsibilities, time constraints, information representation and displays (Sheridan, 2009). The identification of the best shared situation awareness measure across NextGen procedures and tasks has yet to be resolved. Sheridan suggests that the best measures may be those based on post task or real-time debriefings.

Automation will also have an effect on situation awareness. Some of the proposed collaborative automation could increase shared situation awareness, but by automating certain tasks, collaborators may lose some essential aspect of awareness. In their review of separation assurance and collision avoidance concepts, Dwyer and Landry (2009) examined the distribution of responsibility. Under one concept of supervisory control, ATC would manage the airspace based on global flow factors for each sector and automation would manage the separation based on those factors. Under such conditions, the researchers estimate that under off-nominal conditions, ATC could adjust the flow factors to meet the situation, but ATC would not have situation awareness of the actual traffic and potential conflicts. This would result in situations where ATC would not be able to identify automation anomalies nor would they be able to take over in the case of a system failure (Dwyer & Landry, 2009).

The second general category of NextGen human factors issues addresses workload and subsequent concerns. This category deals with top issues since it is an essential consideration under NextGen, where time becomes much more constrained and also needs careful attention in collaborative procedures, where the act of collaboration can potentially put workload pressures on one or more collaborators. Workload, especially cognitive workload, can become an issue when operators have either too much work to do and are overloaded or too little, resulting in problems associated with low workload that include inattention and boredom (Sheridan, 2009). Recently, a number of physiological cognitive workload measures have been proposed, but Sheridan suggests they may not be useful due to large human variability. His recommendation is to use the more traditional measures such as the NASA TLX in NextGen studies. Sheridan further suggests that secondary tasks may be used as workload measures in simulations that do not affect the safety of flight--but not in operational settings.

Technology specific human factors considerations. In their analysis of existing collaboration between ATC and FOC, Idris et al. (2006) determined that collaboration worked best for planning where there was up to eight hours for the coordination to take place. They concluded that there was a need for improved collaboration in conditions under several hours. This form of more immediate collaboration would require a better communication. Apparently, the current communication system would increase workload if it were used in more time critical situations. Specific new technologies may be required to ensure a reduction, or at the very least no increase, in collaborator workload. NextGen will require both the new technologies with additional supporting ground and airside tools and displays. The more required technologies, the more different types of failures are possible with the likelihood of a greater overall frequency of failures. From a human factors perspective, this risk will require a more integrated systems design concept to avoid the piecemeal approach taken with current technology development and implementation. It will require a better way to categorize technology failures along with a system to simplify the procedures used to address those failures. Such an approach should be developed under the recent research into NextGen off-nominal events (Hooey et al., 2009) that should include both environmental as well as system off-nominals. Currently, procedures to address system failures tend to be unique to each system. What is needed is a unified set of failure categories where each category requires a similar procedure to address system failures. This should substantially reduce the complexity of managing the required technology and simplify operators' responses to individual as well as multiple failures.

An analysis of the technologies required to improve collaboration between the flightdeck, ATC and FOC will generate a more detailed understanding of the human factors issues and considerations. Data Comm and NVS will affect issues related to both collaborator workload and situation awareness and ADS-B, NNEW and SWIM will affect shared situation awareness. Beyond the effects of the technologies on human factors is the essential aspect of how those technologies are implemented. Implementation will have to be conducted using both in an evolutionary and an integrated approach. The evolutionary approach encourages the implementation of new technologies first as basic tools to allow operator familiarity. Once familiarity and confidence is established, the tool functionality can be expanded to take over some of the operator's functions. The integrated approach to technology implementation will also help to ensure its more successful adoption in air traffic management. Current implementations tend to be system and function specific such as that for Data Comm or the Electronic Flight Bag (EFB). These implementations are not always well integrated with other existing systems, procedures and training and often address a narrow function or sub-function. This piecemeal, short term, approach to implementation can lead to overly complex work environments for the flightdeck, ATC or FOC. Combining technologies into an integrated system will lead to more usable technologies and operational procedures as well as facilitate the management of automation failures.

The research on air traffic human factors considerations has matured from a focus on the ground side tools to those on the flightdeck and within FOC. Much of that research has concentrated on considerations under nominal conditions. More recently, there has been a push to start identifying and assessing human factors considerations of NextGen technology under off-nominal conditions to ensure that the technology is sufficiently robust and that the operational procedures address the possible range of off-nominals (Hooey, et al. 2009). Improved collaboration will require additional technologies, but the failure of those technologies should not place the collaborators in a position where they cannot efficiently and quickly recover.

4.1.5 Required technologies

Current collaboration is limited by a number of factors including the lack of full implementation of the foundational technologies enumerated earlier in this section that include ADS-B, Data Comm, NNEW, NVS and SWIM (Federal Aviation Administration, 2009). These five systems will be required to support the information flows to allow substantially improved collaboration between the flightdeck, ATC and FOC. These foundational technologies are necessary but not sufficient to allow NextGen to transition from current limited automation to advanced automation. The foundational technologies will facilitate shared situation awareness and greater precision, but other elements such as collaborative procedures, organizational issues, function allocation and responsibility assignments will also be required. Much of the current research has emphasized the groundside, and to a lesser extent airside, automation, but a more integrated approach to automation research will be required to ensure robust collaboration based on shared situation awareness. Achieving that shared awareness is challenging in the air traffic environment where collaborators have different information requirements, temporal demands and responsibilities (Sheridan, 2009).

It is beyond the scope of this research to address all five foundational technologies required for NextGen advance automation, but a brief overview of Data Comm will outline some of the challenges that must be met in order to approach an improved collaborative environment. Data Comm is a key requirement for full implementation of TBO (Federal Aviation Administration, 2009). ADS-B Out will be required to report more accurate aircraft positions to ATC, but it is Data Comm that allows ATC to communicate more rapidly and accurately with the flightdeck permitting the negotiation of trajectories, in other words, collaboration. There are multiple visions of how NextGen will evolve with a large number of technologies being considered. Data Comm, though not always consider advanced automation, can potentially reduce ATC workload without changing primary TBO responsibilities (Prevot, 2009). In more advanced versions of automated separation, more likely in far-term NextGen, Wing et al. (2010) indicate that Data Comm will serve as the foundation for ground based as well as airborne trajectory management.

Data Comm has been extensively researched, with a number of the studies published prior to 2000 with Rehmann (1997) and Navarro and Sikorski (1999) summarizing many of the earlier studies. Rehmann (1997) provides a review of the Controller Pilot Data Link Communications (CPDLC) literature. When implementing CPDLC, three human performance areas were deemed most critical. First, the removal of party line information may reduce flight crew situation awareness. Second, the use of CPDLC could reduce the flight crew's ability to negotiate a desired ATC clearance, especially in a data only environment. Third, the use of CPDLC could increase visual requirements inside the flightdeck along with head down time, especially in the terminal environment where external vision is essential. Navarro and Sikorski (1999) summarized the risks and benefits of Data Comm based on the review of 15 previous studies. A number of known risks were cited, including the possible interference with other required visual tasks and reduced situation awareness due to the loss of party line information and vocal cues not present in text messages. They cited possible benefits including a reduction in flightdeck workload when there was not any need to listen continuously for ATC communications.

More detailed effects of Data Comm were identified in a study reported by Harvey, Reynolds, Pacley, Koubek and Rehmann (2002). The presence of Data Comm as well as the location of its display on the flightdeck both affect crew communications. When the Data Comm system was forward facing with buttons on the glare shield, the overall frequency of communication was significantly greater compared with when it was located on the Control Display Unit (CDU) for the Flight Management System (FMS). Additionally, the within crew communication types on the flightdeck with Data Comm were different from those with voice only ATC communication. Specifically, there were new categories of pilot to pilot communication on flightdecks with Data Comm, with crews discussing the Data Comm messages. The researchers concluded that Data Comm decreased ATC communications between the flightdeck and ATC, but increased within flightdeck communication. Overall communication frequency under the Data Comm condition was significantly higher. This result is noted here and will have greater significance in future efforts that will be expanded to include within flightdeck, ATC and FOC collaboration.

More recently, researchers (Cox, Sharples, Stedmon & Wilson, 2007) concluded that Data Comm can limit shared understanding such as that established within ATC through access to the verbal information that is communicated across the ATC working environment. Data Comm's possible limiting of shared understanding should be taken into consideration as that technology is further implemented on the ground side. Based on these reviews and studies, it is likely that Data Comm may change the shared understanding and situation awareness both within the flightdeck and ATC. One can go further to hypothesize that shared understanding between organizations, such as between the flightdeck and ATC, may also be affected by Data

Comm. This shift in shared understanding will require careful attention as the Data Comm implementation is expanded. This brief overview of just one of the five foundational technologies, suggests that each of these new systems can have unintended consequences both within and between collaborators. Ultimately, these foundational systems will have to be analyzed in combination to determine their interactive effects on air traffic collaboration.

Research on NextGen required technology is evolving from the narrower focus on ATC ground system automation to a consideration of the other collaborators and their system requirements. In their research Battiste et al. (2008) concentrated on flightdeck acceptance of automated conflict resolutions. Their results showed that there was greater acceptance of automated conflict resolutions when they were reviewed by flightdecks and ATC. This suggests that technology be implemented based on a more evolutionary approach when automating aspects of collaborative air traffic management. The evolutionary approach should take into consideration the functions being automated, the proposed levels of automation and the environment where they are implemented such as the phases of flight. The different functions to be automated can be viewed as a hierarchy of functions such as the four levels of Airborne Separation Assurance (FAA/EUROCONTROL, 2001). Starting at the lowest functional level, Airborne Traffic Situation Awareness, the CDTI could be used to gain better traffic awareness. Moving up to Airborne Spacing, the flightdeck could use the CDTI to maintain spacing while ATC would still be responsible for separation. The CDTI could then assists Airborne Separation where the flightdeck is given limited delegation while at the highest level, Airborne Self-Separation, the flightdeck would have full responsibility.

Another example of such an evolutionary approach to implementing technology is proposed by Erzberger, Lauderdale and Chu (2010) for the implementation of separation assurance. The existing Traffic Alert & Collision Avoidance System (TCAS) could be treated as the initial and lowest level of separation assurance. Building on that, automated near-term separation could be introduced as a decision aid to be used within three minutes to LOS. Taking phase of flight into consideration, this near-term separation decision aid could be introduced first in the less congested and lower workload environment of the en route airspace. The implementation could then evolve to the use of a longer-term separation autoresolver, again as a decision aid in the en route environment. Once Data Comm is more widely implemented, it could be used to uplink autoresolved trajectory resolutions that can be further negotiated between the flightdeck and ATC. The evolutionary approach to implementing separation assurance technology might include the following steps:

- Start with TCAS
- Introduce automated near-term separation as a decision aid
- Evolve to the use of a longer-term separation autoresolver as a decision aid
- Use Data Comm to uplink those autoresolved trajectory resolutions.

This would result in the integration of separation and trajectory management into a unified system to achieve the automated separation assurance envisioned in far-term NextGen (Erzberger et al., 2010). Such a system, if implemented incrementally, could ultimately combine the resolution of traffic conflicts, arrival sequencing and weather avoidance into a unified system that presents the human operator with an integrated system rather that a set of standalone technologies.

4.2 Trajectory based operations example

Moving from the more general NextGen collaborative procedures to more specific TBO collaborative issues provides some examples of the effect of adding the dimension of time to trajectories. TBO includes the three dimensions of space plus the fourth dimension of time for more precise trajectory management. To illustrate this example, we look briefly at the key elements of a collaboration assessment framework including the collaborators, the collaborative procedures, human factors considerations and required technologies.

Collaborators. TBO provides a good example and way to test a Collaborative System Assessment (CSA) framework because it will likely require the involvement of all four collaborators: 1) Flightdeck, 2) ATC, 3) FOC and, 4) Automation. One way to simplify the transition to a new set of procedures, such at those required for TBO, is the approach outlined in Borgman et al. (2010) of not changing the primary responsibilities between the collaborators. Keeping the current high level responsibilities when transitioning to new collaborative procedures helps to maintain continuity, and more importantly, preserves the current allocation of expertise. In other words, those that are currently proficient at specific tasks maintain the current responsibility for those key tasks. This underscores the importance of understanding the current responsibilities in procedures between the flightdeck and ATC or FOC, especially in order to determine the different loci of expertise. Maintaining current responsibilities is a viable approach when first introducing new procedures, but it does present a problem when considering a fuller implementation of TBO.

Collaborative procedures. Although most of NextGen procedures involve some aspect of TBO, a review of the procedures listed in Table 4.1 was conducted to determine those that were directly related to TBO. The results of that review are listed in Table 4.2 showing the reference, the name of the TBO collaborative procedure and the possible collaborators, whether flightdeck, ATC, FOC or automation. All the collaborative procedures in Table 4.3 deal with some aspects of trajectory management as well as specify the possible collaborators. Almost all these TBO related collaborative procedures likely involve the flightdeck and ATC. In addition, a number of the procedures have specified a substantial level of automation that in some cases (e.g., Ho et al. 2009) assumes responsibility for a function such as separation. Collectively, these procedures provide a good sample of the range of possible collaboration under NextGen TBO by addressing the key ground and inflight operations, airborne versus ground-based management and the main functions of spacing, separation and trajectory management. A number of these procedures, including Surface Traffic Management (STM), TBO Function Allocation Concepts, Conflict Avoidance Responsibility Allocation, Flight Deck-Based Merging and Spacing, Collaborative Air Traffic Management and Airborne Trajectory Management with Self-separation, provide good examples of both the risks and benefits of greater collaboration in air traffic management.

Human factors considerations. Considering TBO in the context of shared situation awareness and workload provides a set of human factors issues that need to be examined for each collaborative procedure. For example, Smith and Billings (2009) point to the need to ensure that ATC traffic managers and dispatchers at FOCs are collaborating with the 'same picture.' This shared situation awareness is required before solutions can be proposed and ATC and FOC can then collaborate to arrive at an assessment or determine a solution. Similar requirements exist for the collaborative procedures between the flightdeck and ATC. Lee et al. (2004), in their simulation of trajectory negotiations via Data Comm, found that pilots had difficulty in seeing the 'big picture' and in understanding why controllers either accepted or rejected flightdeck clearance requests.

Table 4.2: Listing of Possible NextGen TBO Collaborative Procedures

Reference	Name of NextGen Procedure	Possible Collaborators
Becher et al. (2010)	Dynamic Airborne Reroute Procedures (DARP)	Flightdeck and ATC
Borgman et al. (2010)	Integrated Arrival/Departure Air Traffic Control Service (IA/DC with DDR and ISM)	Flightdeck, ATC and FOC
Foyle et al. (2009)	Surface Traffic Management (STM)	Flightdeck and ATC
Ho et al. (2009)	TBO Function Allocation Concepts	Flightdeck, ATC and Automation
Idris et al. (2007)	Distributed Trajectory-Oriented Approach	Flightdeck, ATC and Automation
Ligda et al. (2010)	Conflict Avoidance Responsibility Allocation	Flightdeck, ATC and Automation
Moertl & Wang (2007)	Airline Based En route Sequencing and Spacing (ABESS)	FOC and Flightdeck with ATC
Mohleji & Wang (2010)	Airborne Spacing- Flightdeck Interval Management (ASPA-FIM)	Flightdeck and ATC
Penhallegon & Bone (2007)	Flight Deck-Based Merging and Spacing (FDMS).	Flightdeck and ATC
Prevot et al. (2005)	Co-Operative Air Traffic Management (CO-ATM)	Flightdeck, ATC and Automation
Prevot et al. (2005)	Distributed Air-Ground Traffic Management (DAG-TM)	Flightdeck, ATC and FOC
Prevot et al. (2009)	Ground-Based Automated Separation Assurance	Flightdeck, ATC and Automation
Sheth et al. (2010)	Equitable Credit-based User Preference System (e-CUPS)	ATC and FOC
Smith & Billings (2009)	Collaborative Air Traffic Management (CATM)	Flightdeck, ATC and FOC
Willems & Koros (2007)	High Altitude Airspace RVSM and User-Preferred Routes	Flightdeck, ATC and FOC
Wing et al. (2010)	Airborne trajectory management with self-separation	Flightdeck, ATC and Automation
Wing et al. (2010)	Ground-based automated separation assurance	ATC and Automation

Workload is a key consideration across the TBO procedures listed in Table 4.2 because of the addition of the time dimension. TBO adds a dimension of time and increases the precision required in the space dimension. Both of these factors have an affect on the cognitive workload for all involved in collaborative procedures. As Barhydt and Adams (2006) indicated, under TBO related procedures, flightdecks need to pay closer attention to loading and briefing their Standard Instrument Departures (SIDs) and Standard Terminal Arrival Routes (STARs) because they can be more detailed and precise than those currently used. TBO procedures will require strict adherence to published paths and have a lower tolerance for any differences in path construction due to variances between FMS models. Barhydt and Adams (2006) concluded that TBO procedures may require greater consideration of both the workload and situation awareness demands on flightdecks. Prevot et al. (2009), in their evaluation of ground-based automated separation assurance concluded that flightdeck would be responsible for responding quickly to Data Link uplinks. Both the requirement to meet time constraints under TBO and the requirement for greater timeliness on the part of flightdeck's execution can place a greater demand on pilot workload.

Automation will play an increasing role in TBO procedures affecting both situation awareness and the workload experienced on the flightdeck, in ATC and FOC. The increase in air traffic and resulting controller workload has been a key driver for NextGen, and ATC automation has been considered both a likely solution as well as a cause for additional human factors considerations. In their investigation of different automation scenarios under NASA's Advanced Airspace

Concept (AAC), Dwyer and Landry (2009) present different levels of automation. In comparing current procedures with more collaborative separation assurance procedures, the researchers outlined the human factors effects of the different levels of automation. Those levels range from no automation, through to automated conflict identification, to conflict identification with automated resolution. Based on their review of proposed separation assurance concepts, Dwyer and Landry (2009) estimated or predicted the effects of these different concepts on situation awareness and workload both on the flightdeck and in ATC. Based on their estimates, their general conclusion was that the more tasks are automated, the greater the reduction in controller situation awareness. The reverse was the case for controller workload where they estimated that under increased traffic levels, no or less automation resulted in excessive workload while automatic conflict identification with an autoresolver should have produced a moderate reduction in controller workload. They conclude that with most of the automation on the ground side, the effects on flightdeck situation awareness and workload will change little from the current procedures.

Automation, and especially its possible failures, must be considered from a phase of flight perspective (Sheridan, Corker & Nadler, 2006). When evaluating the different procedures, it should be recognized that TBO preflight and surface operations trigger different automation failure issues compared with inflight operations. Human factors issues will vary depending on phases of flight, how much of the automated system has failed and whether the flightdeck or ATC is in the early or late stages of the failure. In later stages of automation failure, where recovery is not likely, resuming manual control may be required. Such situations where there is a need to revert to some level of manual control affect an operator's required skills with strong implications for both off-nominal procedures and their training. Automation failure modes should be classified and recovery procedures should be evaluated with operators in simulated environments (Sheridan et al., 2006). Phase of flight can play an essential part in determining the human factors considerations in the context of TBO trajectory negotiation procedures. In their review of automation under TBO, Zemrowski and Sawyer (2010) indicate that managing trajectories is not just concerned with separation and flow control, but includes collaboration between the flightdeck, ATC and FOC to ensure that the system can be used to address their different needs. To meet these requirements, developers and researchers need to determine which alternatives need to be presented to the collaborators, how to weight different user preferences and how much time to allow for the process before a decision must be made. They conclude that not only human factors issues need to be considered but also teamwork issues and measures.

McNally et al. (2010) point out that using TBO automation to achieve fuel efficient trajectories in today’s airspace with existing Data Comm and the currently equipped fleets has not been demonstrated in operational settings. Although some simulations have shown promise, these authors conclude that operational testing is required to identify specific requirements for an implementation of near-term TBO in the NAS. They point out that due to the expense of the required ground and aircraft systems, it is essential to identify what benefits can be achieved with current technology for near and mid-term NextGen. They outline an operational test to identify those benefits as well as identify specific TBO requirements. Their cost effective, near-term TBO concept of operation involves the use of automation to accurately and frequently update aircraft trajectories in such a way that time constrains are only issued when absolutely necessary. This more flexible TBO concept can be applied to the current mix of aircraft with existing equipage. Their laboratory simulation of this near-term TBO concept provided a number of results that would need to be further investigated through operational testing. Overall, the results showed that their approach provided good trajectory solutions to traffic conflicts reducing the number of clearances required in current operations. Although their concept of operations placed fewer constraints on aircrafts, trajectory maneuvers had to be executed at more precise points, possibly requiring the addition of a well defined starting point. Top-of decent prediction errors, usually due to the lack of complete information about a specific aircraft's weight or performance, was the leading cause for loss of separation. There was a similar problem with climb predictions that must also be addressed. McNally et al. (2010) concluded that a cost effective version of TBO based on today's equipage mix could be feasible by addressing the few failure points.

Required technology. Finally, at the most detailed level, required technology, whether on the ground or in the air, presents the greatest number of human factors issues. TBO collaborative procedures may have technical requirements that are not directly involved with collaboration but that may be necessary to successfully address or complete specific tasks or responsibilities. For example, Cheng, Andre and Foyle (2009), in discussing the flightdeck information requirements for Trajectory Based Surface Operation, suggest the value of presenting pilots with both speed and time information displays. Human factors considerations for how to best display these types of information can involve a substantial range of issues from how to represent the information, which type of display to use and the placement of the displays in what can be at times an already space limited flightdeck. Each of these issues, individually as well as in combination, affects the human factors considerations of situation awareness and cognitive workload along with other performance measures related to response and head-down time. Other technologies required for greater flightdeck collaboration in air traffic management are those related to ADS-B (Zingale & Willems, 2009). ADS-B systems can be used to collect information about aircraft that can be transmitted to both ground and flightdeck systems. Flightdecks with aircraft equipped with CDTI and ADS-B In, could provide crews with enhanced situation awareness. Zingale and Willems (2009) conclude that this could possibly allow for greater responsibility for separation and spacing on the flightdeck. From a human factors perspective, possible gains in situation awareness must be evaluated against the effects on workload and also against interactions with other systems required to perform the collaborative procedure under consideration.

4.3 Summary of NextGen collaboration

Section 4 outlined possible NextGen changes in collaboration between the flightdeck and ATC, FOC and automation by first looking at general NextGen considerations and then examining proposed NextGen collaborative procedures. The overview concluded with a review of TBO collaborative procedures. The development and assessment of NextGen collaborative systems and procedures possesses a very large complex of possible considerations that can be better managed by taking into account the fundamental differences between collocated versus distant collaborators as well as between synchronous versus asynchronous collaboration. The discussion of collaboration focused on dispersed collaborators, referred to as those collaborating between groups such as between the flightdeck and ATC. With regard to the time dimension, collaboration during preflight is more manageable given the greater amount of time available. Asynchronous collaboration has received substantially more attention up to this point, especially in the form of CDM between ATC and FOC where operator needs were included in air traffic management decisions. FOC involvement has increased under CDM, but it is still described as being largely centralized in the air traffic manager decisions (Idris et al., 2006). Future CDM will require better shared information, improved procedures and the automation envisioned under mid and far-term NextGen.

Shared situation awareness and workload are two key issues in the current air traffic control system that both limit and, when properly addressed, could substantially improve collaboration. In the current environment, the focus has been on within collaborator situation awareness, whether on the flightdeck between pilots or within ATC between control personnel. Collaboration between these groups, including FOC, will required shared situation awareness that both gives collaborators a common view and understanding of traffic while still providing individual collaborators with information required to perform their specific tasks. Achieving shared situation awareness will be challenging because the different collaborators, such as flightdeck versus ATC users, have different responsibilities, time constrains and displays. The challenge is twofold. First, system and procedure developers will have to determine what information must be shared and what information is unique to each collaborator. Then, they must decide how to represent the shared information to the different groups so that each group can best use it to perform its functions and tasks. Foundational systems such as ADS-B, NNEW and SWIM will have the capability of supplying some of the essential shared traffic and weather information, but researchers are still experimenting with optimal representations between flightdeck and ATC that will encourage shared situation awareness without increasing workload or information overload.

In its simplest form, the workload challenge within collaborative air traffic management is one of optimal function allocation between collaborators including automation. Collaboration is seen as a possible way to better distribute workload between collaborators, but greater collaboration does not always lead to reduced workload as shown in the evaluation of ATFM by Wolfe et al. (2009) where increased FOC collaboration did not reduce ATC workload. Their experiments provided valuable insight about workload and automation in the context of collaboration. Greater FOC input in the planning stages either placed greater constraints on ATC's route selection or it resulted in FOC selecting routes that were not acceptable. After analyzing a number of different FOC strategies, the researchers concluded that the solution was not to try and specify or limit those strategies because different operators have different air traffic flow needs leading them to select optimal strategies to maximize their corporate business model. The researchers suggested that automation, rather than increased collaboration, was more likely to reduce overall ATC workload. They also suggested that the earlier FOC is involved in the collaborative traffic flow management process, the more likely FOC will arrive at better traffic flow solutions.

Automation can help if it is designed as an integrated system and implemented based on an evolutionary approach. From a technology perspective, advance automation will require the NextGen foundational systems of ADS-B, Data Comm, NNEW, NVS and SWIM implemented so as to integrate communication, navigation and surveillance. At present, many of the studies have examined just one or two of these foundational systems usually evaluating them in the context of a single function such as separation, spacing or trajectory management. This univariate approach allows for a more focused examination but does not answer questions about the effects of NextGen advanced automation on multiple air traffic management functions. Increased collaboration in a single function, like separation or trajectory management, could improve operations, but collaboration applied to several functions would require careful design so as not to overload the flightdeck, ATC or FOC. The research on far-term NextGen needs to work with most of the foundational systems to provide not only improved communication but also the shared situation awareness required for better collaboration across most of the air traffic management functions. These foundational technologies will have to be designed as an integrated system rather than as individual components.

The NextGen foundational systems are just one of a number of requirements to transition to advanced automation. Those technologies can facilitate shared situation awareness and allow for greater precision, but other requirements such as organizational issues, collaboration incentives, function allocation with an integrated and evolutionary implementation will determine whether increased collaboration between the flightdeck, ATC and FOC will actually improve air traffic management. An examination of these additional requirements suggests that researchers and developers should move beyond developing or evaluating unique forms of collaboration for each air traffic function to a form of collaboration with substantial consistency across functions such as separation, spacing and trajectory management. That consistency will be essential when developing procedures to address automation anomalies and failures so that operators have common solutions based a few failure categories rather than a large range of failure procedures. The research on NextGen automation, in general, and collaborative procedures, in particular, needs to not only look at automation failures but at a fuller range of off-nominal events that can change assigned responsibilities as well as the form of collaboration. Consideration of off-nominal events is growing in importance in NextGen research, especially in research connected with collaborative interactions between the major players. Off-nominal conditions or events pose a challenging problem for collaboration that has been observed in current air traffic flow collaboration between ATC and FOC (Wolfe et al., 2009). Collaboration becomes more constrained when problems become more severe, the very times when collaboration is most needed.

Collaborative procedures should be used as a core component of any framework to assess possible approaches to NextGen collaboration. Many NextGen research studies were reviewed in order to determine the characteristics of collaborative procedures. A bottom-up approach was used to arrive at a definition of collaborative procedures that were defined as specific NextGen processes involving substantial interaction between the flightdeck, ATC, FOC or automation. A collaborative systems assessment (CSA) framework should concentrate on the comparison and evaluation of specific proposed collaborative procedures rather than on a large number of hypothetically derived collaborative options. Working with a limited set of procedures that have been either proposed or tested in the context of specific collaborators provides a substantially more realistic and coherent structure than working with all possible combinations of collaboration across the key air traffic management functions.

In order to better develop and test the utility of a CSA framework under NextGen improvements, an example of TBO procedures was used. Narrowing CSA's original scope from the general NextGen collaborative procedures to a TBO example allows this research to concentrate on issues related to time, a key dimension emphasized under TBO. Working with the fundamental collaboration dimensions of time and space, Figure 4.1 shows the TBO domain that will be assessed in the initial trial version of applying the CSA framework. Specifically, the collaboration between flightdeck and ATC or FOC is the key area divided into asynchronous collaboration, such as in the planning phase, and more synchronous collaboration, such as that involved in the near-term separation under TBO. The shaded areas in Figure 4.1 would be reserved for a future, expanded CSA that would help in the assessment of within group collaboration procedures such as those involving flight planning on the flightdeck during the preflight setup. Those would be lower level functions most likely involving communication, coordination or cooperation in a face-to-face or collocated environment.

The CSA domain area represented in Figure 4.1 provides a well defined space that, when illustrated through an example of TBO collaborative procedures, allows users of the framework (e.g, ConOps and system developers) to evaluate its utility. With this research directed towards assessing high level air traffic management functions and possible changes in collaborator responsibility, the focus is on procedures such as flow control, spacing, separation and trajectory management. The asynchronous collaboration procedures, those where collaboration is easier to implement because of the greater amount of time to resolution, would include flow and trajectory planning along with long-term separation. The synchronous collaboration procedures which will be more difficult to implement, but for which there may be a greater need, would include trajectory, spacing and merging functions along with near-term separation.

	Collaboration Under TBO Within Flightdeck, ATC or FOC	Collaboration Under TBO Between Flightdeck, ATC or FOC
Asynchronous Collaboration	ADDRESSED IN FUTURE CSA Flight Planning on the Flightdeck in FOC and in ATC	ADDRESSED IN THIS CSA Flow, Long-term Separation and Trajectory Planning between ATC and FOC or Flightdeck
Synchronous Collaboration	ADDRESSED IN FUTURE CSA Clearance management on the Flightdeck and within ATC	ADDRESSED IN THIS CSA Near-term Separation, Clearance/route/trajectory management between Flightdeck and ATC or FOC

Figure 4.1: Domain of current CSA TBO collaborative procedures.

The review of NextGen collaborative procedures helped to identify the key elements that should be taken into account when specifying the structure of a CSA. Based on the review of collaborative procedures, the groupings in Table 4.3 were identified as the key elements for a CSA framework. The five elements are: Collaborators including automation; Collaborator Responsibilities; Functions and Procedures; and Required Technology.

Table 4.3: Five Key Elements of the CSA Framework

Collaborators
• Flightdeck • ATC • FOC • Automation
Collaborator Responsibilities
• ATC Responsibilities • Flightdeck Responsibilities • FOC Responsibilities • Automation Responsibilities
Functions and Procedures
• Function Allocation • Collaborative Procedures • Tasks
Human Factors Considerations
• Measures & Metrics • Nominal and Off-Nominal Operations • Scenarios • Trade Studies
Required Technology
• System Requirements • Technologies

Recommendations. In assessing an approach to collaboration, when more is known about its allocation of responsibilities, its procedures and its required technology, a better and more detailed set of results are possible. It is recommended that developers concentrate on the assessment of collaborative procedures that have been specified at a sufficient level of detail with clearly stated assumptions. Based on the importance of time in collaboration, it is recommended that time critical collaborative procedures be limited to two collaborators with one of them likely automation. With their greater flexibility, time sensitive collaboration can include up to three collaborators. Planning may include up to four collaborators, especially when the collaboration has more time with up to several hours before a resolution is required.

Increasing collaboration in a single function such as trajectory management could improve flightdeck operations, but increasing collaboration in two or more functions would require careful integration so as not to overload collaborators, especially those on the flightdeck. To help with this integration, it is recommended that collaborative procedures have consistent procedural elements rather than a unique form of collaboration for each function or sub-function. This suggests that developers should move beyond assessing individual collaborative procedures to the evaluation of groupings of such procedures looking for consistency across functions such as separation, spacing and trajectory management. In assessing that consistency, one should look for a balance between flexibility and procedural consistency.

When a function is automated, consideration must be given to how that function is transferred to the human under off-nominal conditions. A risk with advanced automation is that situation awareness may be reduced causing additional challenges when manual operations must be resumed. It is recommended that new automation be implemented through an evolutionary approach where it is first introduced as a limited decision aid, and when user confidence has been established, automation can take over greater functionality. It is further recommended that technology in general also be implemented using an evolutionary approach. It should be recognized that with more automation and technology more failures and anomalies are likely. ConOps and system developers must consider the range of off-nominal conditions and look for consistent procedures for their resolution. A systematic categorization of automation and technology failures is recommended along with a consistent set of approaches to their resolution.

5.0 Framework and Tool for Assessment of NextGen Collaboration

The Collaborative System Assessment (CSA) framework provides a structure for assessing NextGen collaborations in the NAS. This presentation of the CSA uses Trajectory Based Operations as an example. The framework is based on the following five key elements:

- Collaborators
- Collaborator Responsibilities
- Functions and Procedures
- Human Factors Considerations
- Required Technologies.

The first elements for this framework are the collaborators. Collaborators include the flightdeck, ATC, FOC and automation in all possible combinations. The collaboration generally takes place between pairs of collaborators such as between the flightdeck and ATC or between ATC and FOC. Some forms of collaboration may be possible between all four collaborators including automation under conditions where there is more time, such as during the flight planning phase.

The second element is the collaborators' responsibilities. A sample set of flightdeck, ATC, FOC and automation responsibilities was developed based on NextGen collaborative procedures that require changes to current responsibilities. These responsibilities are being reported here to emphasize the proposed changes under NextGen. The sample set was identified by analyzing the changes of responsibilities in the possible collaborative procedures in Table 4.1. Most of the identified collaborative procedures involve the allocation of responsibilities between ATC and flightdeck to maintain separation with some added automation to help reduce workload. These collaborative procedures help detect conflicts, provide alerts or propose new trajectories involving ATC and the flightdeck. Some procedures, for instance, those based on merging and spacing, use automation to help navigate and reduce the number of clearances. Though flightdeck responsibilities remain similar to a VFR approach, aircrafts equipped with CDTI can follow any aircraft in any weather conditions. In merging and spacing procedures roles and responsibilities are similar to the current distribution of responsibilities. This allows collaborators to keep an appropriate authority to accomplish their tasks. This means that when the flightdeck has the responsibility to follow an aircraft it has to meet the ATC responsibility of maintaining safety.

The third element includes functions and procedures. Functions fulfill higher goals of operations and support the organization of the NAS and the procedures are the specific processes to accomplish the functions. Functions in the CSA are more general while the procedures provide a specific description of the process to include tasks and required technologies. Functions can be allocated to collaborators based on the time criticality of operations. A management time horizon, such as used by Sipe and Moore (2009) to determine planning timeliness, can be used to determine who could be responsible for specific functions given a range of time criticality:

- Level 1) Time critical: immediate attention/off-nominal (e.g., emergencies, failures, separation less than 3 minutes to LOS)
- Level 2) Time sensitive: operations (navigation, spacing and merging, separation more management more than 3 minutes to LOS)
- Level 3) Planning: (route planning, scheduling, weather avoidance).

Examples of functions by collaborators for TBO are presented in Table 5.1. There may be others ways to structure this three way interaction, but the important point is that time criticality is an essential dimension in determining which collaborators might best accomplish which functions.

Table 5.1: Functions by Collaborators by the Dimension of Time Criticality

	Flightdeck	FOC	ATC	Automation
Time Critical	Collision avoidance or emergency	Emergency or unusual situation management	Emergency or unusual situation management	Collision Avoidance
Time Sensitive	Navigation	Spacing and merging or management	Separation management	Separation management
Planning	Flight management	Flight management	Flow or airspace management or traffic management	Flow or airspace management

With expected change of responsibilities under TBO, functions will more likely be shared by multiple collaborators. For instance, a dispatcher may take an active role with navigation parameter while the aircraft is airborne and flightdecks may maintain their separation with other traffic, rather than being directed by ATC.

The fourth elements of the CSA are human factors. A set of human factors considerations have been identified by combining the higher level NextGen considerations with those associated with the specific NextGen collaborative procedures and their required technology. This resulted in a set of issues related to the communication, display and representation of information required for collaboration between the flightdeck, ATC and FOC. Automation was evaluated for its possible failures at key phases of flight. There are different human factors at various phases of flight. For example, TBO preflight and surface operations have different human factors considerations than those in flight. Additionally the part and the extent of automation failure need to be considered as well. There are significant human factors to account for when a system failure requires resumption of full manual control. This is especially true when less used skills are needed to maintain separation and trajectory management. Also, the management, and the negotiation of the trajectories under TBO go beyond issues of separation and weather avoidance and include teamwork to address different collaborator needs. Consideration must be given to collaborative alternatives, how to weigh user preferences and how much time to allow for negotiations before a decision is forced.

Finally, the fifth elements refer to required technology. Whether ground or airborne based, required technology presents the greatest number of possible human factors considerations. TBO procedures may require technologies that are not directly involved with collaboration but that are necessary to complete specific tasks or responsibilities successfully. Human factors considerations regarding how to best design and integrate those required technologies raise a complex set of issues. Each of these issues, individually as well as in combination, affects the primary human factors of shared situation awareness and workload. From a human factors perspective, possible gains in shared situation awareness must be evaluated against the effects on workload and also against interactions with other systems required to perform the collaborative procedure. Required technology specifies the main systems necessary to implement a specific NextGen collaborative procedure. The emphasis is on systems that may include algorithms, one or more displays and a user interface to help either the flightdeck, ATC or FOC perform collaborative procedures.

5.1 Collaborative assessment inputs

The CSA allows for a range of inputs from general information to more detailed information about the collaborative system being assessed. When assessing a general collaborative scenario, the ConOps developer would input only the broad assumptions under consideration. When assessing a collaborative procedure, the developer would input substantially more detail about the assumptions.

<u>General scenario assessment</u>: When using the CSA to assess a general scenario, the ConOps developer would input its basic attributes. Scenarios can be used as the basis for an assessment of a collaborative system that is specified at a conceptual level without a detailed listing of its required technology. When assessing a collaborative scenario, the ConOps developer should be able to specify a handful of basic attributes to help guide the evaluation. Input to the CSA about the time dimension includes phases of flight and the time criticality of interest. The following NextGen phases of flight can be specified with the understanding that the preliminary assessment may want to consider all of them:

- Flight Plan
- Taxi
- Takeoff
- Cruise
- Descent and Final Approach.

As discussed earlier, the time dimension is essential when developing a concept of collaboration. To specify that dimension, one should consider whether the concept will address:

- Time critical collaboration (requiring an resolution in under 3 minutes)
- Time sensitive collaboration (requiring a resolution in up to 30 minutes)
- Planning collaboration (having more than 30 minutes prior to resolution).

Collaborators of interest can include different combinations of the flightdeck, ATC, FOC or automation. As a general recommendation, time critical collaborative concepts should include only two collaborators with one of them often being automation. There is more flexibility with time sensitive collaborative concepts, but they would generally include two collaborators and no more than three. Planning may include up to four collaborators, especially when the collaboration has several hours before a resolution is required. Collaborative functions of interest include the following five that are likely to see additional collaboration under TBO based on a review of the collaborative procedures listed in Table 4.2:

- Capacity management
- Spacing management
- Separation management
- Trajectory planning
- Trajectory management.

<u>Collaborative procedure assessment</u>. When using the CSA to assess collaborative procedures that have been defined at a greater level of detail the ConOps developer can input substantially more information. In addition to the attributes presented under the general scenario assessment, it is possible to specify which of the following required technologies are assumed:

- ADS-B
- Data Comm
- NextGen Network Enabled Weather (NNEW)
- NAS Voice Switch (NVS)
- System Wide Information Management (SWIM).
- Delegated Responsibility for Separation
- NextGen RNAV and RNP
- Point in Space Metering
- CPDLC Integrated with FMS is available
- CDTI is available
- Automation support for mixed environments is available
- ERAM is available
- Conformance monitoring tool is available
- NextGen DME is implemented.

5.2 Collaborative assessment outputs

The CSA outputs (see Table 5.3) provide researchers and ConOps developers with key considerations based on elements entered as input. These considerations are identified by synthesizing Human Factors related to procedures and required technologies. The CSA output presents the Phases of Flight of Interest, Time Criticality of Interest, Collaborators of Interest and Functions of Interest based on what is checked off during the input of the assessment. These assumptions direct the two output sections that aggregate potential General Benefits and General Risks for the collaborative function (See example of CSA Output). These two summarize key positive and negative aspects of the collaborative scenario or procedure. For example, for a collaborative procedure related to TBO trajectory management, the General Benefits would summarize positive workload and shared situation awareness considerations for each group of collaborators reported in the NextGen research literature. In a similar way, the General Risks would summarize the general human factors issues and concerns related to the collaborative procedure being assessed.

At a more detailed level, the trades output, shown in the second half of Table 5.3, specify the effect of the proposed collaborative procedure or scenario on the main collaborators. Those developing a ConOps would use the detailed CSA output to assess the effect of the specified procedure with following five metrics of collaboration: 1) Communication Frequency, 2) Efficiency, 3) Flexibility, 4) Shared Situation Awareness and 5) Workload. Detailed Trades consider each collaborator in turn. Communication Frequency refers to the amount of resulting communication where more required communication can increase workload. The second metric, Efficiency, addresses the time to resolution combined with its accuracy. The third metric, Flexibility, addresses the adaptability of the procedure along with its ability to meet changing conditions in the proposed operational environment such as weather. The fourth metric, Shared Situation Awareness, is the information and mental picture shared between the collaborators. Finally the fifth metric, workload, refers to the estimated effect of the proposed procedure on each collaborator. The Detailed Trades for these five collaboration metrics provide ConOps developers with an assessment of the likely results of the proposed collaborative procedure of interest.

5.3 Example of a collaborative system assessment

The CSA can be used to make a general assessment. A general assessment allows for a preliminary evaluation of a NextGen concept of scenario. Its advantage is that the ConOps developer would not need a detailed description of the concept being assessed. A detailed assessment can be conducted when the developer has a full range of specifications for the collaborative system being assessed.

General scenario example. A general collaborative scenario assessment allows for a quick determination of the benefits and risks of a proposed shift in collaboration and responsibilities. This form of assessment only requires the specification of the phases of flight, time criticality, collaborators, high level functions, collaborator responsibilities, and level of automation. For example, a scenario might assume a flight crew is executing a TBO clearance from City A to City B and encounters weather with the need to adjust the flight route. In this scenario, the first step would be to determine the assumptions relative to phase of flight, time criticality, and high level functions. In this case, the phase of flight is cruise, the timeliness is sensitive, and the function is trajectory management.

The options for collaborators are: flightdeck, ATC, FOC or automation. Then, the responsibilities to assume the function can also be distributed across the collaborators. The flightdeck can have no responsibility, shared (delegated) responsibility or full responsibility. In this case:

- No responsibility: Flightdeck is not responsible for maintaining separation. ATC is controlling aircrafts separation and changes in trajectories.
- Shared responsibility: Flightdeck is responsible for maintaining separation and following trajectory, but ATC is responsible for clearing changes in trajectories
- Full responsibility: Flightdeck is responsible for maintaining separation and changing trajectories. ATC is supervising changes and intervening when necessary.

A general collaborative scenario assessment should also specify the level of automation based on the following three:

- No automation: The aircraft has a transponder, a satellite phone and a radio
- Partial automation: same as no automation plus FMS, Data Comm (CPDLC), ADS-B in & out with traffic and weather display
- Full automation: same as partial automation plus Cockpit Situation Display with Route Assessment Tool, with alternative route generated by system or by remote location (ATC, FOC) (autoresolver).

The three levels of automation combined with the three levels of responsibilities yield nine configurations. Those can be assessed with general risks and benefits. In the above scenario example, the assumed configuration for the flightdeck could be partial automation and shared responsibilities. In this configuration, the collaboration for a change in trajectory could follow this possible exchange:

1. Flightdeck coordinates with FOC via data.
   (Flightdeck may receive new trajectory from FOC via data).
2. Flightdeck requests ATC approval for new trajectory.
3. ATC clears new trajectory to flightdeck via data.

The CSA output for such a general assessment would be the benefits and risks regarding shared situation awareness and workload. In this scenario with such configuration, shared situation awareness would not be optimal for the flightdeck. Risks would be high. The flightdeck would not be able to predict safety of new trajectory due to lack of information. The flightdeck would be closely dependent on FOC to propose new trajectories. Benefits would be moderate. The flightdeck would share similar information with ATC and FOC on weather and traffic. This information would lower risks of separation loss and optimize routing of the flight.

Workload would be very high for the flightdeck. The time to propose a new trajectory to ATC may be time consuming given partial automation and the lack of data and technology to plan a new trajectory. The information exchange with FOC would be significant. The level of work would be closely depending on the FOC own role in monitoring the flight and supplying alternative trajectories. The main benefit would be for ATC who would not have to generate a new trajectory but only to approve it. Thought as discussed in Section 4, controllers who have a more passive role may have reduced situation awareness.

This general assessment lacks in specificity. For instance, shared situation awareness and workload would need to be assessed for all collaborators for each of the five tradeoffs. This would provide more specific risks and benefits. The following example demonstrates a detailed assessment.

<u>Collaborative procedure example</u>. An example of a more detailed assessment focuses on the intersection of Collaborative Air Traffic Management (CATM) and Trajectory Based Operations (TBO). This example demonstrates how a CSA could help ConOps developers assess different combinations of procedures, systems and function allocation between humans and automation as they consider different forms of collaboration. The CSA example assumes that the assessment is focused on the cruise phase of flight during a time sensitive event (see the items checked off in the CSA Input Checklist that follows). In addition, the example assumes that the function of interest is trajectory management involving the flightdeck, ATC and automation with responsibility assigned to just the flightdeck and ATC. At a more detailed level, the following technologies and tools are assumed available (see the Collaborative Procedure Detailed Assumptions in the bottom half of the CSA Input Checklist):

- ADS-B Out
- ADS-B In
- Data Comm
- CPDLC Integrated with FMS
- ERAM
- Conformance monitoring tool
- NextGen DME
- Collaborative Trajectory Planning (CTP)
- Enhanced (NextGen) RNAV and RNP
- Trajectory Based Operations Separation Management.

To further focus this example of a scenario, the ConOps developer is interested specifically in a trajectory reroute due to unanticipated traffic, weather or winds. In examining the CSA Input Checklist as well as the CSA Output on the next two pages, it should be noted that a CSA could be used to assess very focused procedures, such as those presented here, as well as more general scenarios that cover several phases of flight and a broader area of responsibilities to include those that could be assigned to FOC.

Table 5.2: CSA Input Checklist - Collaborative System Attributes of Interest

Elements	Collaborative Scenario or Procedure Basic Assumptions					
Phases of Flight of Interest	*Check all Phases of Flight of interest.*	**Flight Plan**	**Taxi**	**Takeoff**	**Cruise**	**Descent Final Approach**
					√	
Time Criticality	*Check all timeframes of interest.*		**Time Critical**	**Time Sensitive**	**Planning**	**All Three**
				√		
Collaborator Responsibilities of Interest	*Check Collaborators Responsible for the Above Collaborative Functions.*		**Pilot**	**ATC**	**FOC**	**AUTO**
	Collaborative trajectory management		√	√		
Collaborative Functions of Interest	*Check all Functions of interest indicating all collaborators involved.*		**Pilot**	**ATC**	**FOC**	**AUTO**
	Merging management					
	Spacing management					
	Separation management					
	Trajectory planning					
	Trajectory management		√	√		√
Level of Automation of Interest	*Check the one level of automation of interest.*		**No Automation**	**Partial Automation**	**Full Automation**	
	Collaborative trajectory management			√		
Elements	**Collaborative Procedure Detailed Assumptions**					
Assumed Systems and Technologies	*Check Yes, No, or Maybe (?) for each of the following assumptions about the collaborative procedure or scenario being assessed.*			**Yes**	**No**	**?**
	ADS-B is available			√		
	Data Comm is available			√		
	NextGen Network Enabled Weather (NNEW) is available					√
	NAS Voice Switch (NVS) is available					√
	System Wide Information Management (SWIM) is available				√	
	Collaborative Trajectory Planning (CTP)			√		
	Conflict Resolution Advisories					
	Delegated Responsibility for Separation					
	NextGen RNAV and RNP			√		
	Point in Space Metering					
	Surface Trajectory Based Operation (STBO)					
	Trajectory Based Operations Capacity Management			√		
	Trajectory Based Operations Separation Management					
	CPDLC Integrated with FMS is available			√		
	CDTI is available				√	
	Automation support for mixed environments is available				√	
	ERAM is available			√		
	Conformance monitoring tool is available			√		
	NextGen DME is implemented			√		

Table 5.3: CSA Output - Based on Collaborative Procedures Research Findings

CSA Output Based on the Following Assumptions	
Phases of Flight of Interest:	Cruise
Time Criticality of Interest	Time Sensitive
Collaborators Of Interest	Flightdeck with ATC and Automation
Functions of Interest:	Trajectory management
Assumed Procedures and Systems	
Collaborative Trajectory Planning (CTP) Delegated Responsibility for Separation NextGen RNAV and RNP	Surface Trajectory Based Operation (STBO) Trajectory Based Operations Capacity Management Trajectory Based Operations Separation Management
General Benefits and Risks	
Benefits	*Collaborative Trajectory Management Between ATC, Flightdeck and Automation*
	With proper Flightdeck displays to generate trajectory reroutes and with the Flightdeck responsible for the reroutes, it is possible to reduce ATC workload with just moderate increase in Flightdeck workload during cruise that generally has lower workload operations.
	With proper Flightdeck tools to help generate and analyzed trajectory reroutes and with the Flightdeck responsible for the reroutes, it is possible to reduce ATC workload with minor increase in Flightdeck workload during cruise operations.
	With shared weather and wind information, it should be possible for ATC and the Flightdeck to maintain shared situation awareness.
	With automation, either ground or airborne, responsible for generating the reroutes with both ATC and Flightdeck options for rejecting the automated solution, along with shared situation awareness, it is possible that both ATC and Flightdeck workload would be reduced.
Risks	*Collaborative Trajectory Management Between ATC, Flightdeck and Automation*
	Collaborative separation management during cruise, combined with delegated or self-separation, could cause Flightdeck work overload,
	Without proper Flightdeck displays and tools to generate trajectory reroutes, it is likely that the increase in Flightdeck workload during cruise could lead to work overload situations.
	Without shared weather and wind information, it is possible that ATC and the Flightdeck would not maintain shared situation awareness.
	With automation, either ground or airborne, responsible for generating trajectory reroutes, without the information for ATC and Flightdeck to maintain good shared situation awareness, it is possible that additional communication and negotiation between Flightdeck and ATC would be required.
Detailed trades	
Flightdeck	*The Flightdeck will likely experience the following*
Communication Frequency	Collaboration between ATC and Flightdeck without good shared situation awareness may increase frequency of Flightdeck communication.
Efficiency	Efficiency of flight can be improved with trajectory input from the Flightdeck.
Flexibility	Flexibility, especially of the operator and Flightdeck, will be improved.
Shared SA	Without appropriate displays, compatible tools and shared traffic, weather and wind data, Flightdeck shared SA with ATC may be problematic.
Workload	Flightdeck workload will be increased but cruise is a relatively low workload phase of flight
ATC	*ATC will likely experience the following*
Communication Frequency	Collaboration between ATC and Flightdeck without good shared situation awareness may increase frequency of ATC communication.
Efficiency	With proper implementation of the automation, ATC should experience improved efficiency.
Flexibility	Depending on how the automation is implemented, flexibility in ATC trajectory rerouting may be reduced.
Shared SA	Without appropriate displays, compatible tools and shared traffic, weather and wind data, Flightdeck shared SA with ATC may be problematic.
Workload	ATC workload should be reduced with either a good implementation of automation or Flightdeck capability to self-reroute.
Automation	*Automation considerations*
Communication Frequency	Communication should not be affected unless there is a problem with the accuracy of the automated reroute or there is a system failure which would then increase overall need for communication.
Efficiency	Automation, if accurate, should improve efficiency of the reroute and the overall system
Flexibility	Automation may reduce the flexibility of the reroute, especially for the flightdeck, depending on the user interface and the processing of the reroute.
Shared SA	Shared SA is not a problem with automation, but the lack of shared data between all three collaborators may lead to unacceptable trajectory reroutes.
Workload	ATC and Flightdeck workload should be reduced given properly functioning trajectory rerouting automation.

The example scenario used for the inputs assumes that a flight crew is executing a TBO clearance from City A to City B and encounters weather with the need to adjust the flight route. In this scenario, the flightdeck and ATC share responsibilities to manage a trajectory in a relative sensitive timeline. The flightdeck is responsible for maintaining separation and following trajectory, but ATC is responsible for clearing changes in trajectories. Partial automation in the flightdeck supports this procedure. With CATM assumptions, data is shared among the flightdeck, ATC, and FOC in real time allowing inflight routing changes.

The sample input in Table 5.2 shows the flexibility of the CSA in that it allows for the assessment of both general scenarios and more specific collaborative procedures. The Basic Assumptions checked off in the top half of the CSA Input Checklist (see Table 5.2) are the same for the general scenario as well as for the collaborative procedure example. That common set of Basic Assumptions results in the General Benefits and General Risks in the top half of Table 5.3. Those benefits and risks are stated at a sufficiently general level without making specific assumptions about the required technology. The bottom half of Table 5.2 presents an example of the required technology for a CATM procedure under TBO.

In summary, Table 5.3 shows that with the proper displays and tools and with the flightdeck responsible for the reroutes, it is possible to reduce ATC workload with just a moderate increase in flightdeck workload during the cruise phase of flight. There could be some risks if the procedure of interest were combined with additional flightdeck responsibilities for separation management and delegated or self-separation. Such a combination of procedures could result in flightdeck work overload. At a more detailed level, this procedure will require good shared situation awareness so that there will not be an increase in required communication between the flightdeck and ATC. Finally, with accurate data and the proper implementation of automation, the procedure should improve trajectory management.

5.4 Future Directions

Section 5 describes the Collaborative Systems Assessment (CSA) framework through an example of what the user of the framework would need to specify for a general or specific assessment of NextGen collaborative scenarios. The CSA Input and Output format used in Tables 5.2 and 5.3 could be used to present the process and results of these types of assessments. Another option could be to use the format as part of the interface for a software tool where inputs are entered step-by-step in response to a sequence of questions. Such a tool could allow for either general or detailed assessments of collaborative systems based on what the user wanted to specify. In order to maintain operational fidelity, the questions could be tied closely to aspects of realistic flight scenarios. Outputs would provide the benefits and risks as well as trades that were shown in the CSA Output. In addition, outputs could be linked to related documents and research if more comprehensive information was desired.

A software tool is not the only option. A third way to utilize the CSA framework is in the design a handbook with a set of sections that include general and specific assessments based on a pre-determined set of scenarios. Given there are many NextGen procedures and technologies, many topic areas can be identified. For example, one area of implementation, such as TBO, could specify scenarios of greatest interest and concern to trajectory management. Alternatively, input scenarios could grow in specificity as more details are known or new automation technologies become available. Many other options for developing such a handbook are possible depending on the targeted users and their needs. The most effective implementation of the CSA framework would depend on the needs of stakeholders, customers and fellow researchers in providing collaborative system assessments that are based on a common set of concepts, measures and NextGen assumptions.

6.0 References

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Appendices

Appendix A: Pilot communication survey

Pilot Communication Survey

This survey is part of NextGen research to identify the most likely methods for collaboration between pilots, ATC and AOC, focusing on Trajectory Based Operations (TBO). The survey is based on a task list by phase of flight detailing pilot communication with air traffic controllers (ATC) or dispatchers that have been identified inflight operations manuals.

The objective of the survey is to identify the frequency and safety criticality of the key pilot to ATC and dispatch communications. On this page, please complete the Background Information. Do not provide your name or other identifying information, and all data will be held in confidence.

After completing the Background Information, please proceed to the second page and rate communications generally taking place in Nominal operations. Rate Frequency based on the how often the specific communication takes place across all operations at your airline (not just your immediate personal experience). The last page asks you to rate communications under conditional or off-nominal operations. These are items that are by definition, less frequent, so please rate their Frequency, from Very Low to High based on all off-nominal or conditional operations.

Background Information: Please complete all boxes (Confidential Data)

Total flight time (hours) ________	Years using **RNP** Required Navigation Performance ________
Years with current operator ________	
Current Fleet (**circle one**) A319/20 A330 B737 B757/67	As a pilot, what are the 2 most workload intensive interactions with **ATC?** 1________ 2________
Years in current Fleet _______	What are the 2 most workload intensive interactions with **Dispatch?** 1________ 2________
Flight time in current fleet (hours) ______	As a pilot, what are the 2 **ATC** interactions most needing automation? 1________ 2________
Current seat (**circle one**) CAPT FO	As a pilot, what are the 2 **Dispatch** interactions most needing automation? 1________ 2________

Instructions: *On the next two pages, you are presented with nominal and off-nominal types of communication required from the flightdeck. Please read each communication, either with Air Traffic Control (ATC) or dispatch and determine its frequency and criticality within overall operations.*

For Frequency, please use the following rating guideline by circling just one frequency (VL L M or H) for each type of communication and note the different meaning of frequency for nominal vs. off-nominal operations:

VL *- Very Low (Less than 5 percent of operations - very infrequent)*
L *- Low (Less than 25 percent of operations - infrequent)*
M *- Medium (More than 25 percent and less than 75 percent of operations)*
H *- High (More than 75 percent of operations - something that usually occurs)*

For Criticality, please use the following rating guideline by circling just one Criticality (L M or H) for each type of communication:

L *- Low (Little risk to the safety of the flight)*
M *- Medium (Moderate risk to the safety of the flight)*
H *- High (High risk to the safety of the flight)*

Thank you for your participation and time!

Table A.1. Nominal Operations Pilot Communication (Please Circle one for Frequency and One for Criticality)

Flight Phase	Communication Procedure/Subtask	Frequency	Criticality
Preflight	Call dispatch when at the gate to get preflight briefings	VL L M H	L M H
Preflight	Ask ATC for clarification if conflict exists when building a transition	VL L M H	L M H
Preflight	Request PDC via ACARS	VL L M H	L M H
Preflight	Inform controllers on initial contact of the ATIS identifier they have reviewed	VL L M H	L M H
Preflight	Advise dispatch if route clearance differs from flight release IFR routing	VL L M H	L M H
Preflight	Notify the controlling dispatch when duty limitations necessitate departure time adjustment	VL L M H	L M H
Preflight	Contact dispatch if a change in either route or altitude is desired	VL L M H	L M H
Preflight	Contact dispatch if an alternate is not required for the destination	VL L M H	L M H
Preflight	Concur with dispatch if hold fuel is to be reduced or eliminated	VL L M H	L M H
Preflight	Coordinate with dispatch if there are any changes to the release	VL L M H	L M H
Taxi	Obtain taxi clearance from ATC prior to taxiing onto a movement area	VL L M H	L M H
Taxi	Acknowledge any hold short instructions to ATC	VL L M H	L M H
Taxi	Advise ATC if either pilot is uncertain of airport orientation of location on runway	VL L M H	L M H
Taxi	Contact ATC if holding in position for more than 90 seconds or upon seeing a potential conflict	VL L M H	L M H
Taxi	Conference with dispatch if on aircraft flight delay	VL L M H	L M H
Taxi	Advise ATC and dispatch of decision to return to gate	VL L M H	L M H
Taxi/takeoff	Request ATC clearance prior to operating an aircraft on a runway or taxiway or taking off	VL L M H	L M H
Taxi/takeoff	Request a different runway other than the noise abatement runway in the interest of safety	VL L M H	L M H
Taxi/takeoff	Contact dispatch by VHF or phone to obtain departure clearance with applicable void time	VL L M H	L M H
Taxi/takeoff	Notify ATC of any delays upon reaching the end of the runway	VL L M H	L M H
Taxi/takeoff	Notify ATC if max thrust takeoff was not successful or not attempted	VL L M H	L M H
Inflight	Confirm clearance paying attention those received in areas of high terrain, or include a change to heading, route/waypoints, altitude, or involve instructions for holding short of a runway	VL L M H	L M H
Inflight	Advise ATC if cruising airspeed varies from that given in the Flight Release	VL L M H	L M H
Inflight	Acknowledge receipt of traffic advisories	VL L M H	L M H
Inflight	Inform ATC if traffic in sight	VL L M H	L M H
Inflight	Advise ATC if a vector to avoid traffic is desired	VL L M H	L M H
Inflight	Advise ATC if traffic advisory service is not desired	VL L M H	L M H
Inflight	Advise ATC if unable to maintain visual separation	VL L M H	L M H
Inflight	Request VFR-on-top	VL L M H	L M H
Inflight	Advise ATC prior to any altitude change to ensure the exchange of accurate traffic information	VL L M H	L M H
Inflight	Request clarification from ATC if uncertain of an ATC clearance	VL L M H	L M H
Inflight	Report time and altitude of passing each designated reporting point	VL L M H	L M H
Inflight	Report any information related to the safety of flight	VL L M H	L M H
Inflight	Make enroute position reports for traffic control purpose at all compulsory points and at additional points as requested by FAA	VL L M H	L M H
Inflight	Report vacating any previously assigned altitude or flight level for a newly assigned level.	VL L M H	L M H
Inflight	Report unable to climb/descend at a rate of at least 500 FPM.	VL L M H	L M H
Inflight	Request clearance for specific action (i.e., to alternate airport, another approach, etc.)	VL L M H	L M H
Inflight	Report time and altitude, or flight level, upon reaching a holding fix or point to which cleared	VL L M H	L M H
Inflight	Report leaving any assigned holding fix or point	VL L M H	L M H
Inflight	Advise ATC if an airspeed greater than the maximum holding airspeed is necessary.	VL L M H	L M H
Inflight	Notify dispatch of ETA changes greater than 5 minutes.	VL L M H	L M H
Inflight	Notify ATC if speed differs from flight plan by more than 5% or 10 knots	VL L M H	L M H
Inflight	Coordinate with dispatch to determine best route/altitude if fuel consumption greater than planned	VL L M H	L M H
Inflight	Advise dispatch if given a clearance change (reclearance)	VL L M H	L M H
Inflight	Notify dispatch if route changes significantly	VL L M H	L M H
Inflight	Notify dispatch if unplanned holding or delaying vectors and/or reduced airspeed	VL L M H	L M H
Approach	Advise ATC If a visual approach is not desired	VL L M H	L M H
Approach	Advise ATC immediately if the pilot is unable to continue following the preceding aircraft, cannot remain clear of clouds, needs to climb, or loses sight of the airport.	VL L M H	L M H
Approach	Report leaving final approach fix inbound on final approach WHEN NOT IN RADAR CONTACT	VL L M H	L M H
Approach	Report a corrected ETA anytime it becomes apparent an ETA, as previously submitted, is in error in excess of 3 minutes WHEN NOT IN RADAR CONTACT	VL L M H	L M H
Approach	Transmit “Traffic in sight” to ATC as soon as you are confident the traffic can remain in sight when flying LDA/PRM procedure after being notified there is traffic on the ILS	VL L M H	L M H

Table A.2. Off-Nominal Operations Pilot Communications (Note that Frequency is based on Off-Nominal Ops)

Flight Phase	Communication Procedure/Subtask	Frequency	Criticality
Preflight	Contact dispatch (If performance limitations or inflight restrictions preclude operations)	**VL L M H**	**L M H**
Preflight	Communicate mechanical delays to dispatch	**VL L M H**	**L M H**
Preflight	Captain and dispatch will determine if pair is acceptable (If SPAR condition/procedure pair)	**VL L M H**	**L M H**
Preflight	Notify dispatch if FOB exceeds release fuel (If weight restricted flight)	**VL L M H**	**L M H**
Preflight	Contact dispatch (If TPS but no performance adjustment entered)	**VL L M H**	**L M H**
Preflight	Contact dispatch (If fuel is greater or less than the Gate Release fuel)	**VL L M H**	**L M H**
Preflight	Notify dispatch if TPS data are not correct	**VL L M H**	**L M H**
Preflight	Notify dispatch if any condition prohibits acceptance of PRM clearance (If departing to airports where PRM operations are authorized)	**VL L M H**	**L M H**
Preflight	Performance adjustment made by dispatch	**VL L M H**	**L M H**
Preflight	Notify dispatch if actual fuel on board exceeds gate release fuel by any amount (If weight restricted or capped flight)	**VL L M H**	**L M H**
Preflight	Concur with dispatch whether operations can continue (If precipitation accumulation on runway more than .5 inch)	**VL L M H**	**L M H**
Preflight	Contact dispatch (If nil braking action report)	**VL L M H**	**L M H**
Preflight	Notify ATC of the discrepancy (If incorrect indication of icing restrictions)	**VL L M H**	**L M H**
Preflight	Obtain clearance from ATC prior to starting engines and/ or taxiing out of any de/anti-icing area	**VL L M H**	**L M H**
Preflight	Obtain amended release from dispatch (If immediate maintenance action not required)	**VL L M H**	**L M H**
Preflight	Confer with dispatch (If clearance differs from the Flight Release routing)	**VL L M H**	**L M H**
Taxi	Contact dispatch (If discrepancy prior to takeoff)	**VL L M H**	**L M H**
Inflight	Obtain ATC clearance (If diverting)	**VL L M H**	**L M H**
Inflight	Determine nearest suitable airport with dispatch (If emergency landing)	**VL L M H**	**L M H**
Inflight	Notify dispatch (If landing at unauthorized airport)	**VL L M H**	**L M H**
Inflight	Contact ATC and dispatch once aircraft is under control (If emergency)	**VL L M H**	**L M H**
Inflight	Declare emergency fuel status (If emergency fuel advisory)	**VL L M H**	**L M H**
Inflight	Advise ATC if unable to comply with RNAV procedure	**VL L M H**	**L M H**
Inflight	Advise ATC if unable to comply with RNP procedure	**VL L M H**	**L M H**
Inflight	Report unable RNP-10 (If less than dual FMS with at least dual INS or a single INS and GPS)	**VL L M H**	**L M H**
Inflight	Contact OCC prior to requesting a routing that deviates from the filed NRP route	**VL L M H**	**L M H**
Inflight	Contact ATC (If an FMC, FMGC, GPS/IRS fails inflight)	**VL L M H**	**L M H**
Inflight	Notify ATC (If loss of All GPS/IRS and FMC procedures)	**VL L M H**	**L M H**
Inflight	Report to ATC a degrade in the aircraft's navigational capability as soon as possible	**VL L M H**	**L M H**
Inflight	Report to ATC (If loss of VOR, ADF, complete/partial loss of ILS receiver capability)	**VL L M H**	**L M H**
Inflight	Request new clearance (If any RVSM system fails)	**VL L M H**	**L M H**
Inflight	Advise ATC (If anything affects the RVSM status or ability to maintain flight level within 150 feet)	**VL L M H**	**L M H**
Inflight	Notify ATC (If RNP-10 minimum equipment is not available)	**VL L M H**	**L M H**
Inflight	Contact ATC & request authority to continue operating at cleared flight level (If transponder fails)	**VL L M H**	**L M H**
Inflight	Advise ATC and OCC of the failure (If radar failure)	**VL L M H**	**L M H**
Inflight	Contact ATC or OCC for PIREPS and other information (If radar attenuation)	**VL L M H**	**L M H**
Inflight	Notify ATC via PIREP of any severe weather condition that might adversely affect safety of flight	**VL L M H**	**L M H**
Inflight	Advise dispatch (If unforecasted or unreported weather conditions that might affect operations)	**VL L M H**	**L M H**
Inflight	Notify ATC (If significant weather observations)	**VL L M H**	**L M H**
Inflight	Contact ATC as early as possible for deviations (If hazardous weather)	**VL L M H**	**L M H**
Inflight	Keep ATC advised of intentions and obtain traffic information (If deviation greater than 10 NM)	**VL L M H**	**L M H**
Inflight	Coordinate with ATC and other aircraft (If wake turbulence is encountered or anticipated)	**VL L M H**	**L M H**
Inflight	Notify ATC and request a revised clearance prior to deviating (If unable to maintain routing)	**VL L M H**	**L M H**
Inflight	Contact dispatch (If diverting)	**VL L M H**	**L M H**
Inflight	Revert to voice procedures (If any question about clearance received via datalink)	**VL L M H**	**L M H**
Inflight	Contact ATC by voice (If no reply within 15 minutes of datalink request for clearance)	**VL L M H**	**L M H**
Inflight	Acknowledge the clearance by datalink as soon as possible (If given a clearance via datalink)	**VL L M H**	**L M H**
Approach	Coordinate with ATC prior to applying any corrections (If Cold Temperature Approach Altitude Corrections)	**VL L M H**	**L M H**
Approach	Notify ATC the flight will level off at the controlling minimum altitude (If the Cleared Altitude is Below the Applicable Minimum Altitude)	**VL L M H**	**L M H**
Approach	Notify ATC within 100 miles of the airport (If ILS/PRM procedures are in effect and they cannot fly the approach)	**VL L M H**	**L M H**

Appendix B: ATC data collection methodology

This appendix describes the methodology used to collect data on controllers' responsibilities and controllers' interactions with pilots and dispatchers. Two methods were combined: 1) Analyses of tasks and responsibilities, and 2) A process charting method.

In both methods, data was collected and analyzed by interviewing three Subject Matter Experts. The SME were retired controllers who had practice with procedures currently used in ATC facilities. There was a Radar Controller from an En Route Center, a Radar Controller/Supervisor from a TRACON facility, and a Local Controller from a large airport Tower.

The method to analyze controllers' responsibilities followed a cognitive task analysis process, but instead of analyzing tasks, the focus was on responsibilities. For each controllers' responsibility listed in section 2-10 in FAA JO 7110.65T, SME described what the controllers do, in which circumstances, what was communicated, the purpose, and from/to whom. This was detailed for each position at each facility. This analysis provided support to understand the controllers' roles and functions in collaborations with other controllers, and with both pilots and dispatchers in various situations.

The method to analyze controllers' collaborative tasks followed the processing chart method to obtain Operation Sequence Diagram (Stanton, Salmon, Walker, Baber, & Jenkin, 2005). This method has three steps. First, activities and related tasks are identified. Second, activities are decomposed into specific task steps. Third, process flows are built to depict the progress of tasks and collaboration between the operators. All three steps were conducted with SMEs.

The first step of identifying activities and tasks was achieved by interviewing SMEs. Semi-structured questions were used to cover the work environment, the technology used, the schedule, the relationships with colleagues and customers, the regulations, the function and the activities of each position in a sector. For the activities, the task, the treatment of information, the importance and the type of errors were also gathered. Significant topics such as, emergencies, change of runway configuration, weather, transfer of control and separation of traffic were discussed.

The second step involved reviewing interviews and identifying significant activities with regards to responsibilities and function of the positions. Controller activities were highly redundant and did not appear to follow a particular order of activities. At a lower level of tasks, specific tasks seem to be done in similar ways. At on a higher level of activity, many tasks are repetitive and seem to be dependent on the traffic demand. From the flightdeck perspective, a flight is a linear product that progress from point A to point B. Because of these two different work processes, controllers described recurrent control activities, as well as various flight progresses. The following flight progresses were identified for Tower and TRACON: Departure, approach, and missed approach. The following activities were identified for En Route Center: Cruise, climb, descent with handoff to TRACON, approach, and landing to airport with or without a Tower. Then, for each flight progress, the sequence of control was described in detail by SMEs. Each activity was decomposed into sub-activities following a step-by-step process (task list). Steps were defined by the content and the goal of each action, whether they were individual or interactive. Physical movements were not described. Variations of steps were included to take into account needs of coordination depending on situational constraints.

Third, these sequences were depicted in process charts following the Operation Sequence Diagram method. SMEs consulted to build the process charts and reviewed them for accuracy. Microsoft Visio software was used to draw the charts. Symbols were taken from the AMSE standards (AMSE, 1972). The advantage of such method is that is shows clearly the sequence of actions, its interdependencies, its outcomes. From the collaborator point of view, it shows the type of task and information transfer one is handling for a given product. A process chart of a handoff is presented in Figure 1. The process charts indicate the most common interactions points between ATC and between ATC and flightdecks or FOC, for all types of facilities and sectors, and thus for all phases of flights.

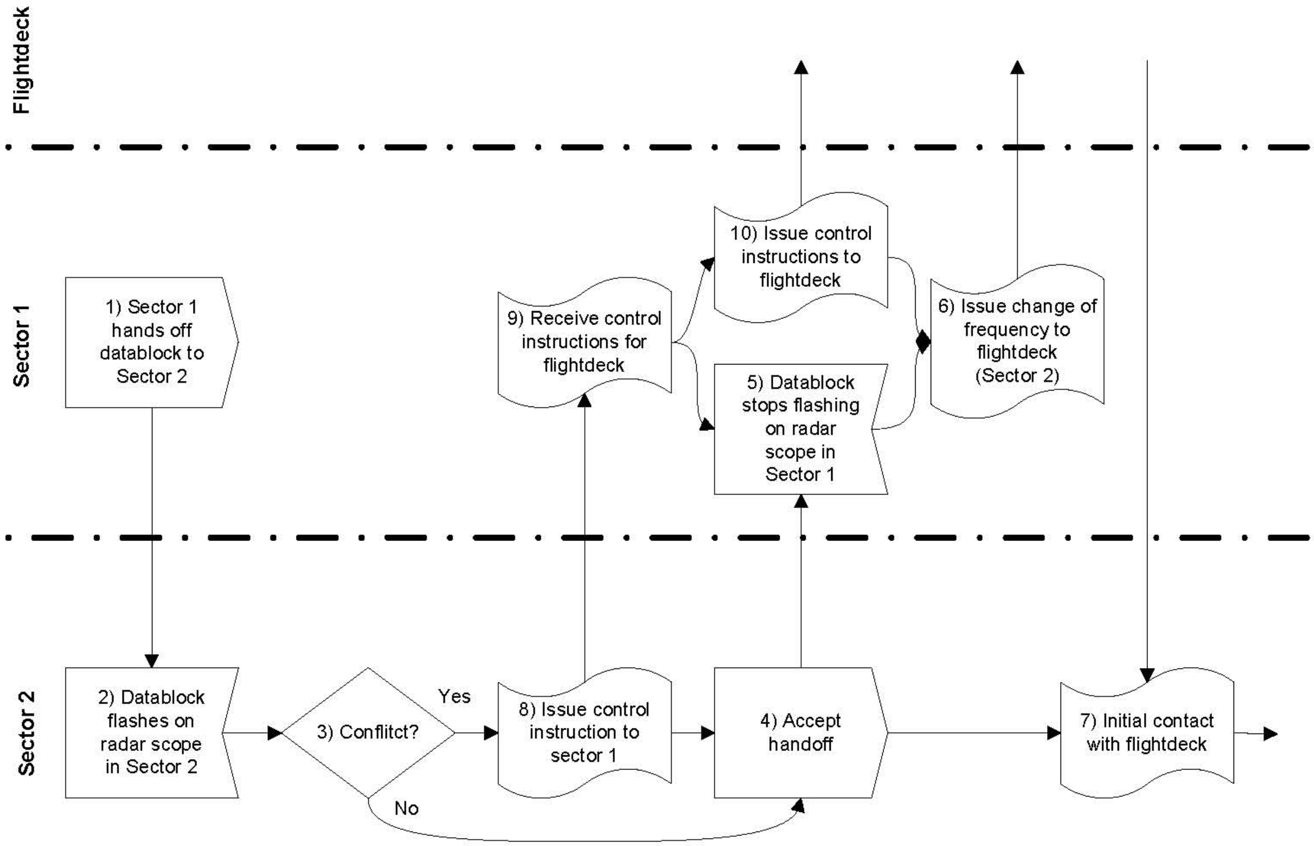

Figure 1. Extract of a handoff between 2 sectors at ARTCC.

The Figure 1 shows an example of a simplified process of handoff between two sectors and the relative interactions with the flightdeck. The two dotted lines represent a physical separation between the people who interact. In this process there are 2 controllers in two separate sectors at an En Route Center, as well as the pilots in the flightdeck. Each symbol represents a step. The arrows indicate the direction of the flow in the process. Each figure has a number to facilitate the description of the process. The process is the following:

1) A Radar Controller in Sector 1 hands off the flight's datablock to Sector 2, via PVD.
2) The flight's datablock flashes on the radar scope in Sector 2.
3) The Radar Controller in sector 2 sees Sector 1 would like to hand off the flight. The Radar Controller then checks if there is any need to issue control instructions to Sector 1 before the flight enter Sector 2. The most common reason is the potential risk for conflict with traffic in Sector 2. If it is not the case, the Radar Controller accepts the handoff (see point 4), otherwise the Radar Controller will issue control instructions to Sector 1 (see point 8).
4) There is no need to issue control instructions to Sector 1. The controller in sector 2 accepts the handoff on the keyboard.
5) The datablock in Sector 1 stops flashing indicating that the controller in Sector 2 has accepted the handoff.
6) The controller in Sector 1 requests the flightdeck to contact new sector onto new radio frequency.
7) The flightdeck makes an initial contact with the Radar Controller in Sector 2 onto the new frequency.
8) There is a need to issue control instructions to Sector 1. The controller in sector 2 issues control instruction to Sector 2 for the incoming flight.
9) The controller in Sector 1 receives and agrees on the control instruction to relay to the flightdeck.
10) The Radar Controller in Sector 1 issues the control instructions to the flightdeck.
    - 6) The Radar Controller will likely add the request to change frequency and contact Sector 2 in the same clearance.
    - 4) In the meantime, the Radar Controller in Sector 2 accepts the handoff, and,
    - 5) the Radar Controller in Sector 1 see that the Radar Controller in Sector 2 has accepted the handoff.
    - 7) Then, the flightdeck makes an initial contact with the Radar Controller in Sector 2 onto the new frequency.

Appendix C: ATC interactions by controller positions and facility.

The following tables (C1, C2, and C3) list the interactions from ATC with the flightdeck or FOC. Table C-1 lists the interactions under nominal conditions with the flightdeck and FOC (indicated in gray lines). Table C-2 lists the interaction within ATC under nominal conditions. Table C-3 lists the interaction under off-nominal condition both with flightdeck and FOC, and within ATC. The interactions are also listed by facilities (white lines). The controllers' positions are also indicated in regards off each interaction. The acronyms are the following: R stands for Radar Controller; RA stands for Radar Associate; LC stands for Local Controller; GC stands for Ground Controller, CD/FD stands for Clearance Delivery/Flight Data; Sup stands for Supervisor; and finally TMU stands for Traffic Management Unit.

Table C-1. Interactions with flightdeck and FOC under Nominal conditions.

Interactions under Nominal conditions	
With flightdeck	
By En Route, TRACON and Tower Controllers	***Controller position***
Initial contact with pilots	R, RA, LC, GC, CD/FD
Request pilots to contact other controller onto a new frequency	R, RA, LC, GC, CD/FD
Read back communication from pilots	R, RA, LC, GC, CD/FD
Request pilots to report identification, position, altitude, or information	R, LC, GC
Check with pilots if STAR or ATIS (if applicable) statuses are current	R, LC, GC, CD/FD
Relay ATIS information to pilots	R, LC, GC, CD/FD
Advise pilots to get new ATIS information	R, LC, GC, CD/FD
Relay PIREPs to other pilots	R, LC, GC
Inform pilots about adverse conditions	R, LC, GC
Advise pilots for traffic	R, LC
Receive traffic in sight advisories by pilots	R, LC
Caution pilots for wake turbulence	R, LC
Control flight data accuracy with pilots	R, LC, GC
By En Route and TRACON Controllers	
Receive pilots' intentions (altitude, heading, speed, route, deviation, destination, approach, runway)	R
Receive pilots' report of change of altitude, heading, or passing location	R
Provide control instructions and clearances to pilots regarding their heading, altitude, speed, fix point, via radio (as filed, to allow a shortcut or to delay (vectoring, sequencing)	R
Clear pilots for change of altitude, heading, speed, approach.	R
Communicate altimeter at or under 17'000ft to pilots	R
Clear pilots for a different approach than filled or advised (e.g. visual instead of ILS)	R
Verify identity and altitude leaving and assigned + provide additional instructions to pilots, if needed.	R
By Tower Controllers	
Receive pilots' intentions (Pre-Departure, pushback, star engines, taxi, runway, de-icing, departure time, takeoff, gate)	LC, GC, CD/FD
Receive pilots' report of position	LC, GC
Receive a Pre-Departure Clearance (flight plan) request from pilots, digitally (ACARS) or by voice (radio)	CD/FD, GC, LC
Amend Pre-Departure Clearance (flight plan), digitally (ACARS) or by voice (radio), (based on weather, traffic constraints)	CD/FD, GC, LC
Clear Pre-Departure Clearance (flight plan) to pilots	CD/FD, GC, LC
Issue delay/flow restrictions to departing aircraft	CD/FD, GC, LC
Coordinate delay/flow restrictions with departing aircraft	CD/FD, GC, LC
Clear pilots for pushback, taxi route, crossing taxiway and runway	GC, LC
Clear pilots for takeoff, landing, exit point of runway	LC
Abort takeoff	LC
Issue a clearance limit to pilots (hold short point)	LC, GC
Coordinate pilots position and movements requests prior to departure	GC, LC
Initiate rundown for departing flights with flightdecks	LC
Clear approach to runway to pilots	LC
Inform pilots of wind, runway condition, breaking actions	LC
With FOC By any facility	
Receive flight data in the system from dispatch	CD/FD, RA, R
Relay information between dispatch and pilots (when needed)	Sup
Coordinate customers questions (most often dispatch, about weather, runway or approach condition and configuration, restricted airspace)	Sup
Coordinate alternative flight destinations with dispatch (when needed)	Sup

Table C-2. Interactions within ATC under Nominal conditions.

Interactions under Nominal conditions	
Within ATC	
By En Route, TRACON and Tower Controllers	***Controller position***
Receive flight strips (automatically printed 30 min before flight operation is expected at fix point or airport)	CD/FD
Process and transfer paper flight strips to controller	CD/FD to GC/RA/R, GC to LC, RA to R
Receive flow control instructions from TMU	R, RA, LC, Sup
Coordinate with other sectors about aircraft separation, sequencing or delaying traffic, approach configuration, adverse conditions	R, RA, LC, Sup
Relay information about adverse conditions to other sectors, facilities and flow control (e.g., PIREPs, RWY conditions, emergencies, equipment failure)	Sup
By En Route and TRACON Controllers	
Coordinate alternative flight destinations with FOC (when needed)	Sup
Accept handoff (datablock PVD) from radar controller of neighboring sector, electronically (keyboard)	R, RA
Request radar controller (R or RA) of neighboring sector to relay control instructions prior to entering into sector	R, RA
Inform neighboring sector controller (R or RA) about restrictions (speed, altitude, heading)	R, RA
Forward datablock (PVD) to other related sectors (examples: From high altitude sector to a sequencing sector (En Route), From a feeder sector to a final approach sector (TRACON), From a departure sector to a feeder sector after a missed approach (TRACON)	R, RA
Coordinate a pointout with other sector (R or RA)	R
If approach to non-equipped tower (class C to F), inform Tower controller of aircraft approach, time of arrival, call sign, type of aircraft, and direction if approach is visual, at least 10 min prior to landing.	R
Provide departure clearance + amendment for given flight to Local controller, over the phone	R, RA
Accept/release departing flight digitally or by phone (with Local controller)	R, RA
Amend flight plan for Local controller prior to departure	R, RA
By Tower Controllers	
Coordinate FP amendments with other sectors (TRACON, En Route)	CD/FD, GC, LC
Coordinate runway crossing	GC with LC
Request departure release to departure sector, by phone	LC
Activate flight data of departing flights (input or scan flight information (squawk or SID codes))	LC
Inform flightdecks of off-nominal mechanical issues (gears problem, fire)	LC
Request departure release for flight, via digitally (scan) or voice (phone)	LC

Table C-3. Table C-1. Interactions with flightdeck or FOC, and within ATC under Off--Nominal conditions.

Interactions under Off-Nominal Conditions	
Holding by En Route Controllers	**Controller position**
With Flightdeck or FOC	
Warn pilots of holding instruction at least 5 minutes before reaching holding fix point	R
Provide control instructions to pilots for holding procedures as published or else	R
Clear pilots to go on holding or to continue as filed	R
Coordinate with pilots/FOC for an alternative destination if minimum fuel, when holding	R, Sup
Within ATC	
Advise other sectors, when aircraft goes on holding	R, RA, Sup
Coordinate with flow control, sup or TRACON sector for allowing aircraft to continue, when aircraft is on holding	R
Missed Approach by TRACON or Tower Controllers	
With Flightdeck or FOC	
Initiate go-around (missed approach) + plus give instruction for altitude and heading to pilots	R, LC
Relay control instructions from departure sector to pilots (missed approach)	R, LC
Within ATC	
Coordinate aircraft missed approach with other sectors	R, RA
Coordinate missed approach with departure sector	R, RA, LC
Emergency (medical or mechanical) by En Route, TRACON or Tower Controllers	
With Flightdeck or FOC	
Declare emergency to pilots	R, LC, GC
Coordinate with pilots emergency declaration	R, LC, GC
Request the pilots to state the number of souls on board, remaining fuel and cause of emergency	R, LC, GC
Coordinate with pilots how ATC can help, during emergency	R, RA, LC, GC
Coordinate with dispatch in case of emergency	Sup
Coordinate ATC help to pilots during emergency	Sup
Inform pilots of off-nominal mechanical issues (gears problem, fire)	LC
Within ATC	
Alert supervisor and other sectors of aircraft in emergency	R, RA, LC, GC
Coordinate change of runway configuration with other facilities	Sup, TMU

Note: unless specified otherwise, Ground-Ground communication (between controllers themselves and with dispatchers) is over the telephone/interphone, and air-ground communication (between controllers and flightdecks) is over a radio frequency.

Appendix D: FOC communication survey

The following tables (D-1 to D-4) show the questions of the FOC communication survey the dispatchers filled out after the observations described in section 2.3.3. The methodology used for the FOC communication survey was similar to the one used for the flightdeck survey in section 2.3.1. Respondents had to rate 36 interactions with the flightdeck, and 21 with ATC, among them, half were in off-nominal conditions. The items were rated for frequency and criticality. The scales were identical to the pilots' questionnaire: Frequency (1 = Very Low, 2 = Low, 3 = Medium, 4 = High) and criticality (1 = Low, 2 = Medium, 3 = High) using the same scales in the pilots' survey.

Table D-1 lists nominal interactions with the flightdeck. Table D-2 list off-nominal interactions with the flightdeck. Table D-3 lists nominal and off-nominal interactions with ATC. Table D-4 was used for additional items the dispatchers could suggest and rate.

Dispatch Frequency and Criticality of Interactions

Below is a listing of nominal communication or interaction you may have with Aircraft or Pilots. Read each communication and determine its Frequency within Nominal operation and its Criticality to safety of flight.

Please Circle One for Frequency and One for Criticality where VL=Very Low L=Low M=Medium H=High
<5% of time 5-25% 26-75% >75%

Table D-1. Nominal Operation Communication or Interaction with Aircraft by Frequency and Criticality.

Flight Phase	Nominal Operations Communication or Interactions with Aircraft	Frequency	Criticality
Preflight	With aircraft/pilot to get preflight briefings	VL L M H	L M H
Preflight	With aircraft/pilot requesting PDC via ACARS	VL L M H	L M H
Preflight	With aircraft/pilot, if route clearance differs from flight release IFR routing	VL L M H	L M H
Preflight	With aircraft/pilot, when duty limitations necessitate departure time adjustment	VL L M H	L M H
Preflight	With aircraft/pilot, if a change in either route or altitude is desired	VL L M H	L M H
Preflight	With aircraft/pilot, if hold fuel is to be reduced or eliminated	VL L M H	L M H
Preflight	With aircraft/pilot, if there are any changes to the release	VL L M H	L M H
Preflight	With aircraft/pilot, if release disagreement	VL L M H	L M H
Preflight	With aircraft/pilot, if cold weather/icing conditions	VL L M H	L M H
Preflight	With aircraft/pilot, if ground delay programs are implemented	VL L M H	L M H
Taxi	With aircraft/pilot, if on aircraft flight delay	VL L M H	L M H
Taxi/takeoff	With aircraft/pilot, to obtain departure clearance with applicable void time	VL L M H	L M H
Inflight	With aircraft/pilot, to establish voice communication	VL L M H	L M H
Inflight	With aircraft/pilot, if ETA changes greater than 5 minutes	VL L M H	L M H
Inflight	With aircraft/pilot, if fuel consumption greater than planned	VL L M H	L M H
Inflight	With aircraft/pilot, if given a clearance change (reclearance)	VL L M H	L M H
Inflight	With aircraft/pilot, if route changes significantly	VL L M H	L M H
Inflight	With aircraft/pilot, if unplanned holding or delaying vectors	VL L M H	L M H
Inflight	With aircraft/pilot, if reduced airspeed	VL L M H	L M H

Below is a listing of off-nominal or conditional communications you may have with Aircraft or Pilots. Read each communication and determine its frequency within all off-nominal or conditional operations.

Please Circle One for Frequency and One for Criticality where VL=Very Low L=Low M=Medium H=High
<5% of time 5-25% 26-75% >75%

Table D-2. Off-Nominal Operation Communications or Interactions with Aircraft by Frequency and Criticality.

Flight Phase	Off-Nominal or Conditional Operations Communications/Interactions	Frequency	Criticality
Preflight	With aircraft/pilot, if their performance limitations or inflight restrictions preclude operations	VL L M H	L M H
Preflight	With aircraft/pilot, if they have mechanical delays	VL L M H	L M H
Preflight	With aircraft/pilot, if FOB exceeds release fuel for weight restricted flight	VL L M H	L M H
Preflight	With aircraft/pilot, if Takeoff Performance System data are not correct	VL L M H	L M H
Preflight	With aircraft/pilot, if fuel is greater or less than the Gate Release fuel	VL L M H	L M H
Preflight	With aircraft/pilot, if any condition prohibits acceptance of PRM clearance If departing to airports where PRM operations are authorized	VL L M H	L M H
Preflight	With aircraft/pilot, if performance adjustment made by dispatcher	VL L M H	L M H
Preflight	With aircraft/pilot, if actual fuel on board exceeds gate release fuel by any amount for weight restricted or capped flight	VL L M H	L M H
Preflight	With aircraft/pilot, to concur with dispatch whether operations can continue, if precipitation accumulation on runway more than .5 inch	VL L M H	L M H
Preflight	With aircraft/pilot, if nil braking action report	VL L M H	L M H
Preflight	With aircraft/pilot, to obtain amended release, if immediate maintenance action not required	VL L M H	L M H
Preflight	With aircraft/pilot, if their clearance differs from the Flight Release routing	VL L M H	L M H
Taxi	With aircraft/pilot, if discrepancy prior to takeoff	VL L M H	L M H
Inflight	With aircraft/pilot, to determine nearest suitable airport if emergency landing	VL L M H	L M H
Inflight	With aircraft/pilot, if landing at unauthorized airport	VL L M H	L M H
Inflight	With aircraft/pilot, if emergency	VL L M H	L M H
Inflight	With aircraft/pilot, if requesting a routing that deviates from the filed NRP route	VL L M H	L M H
Inflight	With aircraft/pilot, if unforecasted or unreported weather conditions might affect operations	VL L M H	L M H
Inflight	With aircraft/pilot, if they are diverting	VL L M H	L M H

Dispatch Frequency and Criticality of Interactions

Below is a listing of communications you may have with Air Traffic Controllers. Please read each communication and determine its Frequency and Criticality.

Please Circle One for Frequency and One for Criticality where VL=Very Low L=Low M=Medium H=High
<5% of time 5-25% 26-75% >75%

Table D-3. Nominal and Off-Nominal Operation Communications or Interactions with ATC by Frequency and Criticality.

Flight Phase	Nominal and Off-Nominal Operations Communications/Interactions	Frequency	Criticality
Preflight	With ATC, to require changes on Flight plan prior to the Flight release clearance	VL L M H	L M H
Preflight	With ATC, if flight data is not correct on flight plan, prior to the Flight release clearance	VL L M H	L M H
Preflight	With ATC, if aircraft has mechanical delays	VL L M H	L M H
Preflight	With ATC, to enquire about runway condition,	VL L M H	L M H
Preflight	With ATC, to obtain PIREPs	VL L M H	L M H
Preflight	With ATC, if flight is delayed over 15min	VL L M H	L M H
Preflight	With ATC, if flight is cancelled.	VL L M H	L M H
Preflight	With ATC, if flight plan needs to refilled, because Flight release becomes void	VL L M H	L M H
Inflight	With ATC, to determine nearest suitable airport if emergency landing	VL L M H	L M H
Inflight	With ATC, to determine alternative airport when aircraft is holding	VL L M H	L M H
Inflight	With ATC, to submit a re-release of flight plan	VL L M H	L M H
Inflight	With ATC, if aircraft is landing at an unauthorized airport	VL L M H	L M H
Inflight	With ATC, if aircraft is diverting	VL L M H	L M H
Inflight	With ATC, to enquire about weather impact	VL L M H	L M H
Inflight	With ATC, to coordinate reroute of flights, because of adverse conditions (weather)	VL L M H	L M H
Inflight	With ATC, to obtain PIREPs	VL L M H	L M H
Inflight	With ATC, to enquire about runway condition (braking actions) at airport of destination	VL L M H	L M H
Inflight	With ATC, to enquire about approach configuration at airport of destination	VL L M H	L M H
Inflight	With ATC, if ground delay programs are being implemented	VL L M H	L M H
Inflight	With ATC, if ground stops are being implemented	VL L M H	L M H
Inflight	With ATC, to transmit information to pilots, because direct communication with pilots is broken down	VL L M H	L M H

In your experience, are there other frequent or critical communications interactions that are not listed above? If so, please describe briefly the purpose of the interaction and rate it for Frequency and Criticality.

Table D-4. Other non-listed Operation Communications or Interactions by Frequency and Criticality.

Interaction	Description	Frequency	Criticality
With aircraft/pilot		VL L M H	L M H
With aircraft/pilot		VL L M H	L M H
With aircraft/pilot		VL L M H	L M H
With aircraft/pilot		VL L M H	L M H
With aircraft/pilot		VL L M H	L M H
With ATC		VL L M H	L M H
With ATC		VL L M H	L M H
With ATC		VL L M H	L M H
With ATC		VL L M H	L M H
With ATC		VL L M H	L M H

Thank you for your help!

Appendix E: Flightdeck-ATC-FOC Interaction Matrix

The following tables (E-1 to E-13) list the main interactions between ATC, Flightdeck and FOC during nominal and off-nominal events in a generic flight. The methodology is described in section 3. For each table, the header are the following: “Media” used to communicate; “subject” with underneath the corresponding “group” and “position” of the person involved (For ATC position, the facility is also specified); “interacting with” with underneath the corresponding “group” and “position” of the person involved (For ATC position, the facility is also specified); finally the “interactions” are specified for each entry in the table. For the ATC position, the facility is also specified, and the following acronyms are used: CD stands for Clearance Delivery; GC stands for Ground Controller; LC stands for Local Controller; R stands for Radar Controller; RA stands for Radar Associate; and finally TMU stands for Traffic Management Unit. The main steps of the flight are indicated with horizontal black line headers. The horizontal gray line headers are sub-steps of main steps. The off-nominal events are indicated in italic and white line horizontal header. The empty lines with “…” indicate indeterminate lapses of time between interactions.

Table E-1. Interactions Between Flightdeck, ATC and FOC During the Flight Planning Phase Before the Release of the Flight Plan of a Generic Flight.

Media	Subject		Interacting with		Interactions
	Group	Position	Group	Position	
Flight planning					
Telcon	ATC	Command Center	FOC	ATC coordinator	Advise current weather, delay program at destination and runway configuration
Face-to-Face	FOC	ATC coordinator	FOC	Flight Dispatcher	Report current weather, delay program at destination and runway configuration
Computer	FOC	Flight Dispatcher	FOC	Computer	Check weather and NOTAMS
Flight planner	FOC	Flight Dispatcher	FOC	Computer	Check aircraft parameters (MEL, estimated payload), departure and arrival runway
Flight planner	FOC	Flight Dispatcher	FOC	Computer	Compute routing, alternate, runway performances, fuel, extra time
Flight planner	FOC	Flight Dispatcher	FOC	Computer	Check prepared flight plan
Host	FOC	Flight Dispatcher	ATC	Host	Release flight plan
Computer	FOC	Flight Dispatcher	FOC	Computer	Monitor weather, NOTAMS, ATIS
Computer	ATC	Command Center - TMU	ATC	Computer	*If applicable:* Assign Expected Departure Clearance Time
Computer	FD	Crew	FD	Computer	Obtain flight plan, fuel, altitude, lengths, alternates, Takeoff and landing weights, dispatch name and phone, weather, maintenance history, NOTAMS, crew, security information
Telcon	ATC	Command Center - TMU	FOC	ATC coordinator	*If applicable:* Advise current weather, delay program at destination and runway configuration
Face-to-Face	FOC	ATC coordinator	FOC	Flight Dispatcher	*If applicable:* Report current weather, delay program, runway configuration at destination
Face-to-Face	FD	Captain	FD	First Officer	Review flight plan: route, weather, fuel, takeoff weight, NOTAMS, runway, maintenance
Phone	FD	Captain	FOC	Flight Dispatcher	Request flight plan changes
Phone	FD	Captain	FOC	Flight Dispatcher	*If applicable (conditional):* Discuss issues on fuel, routing, weather, delays, mechanical, runway performance
Flight planner	FOC	Flight Dispatcher	FD	Captain	Send amended flight plan
Host	FOC	Flight Dispatcher	ATC	Host	Send amended flight plan
Computer or paper	FD	Captain	FOC	Flight Dispatcher	Confirm flight plan concurrence

Table E-2. Interactions Between Flightdeck, ATC and FOC during the Flight Planning Phase After Release of the Flight Plan of a Generic Flight.

Media	Subject		Interacting with		Interactions
	Group	Position	Group	Position	
Pilots in the flightdeck					
ACARS	FD	First Officer	FD	ACARS	Retrieve flight data in ACARS: Flight plan, weight, ATIS code, runway performance, release verification, maintenance release, departure clearance
ACARS	FD	First Officer	FD	Computer	*If required and equipped:* Load flight plan data into Flight Management System (FMS)
Host	ATC	Host	ATC	Tower - CD	Print flight strips (30min prior departure)
Host	ATC	Tower - CD	ATC	Computer	Check flight plan with requirement and whether an EDCT applies
Radio	FD	First Officer	ATC	ATIS	Check ATIS information
ACARS	FD	First Officer	FOC	Flight Dispatcher	Obtain update on weather condition and runway departure configuration
ACARS	FD	First Officer	ATC	Tower - CD	Establish contact
ACARS	FD	First Officer	ATC	Tower - CD	Request Pre-Departure Clearance (PDC)
ACARS	FD	First Officer	ATC	Tower - CD	Advise ATIS identifier
ACARS	ATC	Tower - CD	FD	First Officer	Clear PDC: IFR flight plan updated with requirements, squawk code and hold for release if EDCT
ACARS	FD	First Officer	ATC	Tower - CD	Acknowledge PDC
ACARS	FD	First Officer	FD	Computer	Print IFR clearance
Radio	ATC	Tower - CD	FD	First Officer	*If not delivered by ACARS:* Clear IFR flight plan updated with requirements, squawk code and hold for release if EDCT
Radio	FD	First Officer	ATC	Tower - CD	*If not delivered by ACARS:* Read back IFR clearance
Face-to-Face	ATC	Tower - CD	ATC	Tower - GC	Give flight strips and required altitude hold for TRACON
Phone	FD	Captain	FOC	Flight Dispatcher	*If applicable:* Advise route clearance differences from flight release IFR routing
Phone	FD	Captain	FOC	Flight Dispatcher	*If overfuel (off-nominal):* Obtain verbal confirmation: Quantity, dispatcher's name, date and time
ACARS	RAMP	Load Planner	FD	First Officer	Send load and passengers list
Gate closed					
ACARS	RAMP	Load Planner	FD	ACARS	Send final weight and balance (automated report, may happen at other time)
Face-to-Face	RAMP	Load Planner	FD	Captain	*If not by ACARS:* Gives weight and balance print
FMS	FD	First Officer	FD	Computer	Check weight and balance against FMS
FMS	FD	First Officer	FD	Computer	Compute takeoff performance
Radio	FD	First Officer	ATC	Tower - GC	Establish contact
Radio	FD	First Officer	ATC	Tower - GC	Request departure release
Radio	ATC	Tower - GC	FD	First Officer	Release departure, if applicable, according to EDCT
Radio	FD	First Officer	ATC	Tower - GC	Read back EDCT

Table E-3. Interactions Between Flightdeck, ATC and FOC During the Pushback Phase of a Generic Flight.

Media	Subject		Interacting with		Interactions
	Group	Position	Group	Position	
Pushback					
Radio	FD	First Officer	ATC	Tower - GC	Request permission to pushback
Radio	FD	First Officer	ATC	Tower - GC	State intentions: Taxi to runway
Radio	FD	First Officer	ATC	Tower - GC	Inform about ATIS identifier code
Radio	ATC	Tower - GC	FD	First Officer	Clear for pushback
Interphone	FD	Captain	RAMP	Pushback/Ground	Request pushback
Interphone	RAMP	Pushback/Ground	FD	Captain	Read back pushback
Interphone / gesture	FD	Captain	RAMP	Pushback/Ground	Request parking brakes release
Interphone / gesture	RAMP	Pushback/Ground	FD	Captain	Read back request parking brakes release
Interphone / gesture	RAMP	Pushback/Ground	FD	Captain	Confirm parking brakes release
ACARS	FD	ACARS	FOC	Flight Dispatcher	*If equipped:* Send Off The Gate report (automated)
ACARS	RAMP	Load Planner	FD	ACARS	*If set by break release:* Send final weight and balance (may require computation of takeoff performance)
Interphone / gesture	RAMP	Pushback/Ground	FD	Captain	Give cue to start engine start 1
Interphone / gesture	RAMP	Pushback/Ground	FD	Captain	Give cue to start engine start 2
Gesture	RAMP	Pushback/Ground	FD	Captain	Signal release from guidance
Gesture	FD	Captain	RAMP	Pushback/Ground	Acknowledge aircraft is released from guidance

Table E-4. Interactions Between Flightdeck, ATC and FOC During the Taxi-Out Phase of a Generic Flight.

Media	Subject		Interacting with		Interactions
	Group	Position	Group	Position	
Taxi-out					
Host	ATC	Departure - RA	ATC	Computer	*If applicable:* Amend flight plan amendment
Radio	FD	First Officer	ATC	Tower - GC	Advise ready to taxi
Radio	ATC	Tower - GC	FD	First Officer	Issue taxi clearance to runway
Radio	FD	First Officer	ATC	Tower - GC	Read back taxi clearance
ACARS	RAMP	Load Planner	FD	ACARS	*If has not happened already:* Send final weight and balance (may require computation of takeoff performance)
Radio	FD	First Officer	ATC	Tower - GC	*If applicable (conditional):* Request runway change
Radio	ATC	Tower - GC	FD	First Officer	*If applicable (conditional):* Issue a new taxi sequence and departure procedure clearance
Radio	ATC	Tower - GC	FD	First Officer	Clear taxi movements and hold
Radio	ATC	Tower - GC	FD	First Officer	Request contact LC on new frequency
Radio	FD	First Officer	ATC	Tower - GC	Read back taxi movements, hold and frequency change
Face-to-Face	ATC	Tower - GC	ATC	Tower - LC	Hand over flight strips
Radio	FD	First Officer	ATC	Tower - LC	Establish contact: ID and position
Radio	ATC	Tower - LC	FD	First Officer	Instruct position to hold short of runway
Radio	FD	First Officer	ATC	Tower - LC	Read back hold short of runway
Radio	ATC	Tower - LC	FD	First Officer	*If applicable:* Relay flight plan amendment
Radio	FD	First Officer	ATC	Tower - LC	*If applicable:* Read back flight plan amendment
ACARS	FD	First Officer	FD	Computer	*If applicable:* Amend FMS
Various	ATC	Tower - LC	ATC	Departure - R	*If applicable:* Activate flight data using flight strip, squawk or SID code
URET	ATC	Departure - R	ATC	Computer	Check flight plan, runway, alt, 1st fix
Phone	ATC	Departure - R	ATC	Tower - LC	*If applicable:* Local Controller need permission from TRACON or Center to clear for departure (Release flight)
Radio	ATC	Tower - LC	FD	Captain	Instruct position and hold on runway

Table E-5. Interactions Between Flightdeck, ATC and FOC During the Takeoff Phase of a Generic Flight.

Media	Subject		Interacting with		Interactions
	Group	Position	Group	Position	
Takeoff					
Radio	FD	Captain	ATC	Tower - LC	Advise ready for takeoff
Radio	ATC	Tower - LC	FD	Captain	Clear for takeoff
Radio	FD	Captain	ATC	Tower - LC	Read back takeoff clearance
Face-to-Face	FD	Pilot Monitoring	FD	Captain	Call out V1
Face-to-Face	FD	Pilot Monitoring	FD	Captain	Call out Vr
ACARS	FD	ACARS	FOC	Flight Dispatcher	*If equipped:* Send Off The Ground report (automated)
Face-to-Face	FD	Pilot Monitoring	FD	Captain	Call out V2
Radio	ATC	Tower - LC	FD	Pilot Monitoring	Request contact on departure frequency
Radio	FD	Pilot Monitoring	ATC	Tower - LC	Read back change of frequency
Radio	FD	Pilot Monitoring	ATC	Departure - R	Establish contact: Give ID, altitude change and heading
URET	ATC	Departure - R	ATC	Computer	Check Mode C
URET	ATC	Departure - R	ATC	Computer	Check altitude leaving and assigned to
Radio	ATC	Departure - R	FD	Pilot Monitoring	Read back ID altitude change
Radio	ATC	Departure - R	FD	Pilot Monitoring	*If applicable:* Instruct maintain altitude for given time
Radio	FD	Pilot Monitoring	ATC	Departure - R	*If applicable:* Request climb
Radio	ATC	Departure - R	FD	Pilot Monitoring	*If applicable:* Clear new altitude
Radio	FD	Pilot Monitoring	ATC	Departure - R	read back New altitude
Radio	ATC	Departure - R	FD	Pilot Monitoring	Request contact new frequency
Radio	FD	Pilot Monitoring	ATC	Departure - R	Read back change of frequency
PVD	ATC	Departure - R	ATC	1st Center 1st sector - RA	Initiate handoff
PVD	ATC	1st Center 1st sector - RA	ATC	Departure - R	Accept handoff
URET	ATC	1st Center 1st sector - RA	ATC	Computer	Check first fix point and altitude
Radio	FD	Pilot Monitoring	ATC	1st Center 1st sector - R	Establish contact: Give ID, altitude and heading
Radio	ATC	1st Center 1st sector - R	FD	Pilot Monitoring	Read back ID, altitude and heading
Radio	FD	Pilot Monitoring	ATC	1st Center 1st sector - R	Request to climb
Radio	ATC	1st Center 1st sector - R	FD	Pilot Monitoring	Clear change of altitude

Table E-6. Interactions Between Flightdeck, ATC and FOC During the Cruise Phase of a Generic Flight.

Media	Subject		Interacting with		Interactions
	Group	Position	Group	Position	
Cruise					
PVD	ATC	1st Center 1st sector - R	ATC	1st Center 2nd sector - RA	Request handoff
PVD	ATC	1st Center 2nd sector - RA	ATC	1st Center 1st sector - R	Accept handoff
Radio	ATC	1st Center 1st sector - R	FD	Pilot Monitoring	Request contact new frequency
Radio	FD	Pilot Monitoring	ATC	1st Center 1st sector - R	Read back change of frequency
Radio	FD	Pilot Monitoring	ATC	1st Center 2nd sector - R	Establish contact: Give ID, altitude and heading
Radio	ATC	1st Center 2nd sector - R	FD	Pilot Monitoring	Read back ID, altitude and heading
Radio	ATC	1st Center 2nd sector - R	FD	Pilot Monitoring	*If applicable:* Request change of heading
Radio	FD	Pilot Monitoring	ATC	1st Center 2nd sector - R	*If applicable:* Clear new heading
…		…		…	…
PVD	ATC	1st Center 2nd sector - R	ATC	2nd Center 1st sector - RA	Request handoff
PVD	ATC	2nd Center 1st sector - RA	ATC	1st Center 2nd sector - R	Accept handoff
Interphone	ATC	2nd Center 1st sector - R	ATC	1st Center 2nd sector - RA	*If applicable:* Request change of altitude (prior entering in new sector ZB-1)
Interphone	ATC	1st Center 2nd sector - R	ATC	2nd Center 1st sector - R	*If applicable:* Acknowledge change of altitude
Face-to-Face	ATC	1st Center 2nd sector - R	ATC	1st Center 2nd sector - R	*If applicable:* Relay change of altitude request from ZB-1
Radio	ATC	1st Center 2nd sector - R	FD	Pilot Monitoring	*If applicable:* Clear change of altitude
Radio	FD	Pilot Monitoring	ATC	1st Center 2nd sector - R	*If applicable:* Read back change of altitude
Radio	ATC	1st Center 2nd sector - R	FD	Pilot Monitoring	Request contact new frequency
Radio	FD	Pilot Monitoring	ATC	1st Center 2nd sector - R	Read back change of frequency
Radio	FD	Pilot Monitoring	ATC	2nd Center 1st sector - R	Establish contact: Give ID, altitude and heading
	ATC	2nd Center 1st sector - R	FD	Pilot Monitoring	Read back ID, altitude and heading
…	…	…	…	…	…
ACARS	FOC	Flight Dispatcher	FD	Pilot Monitoring	Establish contact, required every 2 hours
ACARS	FD	Pilot Monitoring	FOC	Flight Dispatcher	Acknowledge message
ACARS	FOC	Flight Dispatcher	FD	Pilot Monitoring	Inform update about weather on east coast and runway at destination
ACARS	FD	Pilot Monitoring	FOC	Flight Dispatcher	Acknowledge message
…	…	…	…	…	…

Table E-7. Interactions Between Flightdeck, ATC and FOC During an Off-Nominal Event in the Cruise Phase of a Generic Flight.

Media	Subject		Interacting with		Interactions
	Group	Position	Group	Position	
Off-Nominal: Command Center decides to reroute traffic due to weather East of destination					
Phone	ATC	Tower - TMU	ATC	Command Center - TMU	Report change of runway configuration because of weather
Phone	ATC	Tower - TMU	ATC	Last Center - TMU	Report change of runway configuration because of weather
Phone	ATC	Tower - TMU	ATC	Approach - TMU	Report change of runway configuration because of weather
Phone	ATC	Command Center - TMU	ATC	3rd to last Center - TMU	Recommend rerouting part of traffic via Center Y
Advisory	ATC	Command Center - TMU	FOC	ATC coordinator	Advise change of runway at destination and recommend rerouting via Center Y
Phone	FOC	ATC coordinator	ATC	Command Center - TMU	Obtain specific information about delay and rerouting via Center Y
Interphone	FOC	ATC coordinator	FOC	Flight Dispatcher	Relay change of runway at destination and reroute via Center Y
ACARS	FOC	Flight Dispatcher	FD	Crew	Downlink fuel on board
Satcom	FOC	Flight Dispatcher	FD	Pilot Monitoring	*If no ACARS:* Obtain fuel on board
Computer	FOC	Flight Dispatcher	FOC	Computer	Compute reroute and alternative and ETA
ACARS	FOC	Flight Dispatcher	FD	Crew	Update about weather east of destination and runway change at destination
Satcom	FOC	Flight Dispatcher	FD	Pilot Monitoring	Inform about weather east of destination and runway change at destination
Satcom	FOC	Flight Dispatcher	FD	Pilot Monitoring	Coordinate on reroute via Center Y and alternative destination
Host	FOC	Flight Dispatcher	ATC	3rd to last Center - RA	Release flight plan amendment for reroute
ACARS	FOC	Flight Dispatcher	FD	Crew	Uplink flight plan amendment for reroute
Radio		Pilot Monitoring	ATC	3rd to last Center - RA	Request clearance of flight plan amendment for reroute
Radio	ATC	3rd to last Center - RA	FD	Pilot Monitoring	Clear flight plan amendment for reroute
Computer	FD	Pilot Monitoring	FOC	Computer	Compute Flight plan on FMS for reroute
ACARS	FD	Pilot Monitoring	FOC	Flight Dispatcher	Downlink flight plan amendment for reroute
…	…	…	…	…	…

Table E-8. Interactions Between Flightdeck, ATC and FOC During the Continuation of the Cruise Phase of a Generic Flight.

Media	Subject		Interacting with		Interactions
	Group	Position	Group	Position	
Telcon	ATC	Command Center	FOC	ATC coordinator	Report weather, rerouting and airport runway configuration at destination
Interphone	FOC	ATC coordinator	FOC	Flight Dispatcher	Relay weather report, rerouting and airport runway configuration at destination
…	…	…	…	…	…
PVD	ATC	2nd to last Center - R	ATC	Last Center 1st Sector - RA	Initiate handoff
PVD	ATC	Last Center 1st Sector - RA	ATC	2nd to last Center - R	Accept handoff
URET	ATC	Last Center 1st Sector - RA	ATC	Computer	Check STAR
PVD	ATC	Last Center 1st Sector - RA	ATC	Last Center last Sector - RA	Send datablock
PVD	ATC	Last Center 1st Sector - RA	ATC	Approach - RA	Send datablock
Radio	ATC	2nd to last Center - RC	FD	Pilot Monitoring	Request contact new frequency
Radio	FD	Pilot Monitoring	ATC	2nd to last Center - R	Read back change of frequency
Radio	FD	Pilot Monitoring	ATC	Last Center First Sector - R	Establish contact: Give ID, altitude and heading
Radio	ATC	Last Center First Sector - R	FD	Pilot Monitoring	Read back ID, altitude and heading
Radio	ATC	Last Center First Sector - R	FD	Pilot Monitoring	Clear change of altitude and heading
Radio	FD	Pilot Monitoring	ATC	Last Center First Sector - R	Read back change of altitude and heading
…	…	…	…	…	…
Radio	ATC	Last Center 2nd to last Sector - R	FD	Pilot Monitoring	Request contact new frequency
Radio	FD	Pilot Monitoring	ATC	Last Center 2nd to last Sector - R	Read back change of frequency
Radio	FD	Pilot Monitoring	ATC	Last Center last Sector - R	Establish contact: Give ID, altitude and heading
Radio	ATC	Last Center last Sector - R	FD	Pilot Monitoring	Read back ID, altitude and heading
Radio	ATC	Last Center last Sector - R	FD	Pilot Monitoring	Clear change of altitude
Radio	FD	Pilot Monitoring	ATC	Last Center last Sector - R	Read back change of altitude

Table E-9. Interactions Between Flightdeck, ATC and FOC During an Off-Nominal Event in the Cruise Phase of a Generic Flight.

Media	Subject		Interacting with		Interactions
	Group	Position	Group	Position	
Off-Nominal: Holding					
Interphone	ATC	Approach - RA	ATC	Last Center last Sector - RA	Request to hold flights
Interphone	ATC	Last Center last Sector - R	ATC	Approach - RA	Agree to hold flights
Radio	ATC	Last Center last Sector - R	FD	Pilot Monitoring	Instruct about holding pattern
Radio	FD	Pilot Monitoring	ATC	Last Center last Sector - R	Read back holding
Radio	FD	Pilot Monitoring	ATC	Last Center last Sector – R	Notify publication for holding pattern
ACARS	FD	Pilot Monitoring	FOC	Flight Dispatcher	Report holding and fuel remaining
ACARS	FOC	Flight Dispatcher	FD	Pilot Monitoring	Confirm information on holding
ACARS	FOC	Flight Dispatcher	FD	FMS	Downloads fuel levels
Computer	FOC	Flight Dispatcher	FOC	Computer	Check remaining fuel and planned fuel
Radio	ATC	Last Center last Sector - R	FD	Pilot Monitoring	Clear to fix, hold as published
Radio	ATC	Last Center last Sector - R	FD	Pilot Monitoring	*If applicable:* Instruct about Expected Further Clearance
Radio	FD	Pilot Monitoring	ATC	Last Center last Sector - R	Read back holding instructions and Expected Further Clearance
Radio	FD	Pilot Monitoring	ATC	Last Center last Sector - R	Report start holding
Radio	ATC	Last Center last Sector - R	FD	Pilot Monitoring	Acknowledge start holding
Phone	ATC	Approach - RA	ATC	Last Center last Sector - R	Advise hold release (clear to continue)
Phone	ATC	Last Center last Sector - R	ATC	Approach - RA	Agree on hold release
Radio	ATC	Last Center last Sector - R	FD	Pilot Monitoring	Clear to continue via cleared routing
Radio	FD	Pilot Monitoring	ATC	Last Center last Sector - R	Read back clearance to continue via cleared routing

Table E-10. Interactions Between Flightdeck, ATC and FOC During the Descent Phase of a Generic Flight.

Media	Subject		Interacting with		Interactions
	Group	Position	Group	Position	
Descent					
Face-to-Face	ATC	Approach - R	ATC	Last Center last Sector - RA	*If applicable:* Request reduce speed incoming aircrafts
Phone	ATC	Approach - RA	ATC	Last Center last Sector - RA	*If applicable:* Request slow down
Phone	ATC	Last Center last Sector - RA	ATC	Approach - R	*If applicable:* Agree slow down
Radio	ATC	Last Center last Sector - R	FD	Pilot Monitoring	*If applicable:* Clear to lower speed
Radio	FD	Pilot Monitoring	ATC	Last Center last Sector - R	Read back change of speed
Radio	ATC	Last Center last Sector - R	FD	Pilot Monitoring	Clear change of altitude and heading
Radio	FD	Pilot Monitoring	ATC	Last Center last Sector - R	Read back change of altitude and heading
Radio	ATC	Last Center last Sector - R	FD	Pilot Monitoring	Request contact new frequency
Radio	FD	Pilot Monitoring	ATC	Last Center last Sector - R	Read back change of frequency
PVD	ATC	Last Center last Sector - R	ATC	Approach - RA	Request handoff
PVD	ATC	Approach - RA	ATC	Last Center last Sector - R	Accept handoff
URET	ATC	Approach - RA	ATC	Computer	Check if STAR is correct
ACARS	FD	Pilot Monitoring	RAMP	Ground	Notify in-range call
ACARS	RAMP	Ground	FD	Pilot Monitoring	Uplink arrival gate assignment and ground power unit status
Approach					
Radio	FD	Pilot Monitoring	ATC	Approach - R	Establish contact: Give ID, altitude leaving and assigned and heading
Radio	ATC	Approach - R	FD	Pilot Monitoring	Read back ID, altitude assigned, heading
Radio	FD	Pilot Monitoring	ATC	Approach - R	Advise approach, runway, ATIS information
Radio	ATC	Approach - R	FD	Pilot Monitoring	Read back approach, runway, and ATIS
ACARS	FD	ACARS	FOC	Flight Dispatcher	Report Expected Time of Arrival report (automated report)
Radio	ATC	Approach - R	FD	Pilot Monitoring	Clear to lower altitude
Radio	FD	Pilot Monitoring	ATC	Approach - R	Read back change of altitude
Radio	ATC	Approach – R	FD	Pilot Monitoring	Request contact new frequency
Radio	FD	Pilot Monitoring	ATC	Approach – R	Read back change of frequency

Table E-11. Interactions Between Flightdeck, ATC and FOC During the Final Approach Phase of a Generic Flight.

Media	Subject		Interacting with		Interactions
	Group	Position	Group	Position	
Final approach					
Radio	FD	Captain	ATC	Final Approach - R	Establish contact: Give ID, altitude leaving and assigned, and heading
Radio	ATC	Final Approach - R	FD	Captain	Read back ID, altitude assigned, heading
Radio	FD	Captain	ATC	Final Approach - R	Advise approach, runway, ATIS information
Radio	ATC	Final Approach - R	FD	Captain	Read back approach, runway, and ATIS
Radio	ATC	Final Approach - R	FD	Captain	Clear approach and runway
Radio	ATC	Final Approach - R	FD	Captain	*If applicable:* Clear lower altitude and new heading
Radio	FD	Captain	ATC	Final Approach - R	*If applicable:* Read back changes of altitude and heading
Radio	ATC	Final Approach - R	FD	Captain	Clear lower altitude and speed
Radio	FD	Captain	ATC	Final Approach - R	Read back lower altitude and speed
Radio	FD	Captain	ATC	Final Approach - R	*If applicable:* Inform request for visual approach
Radio	ATC	Final Approach - R	FD	Captain	*If applicable:* Clear visual approach
Radio	ATC	Final Approach - R	FD	Captain	*If applicable:* Advise traffic
Radio	FD	Captain	ATC	Final Approach - R	*If applicable:* Read back
Radio	FD	Captain	ATC	Final Approach - R	*If applicable:* Report traffic in sight
Radio	ATC	Final Approach - R	FD	Captain	Request contact new frequency
Radio	FD	Captain	ATC	Final Approach - R	Read back change of frequency
Radio	FD	Captain	ATC	Tower - LC	Establish contact: Give ID, altitude, and location
Radio	FD	Captain	ATC	Tower - LC	Request clearance for runway (final approach clearance)
Radio	FD	Captain	ATC	Tower - LC	Request wind condition

Table E-12. Interactions Between Flightdeck, ATC and FOC During an Off-Nominal Event in the Final Approach Phase of a Generic Flight.

Media	Subject		Interacting with		Interactions
	Group	Position	Group	Position	
Off-Nominal: Missed approach					
Radio	ATC	Tower - LC	FD	Captain	Read back ID
Radio	ATC	Tower - LC	FD	Captain	Instruct go-around, and clear new altitude and heading
Radio	FD	Captain	ATC	Tower - LC	Read back go-around, altitude assigned and heading
Interphone	ATC	Tower - LC	ATC	Departure - RA	Notify go-around
Interphone	ATC	Departure - RA	ATC	Tower - LC	Approve go-around procedure
Face-to-Face	ATC	Departure - RA	ATC	Departure - R	Report go-around
PVD	ATC	Departure - RA	ATC	Computer	Reactivate datablock
PVD	ATC	Departure - RA	ATC	Approach - R	Send datablock
PVD	ATC	Departure - RA	ATC	Final Approach - R	Send datablock
Interphone	ATC	Approach - RA	ATC	Departure - R	Request follow given aircraft
Interphone	ATC	Departure - RA	ATC	Final Approach - R	Relay go around and procedure
Radio	FD	Captain	ATC	Departure - R	Establish contact: Give ID, altitude assigned and heading
Radio	ATC	Departure - R	FD	Captain	Read back ID, altitude assigned, heading
Radio	ATC	Departure - R	FD	Captain	Clear new altitude and heading
Radio	ATC	Departure - R	FD	Captain	*If applicable:* Clear speed limit
Radio		Captain	ATC	Departure - R	*If applicable:* Read back speed limit
PVD	ATC	Departure - RA	ATC	Final Approach - R	Request handoff
PVD	ATC	Final Approach - R	ATC	Departure - RA	Accept handoff
Radio	ATC	Departure - R	FD	Captain	Request contact new frequency
Radio	FD	Captain	ATC	Departure - RA	Read back change of frequency
Radio	FD	Captain	ATC	Final Approach - R	Establish contact: Give ID, runway, heading, altitude and speed
Radio	ATC	Final Approach - R	FD	Captain	Read back ID
Radio	ATC	Final Approach - R	FD	Captain	Clear runway
Radio	FD	Captain	ATC	Final Approach - R	Read back runway assignment
Radio	ATC	Final Approach - R	FD	Captain	Clear new heading, and lower altitude and speed
Radio	FD	Captain	ATC	Final Approach - R	Read back changes of heading, altitude, and speed
Radio	FD	Captain	ATC	Final Approach - R	Request visual approach
Radio	ATC	Final Approach - R	FD	Captain	Clear visual approach
Radio	ATC	Final Approach - R	FD	Captain	Request contact new frequency
Radio	FD	Captain	ATC	Final Approach - R	Read back change of frequency
Radio	FD	Captain	ATC	Tower - LC	Establish contact: Give ID, altitude and location
Radio	FD	Captain	ATC	Tower - LC	Request clearance for runway (final approach clearance)
Radio	ATC	Tower - LC	FD	Captain	Read back ID, runway, altitude, location
Radio	ATC	Tower – LC	FD	Captain	*If applicable:* Advise traffic
Radio	ATC	Tower - LC	FD	Captain	Clear to land
Radio	FD	Captain	ATC	Tower - LC	Request wind condition
Radio	ATC	Tower - LC	FD	Captain	Advise wind condition

Table E-13. Interactions Between Flightdeck, ATC and FOC During the Landing and Taxi-In Phases of a Generic Flight.

Media	Subject		Interacting with		Interactions
	Group	Position	Group	Position	
Landing					
ACARS	FD	ACARS	FOC	Flight Dispatcher	*If equipped:* Send On The Ground report (automated)
Radio	ATC	Tower - LC	FD	Captain	Clear to taxiway off the runway
Radio	FD	Captain	ATC	Tower - LC	Read back taxiway off the runway
Radio	ATC	Tower - LC	FD	Captain	Request contact new frequency
Radio	FD	Captain	ATC	Tower - LC	Read back change of frequency
Taxi-in					
Radio	FD	Captain	ATC	Tower - GC	Establish contact: Give ID, gate and position
Radio	ATC	Tower - GC	FD	Captain	Read back ID, position and gate
Radio	ATC	Tower - GC	FD	Captain	Clear taxi route
Radio	FD	Captain	ATC	Tower - GC	Read back taxi route
Face-to-Face	FD	Captain	RAMP	Ground	*If applicable:* Establish visual contact
Face-to-Face	RAMP	Ground	FD	Captain	*If applicable:* Guide aircraft to the jetway
At the Gate					
ACARS	FD	ACARS	FOC	Flight Dispatcher	*If equipped:* Send Into The Gate report (automated)
Face-to-Face	RAMP	Ground	FD	Captain	Show sign aircraft gears are secured
Shutdown					

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