Traffic Flow Management:

ATC Coordinator's Information Requirements for the NAS

Paul Mafera
Kip Smith, Ph.D.

Human Factors and Experimental Economics Laboratory
Kansas State University

March 6, 2000

Prepared for:

The Office of the Chief Scientific and Technical Officer for Human Factors of the Federal Aviation Administration, AAR-100

ATC Coordinator's Information Requirements for the NAS

Page

Introduction 4

Section I: Overview of the Air Traffic Management System

1.1 ATC-Airline Positions 7
1.1.1 Traffic Management Coordinator 8
1.1.2 National Traffic Management Specialist 9
1.1.3 ATC coordinator 9
1.1.4 Dispatcher 10
1.1.5 Sector controller 10
1.1.6 Pilot 11
1.2 Structure of ATC-Airline Communications 11
1.2.1 Communications and information flow 11
1.2.2 Intended flow of information 17
1.2.3 Information flow when ATC-airline communication breaks down 19
1.3 Events and Constraints 20
1.3.1 Events 20
1.3.2 Traffic-flow constraints 22
1.3.3 Flight-related constraints 25
1.3.4 Sequence of constraints 26
1.3.5 Life-cycle of events 27

Section II: The ATC Coordinator Position

2.1 ATC Coordinator Duties 29
2.1.1 Compiling daily log 29
2.1.2 Monitoring ATC-issued restrictions 30
2.1.3 Monitoring teleconferences 31
2.1.4 Planning weather-related strategy 31
2.1.5 Assisting with route planning 32
2.1.6 Clarifying ATC actions 33
2.1.7 Coordinating off-loads 33
2.1.8 Monitoring departure delays 34
2.1.9 Slot-Swapping 34
2.1.10 Compiling diversion list 35
2.2 Information Communication Devices 35
2.2.1 Aircraft Situation Display (ASD) 35
2.2.2 Telephone 36
2.2.3 Teleconference 36
2.2.4 Flight Schedule Monitor (FSM) 37
2.2.5 ATCSCC Advisories 37
2.3 Issues and Problems of Air Traffic Flow 38
2.3.1 Departure delays 38
2.3.2 Arrival holding 40
2.3.3 Route changes 40

Section III: Analytical Account of the Information Requirements

3.1	**General Tasks of an ATC Coordinator**	42
3.1.1	General tasks	42
3.1.2	Monitoring ATC actions	43
3.1.3	Identifying the scope of ATC actions	44
3.1.4	Inferring ATC intent	48
3.2	**Basic Information Needs**	48
3.2.1	Need for causal information	49
3.2.2	Need for information about all constraints	49
3.2.3	Need for historical information	50
3.3	**Classes of Information**	51
3.3.1	Continuous	51
3.3.2	Static	51
3.3.3	Episodic	52
3.4	**The Information Gap**	53
3.4.1	Episodic information as continuous	53
3.4.2	Components of constraints	54
3.4.3	Causal-linked information	56
3.4.4	Recommendation	56

Acronyms 58

References 60

ATC Coordinator's Information Requirements for the NAS

Introduction

This report discusses human factors research conducted by the Kansas State University Human Factors Research Laboratory (KSU HFRL) at six of the Federal Aviation Administration's (FAA) Air Route Traffic Control Centers (ARTCC) and at the Operations Control Centers (OCC) of several commercial airlines. The goal of the research has been to provide the FAA and the airlines with a detailed account of the opportunities and requirements for, and the constraints upon, collaborative decision making (CDM) about the filing of flight plans and rerouting of aircraft. In this context, CDM refers to any and all types of supportive interaction by decision makers pursuing a mutual goal. This report reviews the structure of communication within the National Airspace System (NAS) and identifies an information gap in the system for disseminating ATCSCC (Air Traffic Control System Command Center) Advisories.

The first objective of this report is to examine the communication structure and information requirements of personnel directly involved in managing the flow of air traffic within the NAS. These individuals work at ATC facilities and at the OCC of commercial airlines. The report explores the information that is made available about ongoing air traffic management operations and how this information is disseminated throughout the NAS.

The second objective of this report is to examine the information requirements of the NAS from an airline's perspective, addressing the question 'What information about air traffic flow do airlines need in order to manage flights in a more informed manner?' It is no surprise that the single most important source of this information is ATC. This report specifically addresses the collaboration between ATC and the airlines, and focuses on what information is available, how it is communicated, why the exchange of information is sometimes insufficient, and what can be done to remedy problematic communications.

The report is organized into three focal points. Section I is an overview of the air traffic management system. It begins with a description of the various ATC and airline positions involved in the management of air traffic flow (section 1.1). Section 1.2 provides a decomposition of the communications between these positions. This section focuses on the information available to the personnel at these positions and the flow of information between positions. Section 1.3 examines 1) the constraints on the NAS, which typically take the form of traffic-flow restrictions, and 2) the events that are responsible for triggering these constraint changes.

Section II is a descriptive account of the ATC coordinator position. It starts with a description of the ATC coordinator's duties that expands on how these duties are affected by changes in NAS constraints (section 2.1). The following section provides a description of the tools used by ATC coordinators to acquire and disseminate information (section 2.2). Section II concludes with a discussion of the issues and problems currently facing ATC coordinators (section 2.3).

Section III is an analytical account of the information requirements necessary for successful management of air traffic flow from the perspective of the airlines. Section 3.1 describes a framework that characterizes the duties of the ATC coordinator (discussed in section 2.1) as a cycle comprised of four general tasks. These tasks are further decomposed into subtasks that are dependent on ATC collaboration. The following section describes the information needs of an ATC coordinator in order to perform these tasks effectively (section 3.2). Section 3.3 decomposes the information that is available to the ATC coordinator into three classes of information. The final section (section 3.4) addresses the problems facing the ATC coordinator (discussed in section 2.3) with respect to the information needs of an ATC coordinator (discussed in section 3.2) and the classes of information that are available (discussed in section 3.3). This section ends with a recommendation of how constraints on the NAS might better be communicated to all parties involved in air traffic management. Section III is followed by a list all acronyms used in this report and a reference section.

This report is the culmination of over 400 hours spent with ATC coordinators and dispatchers at the OCC of four major U.S. airlines and with Traffic Management coordinators (TMC) at four ARTCCs. The task analysis methods employed in this research include observations, structured and unstructured interviews, walk-throughs, and talk-throughs. The research was supported by funding from the Office of the Chief Scientific and Technical Officer for Human Factors of the Federal Aviation Administration, AAR-100. Dr. Thomas McCloy was the Technical Monitor. The opinions and errors are that of the authors'. All statements should not be construed as positions taken by the FAA, the airlines, or by any of their employees.

Section I: Overview of the Air Traffic Management System

1.1 ATC-Airline Positions

There are six positions at the airlines and ATC that are responsible for managing the flow of air traffic (Figure 1). The three airline positions that have a direct impact on the flow of air traffic are the ATC coordinator, dispatcher, and pilot. The three ATC positions involved in the flow of air traffic are the National Traffic Management Specialist (NTMS) at the Air Traffic Control System Command Center (ATCSCC), the Traffic Management Coordinator (TMC) at the Air Route Traffic Control Center (ARTCC), and the sector controller. A decision made at any of these six positions usually results in a change in the NAS. Several other positions (meteorology, flight scheduling, software/hardware support, etc.) influence traffic flow, but decisions made by these personnel have an indirect effect. The following sections describe the roles and responsibility of these six positions. The discussion begins with the TMC position at the ARTCC and moves counterclockwise through Figure 1.

Airlines	***ATC***
ATC Coordinator	**National Traffic Management Specialist**
Dispatcher	**Traffic Management Coordinator**
Pilot	**Sector Controller**

Figure 1. The six positions responsible for managing air traffic flow

1.1.1 Traffic Management Coordinator

The TMC position is an air traffic management (ATM) position in the Traffic Management Unit (TMU) at an ARTCC. The ARTCCs regulate the flow of en route traffic between the terminal control centers (TRACONs and Towers) located at major airports. Each of the 20 air route traffic control centers throughout the contiguous U.S. is divided into approximately 30 sectors. One or two sector controllers typically control each sector. The primary responsibility of a TMC is to manage the workload of these controllers (Smith, 1999; Murphy & Smith, 2000). The basic strategy used by TMCs for regulating workload is to modify the constraints on the NAS. As discussed in section 1.3.2, these modifications take many forms, such as changing routes, requiring increased aircraft separation, and restricting airport arrivals and departures.

Three general problems compel TMCs to modify the constraints on the NAS: weather, traffic, and equipment. Weather problems (e.g., thunderstorms, windshears, microbursts) require TMCs to devise alternate traffic flow plans in order to avoid the problem area. This could mean restricting the number of route choices between destinations and/or limiting the number of aircraft traveling around the affected area. Traffic and equipment problems (e.g., radar outage at an ATC facility) are generally handled in the same fashion, but usually with emphasis on reducing the volume of traffic routed through the problem airspace.

An equally important responsibility for the TMC is to monitor air traffic flow modifications initiated by other ATC facilities. This requires the TMC to continually monitor these types of constraint changes and formulate a strategy for meeting the initiating center's air traffic flow requirements. A common strategy involves 1) instructing the appropriate sector controllers to increase the separation between aircraft while 2) decreasing the overall volume of traffic by rerouting some of the traffic destined for the center in question.

1.1.2 National Traffic Management Specialist

The primary responsibility of the NTMS is to match the capacity of the NAS with the demand created by its users. This is often accomplished by coordinating the traffic flow requests made by one ARTCC with the needs of other centers (Yee, et al., 1995). The TMCs at the ARTCC initiate constraint changes with the aim of easing the flow of traffic through their own center's airspace. The problem with restricting the flow or density of traffic through one's own center is that some of the burden of managing air traffic gets shifted to adjacent centers. With the objective of precluding potential workload problems, the NTMS mediates between ATC control centers. In many situations that necessitates ATC initiatives, the NTMS position coordinates a course of action by collaborating with TMCs at the ARTCCs, TRACONs and Towers. Once a course of action has been determined, the NTMS is responsible for publishing the constraint changes via an ATCSCC Advisory system.

1.1.3 ATC coordinator

The airlines created the ATC coordinator position to anticipate, detect, and respond to the dynamics of the air traffic control system. The main responsibility is to coordinate the goals of the dispatchers with the traffic flow constraints on the NAS (section 2.1 expands this description of ATC coordinator position). The ATC coordinator monitors the flow of traffic in the NAS, as well as the actions taken by ATC, and informs the appropriate dispatchers whenever deviations or delays are detected (Federal Aviation Administration [FAA], 1997). Furthermore, the position supplies dispatchers with information about possible future ATC actions. When problems such as weather begin to develop in the NAS, ATC coordinators seek to anticipate the actions ATC will take to resolve the problem. The limited information available about ATC intent makes anticipating ATC actions the most difficult task facing an ATC coordinator.

Not only do ATC coordinators monitor the dynamics of the NAS, they also function as the airline's link to ATC. Specifically, ATC coordinators are responsible for resolving problems facing individual flights (e.g., on-ground delays, route changes, airborne holding). In most cases, clarification of these types of problems requires direct contact, usually by telephone, with the ATCSCC or other ATC facilities.

1.1.4 Dispatcher

Dispatchers are an airline's communication link to pilots. Their main goal is to construct flight plans that will enable aircraft to move safely and economically through the airspace to their scheduled destination (FAA, 1997). They are responsible for filing flight plans (which specify a planned route and altitude, departure time, flight number, fuel load, weight distribution, and equipment limitations) for a fixed number of flights and for monitoring these flights while airborne. They are also responsible for providing en route information, such as weather or route changes, and support to pilots once airborne. These tasks require dispatchers to take into account scheduling, equipment limitations, and NAS constraints imposed by the various ATC facilities.

Dispatchers furnish ATC with a source of airline-intent information in the form of filed flight plans. A flight plan, filed 90 minutes prior to the scheduled departure time, provides ATC with the expected route of the flight. Flight plans are the preliminary and, at times, only reliable information source ATC has for anticipating sector capacity and airport arrival rates.

1.1.5 Sector controller

Sector controllers are the individuals at the ATC centers responsible for maintaining the mandatory minimum separation between aircraft. Controllers accomplish this by monitoring aircraft movement through their sectors and issuing ATC directives when possible separation conflicts arise. They are also responsible for coordinating aircraft exchange (i.e., handing off) with sector controllers in adjacent sectors (FAA, 1998). A concurrent task for sector controllers is to incorporate the current constraints on the NAS with the location and movement of aircraft within their sector. A common example of this occurs when additional spacing is required for aircraft destined for another center's airspace. This change in constraint forces Controllers to provide an extended separation distance for a subgroup of flights destined for the restricted center while maintaining the mandatory minimum separation with all other aircraft in their sector's airspace. A second example occurs when route changes are implemented. This constraint change requires Controllers to redirect traffic flow while continuing to maintain safe separation.

1.1.6 Pilot

Although the duties of a commercial airline pilot are many and varied, ultimately the pilot's responsibility is to safely navigate the aircraft through the airspace from a place of origin to a pre-determined destination. This requires a pilot to follow the filed flight plan and expeditiously respond to directives from sector controllers. These directives consist of heading, altitude, and speed changes.

1.2 Structure of ATC-Airline Communications

1.2.1 Communications and information flow

The complexity and dynamics of the NAS necessitates an elaborate communication system linking ATC and the airlines. The communication structure and flow of information between ATC and the airlines is presented in Figure 2. Figure 2 depicts the six positions that are directly responsible for air traffic flow as discussed above, consisting of the three airline positions (ATC coordinator, dispatcher, and pilot) and the three Air Traffic Control positions (National Traffic Management Specialist, Traffic Management Coordinator, and sector controller). The lines represent direct communication links between positions and the arrows indicate the direction of the flow of information. The broken line connecting the ATC coordinator and TMC denotes a link that is not part of the formal ATC-airline communication structure, since ATC encourages airlines to contact the command center (ACTSCC) instead of individual ATC facilities for clarification of ATC actions. For example, to resolve a departure delay issue at EWR (Newark International Airport) airlines are encouraged to call the command center instead of the TMU at ZNY (New York ARTCC). The lack of a line in Figure 2 indicates an absence of a communication link between positions.

A communication link is defined here as a ***direct*** mode of communication between positions. Two types of communication modes are in place: voice and text. Voice communications are transmitted using telephones, radios, and walkie-talkies. Text

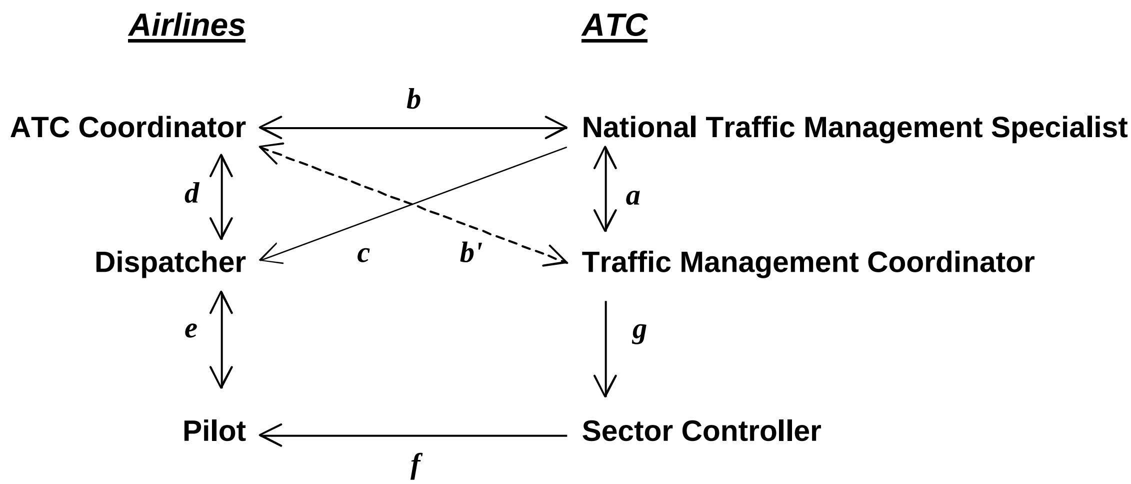


Figure 2. Direct communication links and flow of information between ATC and airlines

communications are sent using an e-mail-type format, a web-based text format, and ACARS (ARINC Communications And Reporting System). Almost all communication links depicted in Figure 2 represent a combination of both modes. The one exception is the link between the TMC and sector controller. Their mode of communication is strictly voice.

Each link between positions is represented in Figure 2 by a letter and an arrow or pair of arrows. The letters (*a*, *b*, *b*', *c*, *d*, *e*, *f*, *g*) identify the corresponding sections in Table 1. Table 1 lists examples of the types of information exchanged between the two positions indicated by that letter. The examples below each position represent information received by that position from the other position in the section. For instance, section *b* indicates that an ATC coordinator receives from the NTMS information about ATC actions, such as route advisories, departure delays, and airborne holding. Similarly, the NTMS receives information about an airline's regional flight problems from the ATC coordinator. This structure applies to all sections. Square brackets [ ] denote information that is passed

Table 1. Types of information communicated between ATC and airline positions

NTMS *to* ← *from*	***a***	*from* → *to* ***TMC***
sector capacity overload excessive landing traffic facility equipment problems local weather problems		restrictions implemented by other facilities
ATC Coordinator *to* ← *from*	***b***	*from* → *to* ***NTMS***
ATC actions (restrictions and programs) airport arrival and departure rates global route recommendations ATC equipment problems explanation and duration of ATC actions		regional flight problems
ATC Coordinator *to* ← *from*	***b'***	*from* → *to* ***TMC***
local route recommendations future ATC actions clarification of individual flight problems		individual flight problems flight constraints (aircraft performance, fuel, time)
Dispatcher *to* ← *from*	***c***	***NTMS***
ATC actions (restrictions and programs)		
ATC Coordinator *to* ← *from*	***d***	*from* → *to* ***Dispatcher***
individual flight problems (delays, equipment, medical) route changes en route weather reports		route planning advise ATC actions (restrictions and programs) explanation and duration of ATC actions weather forecasts
Dispatcher *to* ← *from*	***e***	*from* → *to* ***Pilot***
airborne and on-ground delays route changes of ATC actions en route weather reports equipment and medical problems		explanation and duration of ATC actions
Pilot *to* ← *from*	***f***	***Sector Controller***
heading, altitude, speed changes airborne holding weather-related reports radio frequency information		[en route weather information] [emergency situations]
Sector Controller *to* ← *from*	***g***	***TMC***
ATC actions (restrictions and programs) flow restrictions (miles-in-trail) runway configurations		[high levels of sector workload]

between positions, but not generally as part of routine communications. It should be noted Table 1 is not an exhaustive list, but rather a compilation of the most frequently communicated types of information.

Table 1*a* and Figure 2 depict the communication link between the NTMS and the TMC. This link is a vital source of information for the Command Center that makes it possible for the Command Center to coordinate flow restrictions on the NAS. The TMC supplies the NTMS with information about which sectors are currently exceeding capacity limits or expected to exceed capacity limits within the next several hours. Similarly, TMCs notify the Command Center when the projected number of landing traffic is expected to exceed the arrival rate of one of the center's major airports. The TMCs also supply the NTMS with information about equipment problems at their facility and local weather problems, especially weather affecting a major airport or heavily traveled jet route.

The NTMS communicates to the TMCs and airlines the restrictions implemented by all ATC facilities. Issuing restrictions is the means of changing the constraints on the flow of traffic in the NAS. These restrictions fall into one of two distribution categories: *system-wide* and *select*. Newly formulated restrictions that are intended for *system-wide* distribution are disseminated by the NTMS in the form of ATCSCC advisories (e.g., ground stops, ground delay programs, route advisories, etc.; see ATCSCC Advisory, section 2.2.5). Constraint changes that are intended for only *select* distribution are often in the form of miles-in-trail (MIT) restrictions. MIT is simply the minimum spacing (in miles) between aircraft. These restrictions are requests made by one en route control center to restrict the flow of traffic coming from a neighboring center. In this situation, the NTMS selectively distributes the restriction only to the ATC facilities that are directly affected by the air traffic flow modification.

Generally, the NTMS communicates changes in constraints on the NAS to the ATC coordinator (Table 1*b*, Figure 2). These constraints typically are in the form of traffic flow restrictions, such as airport arrival rates, airborne holding, departure delays, and route changes. The NTMS also provides the ATC coordinator with information about future plans for confronting an impending NAS problem (e.g., strategy to combat a developing weather problem). As valuable as it is for airlines to obtain information about ATC intent, the manner of obtaining this information is rather unstructured. It usually consists of the ATC coordinator listening in on an ATC conference call and inferring intent (see section 2.1.5).

The information supplied to the ATC coordinator by the NTMS and TMC differs in content. Information conveyed by the NTMS (Table 1*b*, Figure 2) is more global in nature than information conveyed by the TMC (Table 1*b'*, Figure 2). The NTMS position is the ATC coordinator's main source of NAS constraint changes. This information is generally not flight-specific, but is pertinent to all users of the NAS as it tends to convey a global sense of air traffic flow. For example, the arrival rate at an airport or the alternate route around weather are types of information that are beneficial to all flights using that particular airspace. In contrast, the TMC, as well as TMCs at terminal facilities, is the airlines' source of information for individual flights. The TMC supplies the ATC coordinator with clarification of specific flight problems. For example, an ATC coordinator will contact the TMU to find out why a particular flight is experiencing an excessive departure delay or how much longer an airborne flight should expect to hold.

It is important to point out that the Command Center maintains a Customer Service Representative (CSR) position for the purpose of addressing user queries. As mentioned above, the airlines are encouraged to contact this Command Center position instead of individual facilities, regardless of the nature of the problem. However, if the inquiry is flight-specific, the CSR will often have to contact the appropriate facility before responding.

Information moving from the ATC coordinator to NTMSs and TMCs is usually limited to information about regional and individual flight problems (Table 1*b* and 1*b'*, Figure 2). Typically, this information concerns on-ground and airborne delays or flight plan re-routes. This communication link is the only opportunity airlines have to inform ATC about flight-related constraints (i.e., fuel, time, and aircraft performance) (see section 1.3.2). These constraints need to be considered by ATC coordinators and dispatchers whenever a flight's filed flight plan has been altered.

As indicated in Figure 2 (and Table 1*b*, 1*b*' and 1*d*), the ATC coordinator directly communicates with the NTMS, TMC, and dispatchers. In all three cases, the flow is generally two-way. The majority of the information flows from the NTMS to the ATC coordinator, who then passes most of the information to dispatchers.

Dispatchers receive information from the NTMS about ATC actions almost exclusively in the form of ATCSCC Advisories (Table 1*c*, Figure 2). This information provides dispatchers with a general sense of the traffic-flow constraints on the NAS. Although dispatchers furnish all three ATC positions with vital flight plan information, the communication of this information is through the Enhanced Traffic Management System (ETMS) and not directly between positions. Since the transfer of flight plan information is not via a direct communication link, it is not represented in Table 1*c* or Figure 2.

It is noteworthy to mention that a communication link from dispatcher to NTMS is not entirely non-existent. The degree to which dispatchers communicate directly with ATC varies depending on the airline. Some airlines espouse a more autonomous approach to dispatching and expect dispatchers to function more independently of the ATC coordinator, acting as their own link to ATC. There is an advantage to this approach in that the ATC coordinator does not become an 'information bottleneck,' especially in times of extended communications between the airlines and ATC. Dispatchers do not have to 'wait in line' for the ATC coordinator to address their problem. Of course the disadvantage is that ATC has to deal with many airline voices instead of the singular voice of the ATC coordinator. From the perspective of ATC, this approach has the potential of increasing workload significantly, particularly for TMCs.

Dispatchers communicate with the ATC coordinator and pilots (Table 1*d* and 1*e*, Figure 2), and in both cases the information flow is two-way. Dispatchers receive information about the nature of constraints on the NAS from the ATC coordinator. Typically this includes the reason behind a particular ATC action, the expected duration, and possible future constraint changes. They receive information from pilots concerning on-ground and airborne delays that are currently being encountered. Periodically, pilots will relay en route weather information to dispatchers, as well as any equipment or medical problems. In turn, dispatchers supply ATC coordinators with information received from pilots about these problems. Dispatchers also furnish pilots with explanations of ATC directives, particularly when directives involve route changes or airborne holding.

In addition to communicating with dispatchers, pilots communicate directly with sector controllers (Table 1*f*, Figure 2), although the flow of information is almost exclusively from controller to pilot. On occasion, pilots need to communicate information to sector controllers. This usually occurs in situations involving emergencies (medical, equipment, fuel) in which the pilot will request special handling, such as a priority landing or a diversion to an alternate airport.

In order for sector controllers to maintain safe separation of aircraft, they need to be continually in contact with pilots. The flow of information is almost always one-way, from sector controller to pilot (Table 1*f*, Figure 2). Information conveyed by controllers to pilots is most frequently in the form of ATC directives (heading, altitude, and speed changes) and, to a lesser extent, weather information previously reported by pilots flying through the sector. Sector controllers also supply pilots with the radio frequency of the next sector before the aircraft is handed-off to that sector controller.

A major responsibility of the TMC is to supply sector controllers with up-to-the-minute information about constraints on the NAS (Table 1*g*, Figure 2). These constraints, as mentioned above, take the form of traffic-flow restrictions. The two most common types of restrictions are airport acceptance rate (AAR) and MIT. An airport's runway configuration is another important piece of information communicated by the TMCs to the sector controllers. The runway configuration often determines which arrival fixes a sector controller will direct traffic to during the approach to an airport.

1.2.2 Intended flow of information

Figure 3 represents the flow of information about changes in NAS constraints from the NTMS to the other positions involved in managing air traffic flow. Once the NTMS and

TMC determine the constraint changes that will best reduce sector controller workload, the information is passed along to the airlines, as well as the sector controllers.

The green arrows in Figure 3 depict the two paths the information flows from the Command Center. First, the NTMS notifies the TMCs at the en route control centers that are directly affected by the traffic-flow restriction. Often a TMC at the ARTCC originating the restriction will provide notification to other TMUs while the NTMS only monitors the exchange. The mode of communications is the telephone regardless if the restriction is earmarked for select or system-wide distribution. Next, the information is sent by the TMCs to sector controllers via voice communications using a telephone or walkie-talkie. These restrictions are then passed from sector controllers to pilots of active flights through radio communications.

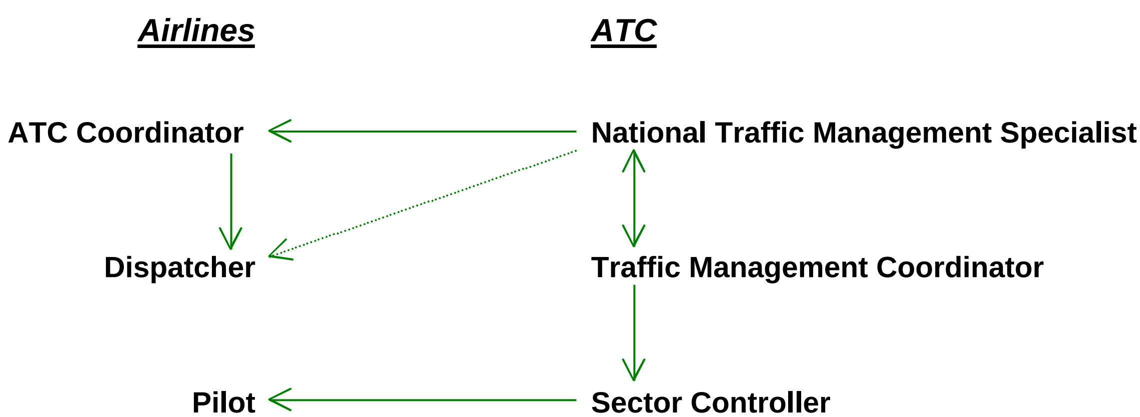


Figure 3. <u>Intended flow of information about constraint changes</u>

The second path by which information flows is from the Command Center to ATC coordinators and dispatchers. This information is comprised mainly of restrictions designated for system-wide distribution. These restrictions are published in the form of an ATCSCC Advisory (see section 2.2.5) and sent as text-based e-mail messages as well as text-based updates on the ATCSCC's Internet/Intranet web site. The green arrow connecting the NTMS and ATC coordinator positions represents the primary communication link used to convey NAS constraints to the airlines. ATC coordinators, in turn, relay advisory information to the appropriate dispatchers. Similarly, nearly all major commercial airline dispatchers receive the text-based ATCSCC Advisories. However, since dispatchers rely on the ATC coordinator for clarification of constraint changes and route planning recommendations (see section 2.1.4), the link between NTMS and dispatcher is incomplete and represented as a dotted arrow in Figures 3.

1.2.3 Information flow when ATC-airline communication breaks down

Under normal operations the ATC system periodically becomes overloaded as a result of weather, traffic, and/or equipment problems. These situations sometimes lead to breakdowns in communications. A common example of this breakdown between ATC and the airlines occurs when information concerning ATC actions is relayed to an airline's OCC by a pilot. Figure 4 depicts how information flows when the proper communication paths break down. The green arrows indicate the correct flow while the red arrows show how ATC coordinators and dispatchers circuitously receive the information. Notably missing from Figure 4 is the communication link between the NTMS and the ATC coordinator (link *b* in Table 1).

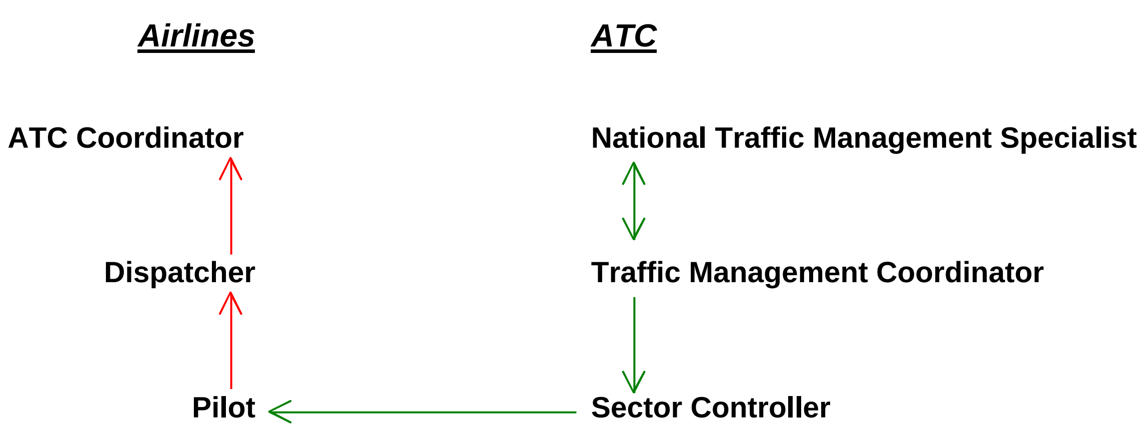


Figure 4. Unintended flow of information about constraint changes

For the airlines, any disruption in communications between ATC and ATC coordinator is a serious impediment to accurately monitoring the NAS. Without explicit knowledge of ATC actions, the airlines are greatly hindered in their attempts to strategically react to problems threatening the NAS. By relying only on observations of air traffic flow as indicated by the Aircraft Situation Display (ASD) (see section 2.2) and reports from pilots, an ATC coordinator can only guess at the actions ATC is taking. In addition, this type of communication breakdown often forces an ATC coordinator to contact ATC in order to confirm or deny their suspicions. The consequence is one or more phone calls to ATC facilities. This ultimately increases the already heavy workload of the ATC coordinator and both NTMSs and TMCs who are obligated to respond to the ATC coordinator's query.

1.3 Events and Constraints

The effectiveness of ATC coordinators and dispatchers depends greatly on how skillful they are at recognizing events that occur within the NAS and understanding the constraints they cause. A *constraint* is a condition that restricts the ability of an aircraft to move through the airspace while *events* are the circumstances that trigger changes in these constraints. The following sections explain these definitions as they relate to the NAS. The two general classes of constraint, *traffic-flow* and *flight-related*, are explained below. The last two parts of this section describes the associated nature of events and constraints and the life-cycle of an event.

1.3.1 Events

An *event* is defined here as an incident, situation or condition within the NAS that leads to changes in the constraints on the NAS. There are three main types of events, *weather*-, *traffic*-, and *equipment-related*. Event types are differentiated by their source (e.g., weather, traffic, and equipment) and not necessarily by the constraint changes they trigger.

The most common source of events within the NAS is weather. Weather produces an event any time it forces a change in the flow of air traffic. During the convective weather season (May – August), thunderstorms are the most frequent cause of weather-related events. When weather does not produce a change in traffic flow (because of its low intensity or size, remote location, slow movement, and/or time of day), it is referred to as a non-event, or not referred to at all. More generally, a non-event is anything that transpires within the day-to-day activities of the NAS that does not produce a change in constraints.

There are four conditions associated with weather that determine whether or not the weather will affect the flow of traffic, thus producing an event. First, the intensity of the weather must be severe enough to force re-routes around it. Second, the size of the weather needs to be large enough to produce meaningful route deviations when aircraft are forced to fly around it. Third and fourth, the weather has to be in a location and during a time of day of high traffic volume. For example, an isolated thunderstorm in eastern Pennsylvania at 4 o'clock in the afternoon will require ATC to restrict the flow of traffic through the affected area, either by routing traffic around the weather and/or limiting the number of flights to and from the New York metro airports. In this situation, a small isolated storm is a source of a major weather-related event. In contrast, a late night, moderate-sized thunderstorm in central Montana will not require ATC to initiate constraint changes and therefore not trigger an event.

Weather is not the only source of events. Many traffic situations produce events. A high volume of traffic within a sector is common source of an event. Traffic-related events require ATC to change the constraints on the flow of traffic through sectors. A third type of event is equipment-related. These events are produced by equipment outages or changeovers. For example, a radar outage at an ATC facility reduces the facility's ability to safely control traffic through its airspace. Equipment-related events force ATC to restrict the volume of traffic through that facility's airspace. Similarly, losing a runway localizer when under IFR conditions reduces an airport's landing capacity. In this situation, the equipment-related event forces ATC to reduce the arrival rate at the affected airport in order to meet its diminished capacity. Another type of event occurs when airports either change runways or switch landing and departure directions due to a change in wind direction. The new runway configuration is the change in the constraints that governs the flow of traffic to and from the airport.

1.3.2 Traffic-flow constraints

For any environment, conditions exist that determine or restrict movement through its space. There are four general classes of *traffic-flow* constraint that can limit travel from one location to another. These classes are constraints on:

- when you can leave
- which way you can go
- how fast you can go
- when you can arrive

These constraints apply to any vehicle or person traveling from a specified location to a pre-determined destination. In the domain of aviation, constraints are the conditions on or limitations of the flow of air traffic in the NAS. The left-hand column of Table 2 presents the four classes of air-traffic-flow constraint in aviation terminology (departure restriction, en route area restriction, en route flow restriction, and arrival restriction). The four classes of constraint represent a mutually exclusive and exhaustive set of all possible traffic flow limitations on the NAS. The right-hand column lists the equivalent ATCSCC Advisory (see section 2.2.5) that is published for each specific type of restriction. These restrictions are intended for system-wide distribution. Restriction types denoted by square brackets [ ] represent ATC-issued restrictions that are not official ATCSCC Advisory types. These restrictions are generally intended for select distribution between ATC facilities.

Departure restrictions are constraints that prevent a flight from departing an airport on time. An airport's departure rate is one type of departure restriction. Visibility, runway configuration, and volume of landing traffic all determine an airport's departure rate. En route spacing delays are a second type of departure restriction. Spacing delays occur when a high volume of overhead traffic limits the available slots (distance between aircraft) for a departing flight. The flight is held on the ground until the next slot becomes available. A third type of departure restriction takes place when problems at the destination airport delay a flight from receiving a departure clearance time. The flight is held on the ground until an arrival slot is available.

Table 2. Traffic-flow constraints on the National Airspace System

Departure Restrictions	Equivalent ATCSCC Advisory
departure rate	Departure Delays
en route spacing delay	Enroute Spacing Program (ESP)
restricted departure to specified destination airport	Ground Stop; Ground Delay Program
En Route Area Restrictions	
restricted use of specified route recommended alternate route restricted use of specified arrival fix restricted airspace (no fly zones) }	Route Advisory; SWAP Route Advisory Ground Stop; Ground Delay Program
restricted use of altitude	Low Altitude Alternate Departure Routes (LAADR)
fix balancing	none
En Route Flow Restrictions	
en route spacing	none [miles-in-trail (MIT)] [number of streams]
en route holding	Airborne Holding
vectoring	none
Arrival Restrictions	
arrival rate	Arrival Delays [airport acceptance rate (AAR)]
approach holding	Airborne Holding

En route area restrictions are constraints that prevent an aircraft from flying through a specified volume of airspace. Weather- and traffic-related events are the most common sources of en route area restrictions. Typically, an en route area restriction closes off a portion of an established route through a center's airspace. Area restrictions are usually accompanied by constraints that indicate alternate routes – routes that are recommended in place of the closed routes. Another type of en route area restriction limits the use of one or more arrival fixes. This often causes considerable route deviations in order for the flight to get into the stream over an alternate arrival fix. A similar constraint is fix balancing. This happens when selected aircraft are rerouted to an arrival fix with less traffic demand in order to distribute the flow of traffic more equally over all four arrival fixes and to optimize an airport's arrival rate.

En route flow restrictions are constraints that reduce or regulate the rate at which aircraft pass a specified location of the airspace. Miles-in-trail is a constraint that specifies a minimum distance (in miles) between each aircraft in a stream of traffic. The greater the MIT, the fewer the number of aircraft that will pass over a fix in a given time period. For example, based on an aircraft making a final approach traveling 230 mph (ground speed), a 15 MIT restriction results in one aircraft passing over an arrival fix every three minutes, while a 40 MIT restriction results in aircraft passing the same fix once every seven minutes. In contrast, en route holding temporarily stops the flow of traffic. High volumes of traffic occasionally force ATC to hold aircraft for an indefinite amount of time in order to meet the flow restrictions imposed by an adjacent center. Another type of an en route flow restriction is requiring aircraft to make minor vector deviations. Issuing vector deviations is a strategy used to slow the progress of an aircraft for the purpose of fitting it into the stream of traffic.

Arrival restrictions are constraints at an arrival airport that prevent a flight from landing on time. Like the departure rate, an airport's arrival rate is constrained by an airport's visibility, runway configuration, and volume of departing traffic. For example, the arrival rate at a major U.S. airport (ATL with runway configuration: landing 26L/27L and departing 26L/27R) with optimal visual conditions is 70 aircraft per hour. However, the arrival rate drops to 65 aircraft per hour under normal VFR conditions and 55 aircraft per hour under IFR conditions. A second type of arrival constraint is approach holding. The total number of landing aircraft is spread out over time by placing a portion of aircraft in a holding pattern, thus, reducing the volume of landing traffic to match the airport's arrival rate. The time an aircraft spends holding is a function of the total volume of landing traffic, the airport's arrival rate, the number and position of aircraft within the holding pattern, and the aircraft's arrival fix. The usual practice is to first hold aircraft at the arrival fix with the lowest traffic volume and, if that does not alleviate the flow problem, initiate holding at one or more of the other arrival fixes.

Regardless of the class of traffic-flow constraint, all restrictions possess a *geographical*, *rate*, *directional*, and *temporal* component. A restriction triggered by an event affects the flows of traffic (rate) through (directional) a specific area (geographical) for a period of time (temporal). For example, a thunderstorm blocking the southeast arrival fix at O'Hare may result in ATC rerouting landing traffic over the northeast and southwest arrival fixes. The restriction reduces dramatically the traffic flow (rate) to (directional) the southeast arrival fix (geographical) until the weather clears and the arrival fix reopens (temporal).

1.3.3 Flight-related constraints

The four classes of traffic-flow constraint described above are conditions or limitations that may have system-wide implications. In contrast, three classes of flight-related constraint are specific to individual flights. These classes of flight-related constraint, *aircraft performance restriction*, *fuel restriction*, and *time restriction* determine the extent to which a traffic-flow restriction affects a particular flight. Table 3 presents the three classes of flight-related constraint.

Table 3. Flight-related constraints on the National Airspace System

Aircraft Performance Restrictions
aircraft type weight equipage MELs weather
Fuel Restrictions
departure delay altitude deviation route deviation airborne holding alternate airport
Time Restrictions
scheduling crew time

Aircraft type is an *aircraft performance restriction* that limits a flight’s range (altitude and distance) and speed. An en route area restriction, such as a route or altitude restriction, affects aircraft types differentially. Generally speaking, a 757 will be able to tolerate greater route deviations than a DC9. Equipage limits the possible routes that a flight can take. An over-water equipped aircraft has a greater number of route choices than a similar aircraft without the equipment. A recommended alternate route over water will require the ATC coordinator of a non over-water equipped aircraft to request an alternate over-land route that may be less direct than the over-water route.

A *fuel restriction* can limit the amount of airborne holding that can be absorbed before an alternate airport is sought. For example, an arrival restriction, such as a 20-minute approach hold, may only delay one flight by 20 minutes but force a second flight to divert immediately due to low fuel reserves. A fuel restriction may also force an aircraft to return to the gate if a departure delay is too long. The ability for a flight to absorb an altitude reduction for an extended portion of the flight plan is also constrained by fuel.

Time restrictions limit the amount of departure delay a flight can absorb. The crew time constraint may force an airline to cancel a flight if the departure delay pushes the flight crew past their legal on-duty limit. Scheduling constraints determine the amount of delay a flight can absorb before it becomes more practical to cancel the flight and use the aircraft for another flight. This is particularly true with airlines using the hub & spoke system. A flight experiencing an extended departure delay is likely to miss most of its passengers’ connecting flights and delay the next leg the aircraft is scheduled to fly.

1.3.4 Sequence of constraints

An important factor concerning events and constraints is that a single event can, and usually does, trigger a sequence of traffic-flow constraint changes. This means that each ATC-issued restriction is associated with a specific event, even in cases where the connection is not apparent. Furthermore, an event only exists as long as there are constraints associated with it. Once all the restrictions associated with an event have expired, the event itself terminates.

The following scenario depicts a probable sequence of constraints triggered by a weather-related event. Weather at a major airport often compels ATC to issue a Ground Stop or a Ground Delay Program in order to reduce landing traffic to a manageable level. These departure restrictions lessen an airport's landing traffic by either preventing flights destined for the affected airport from departing (Ground Stop), or delaying the departure time of those flights (Ground Delay Program). Nonetheless, neither restriction addresses the problem of traffic that is currently en route. Often additional restrictions are necessary for handling airborne traffic. These advisories usually take the form of arrival restrictions. Approach holding is one strategy used to deal with excessive amounts of landing traffic. Because there are limits to the number of aircraft one sector can hold, en route area and flow restrictions (e.g., MIT, fix balancing, reroutes) are commonly implemented to reduce the numbers of aircraft entering sectors that are near saturation. This sequence of restrictions will continue to evolve - some new restrictions are created while existing ones expire - until all restrictions associated with the event have expired.

Although the example starts with an arrival restriction, it is just as likely for ATC to first issue en route area and flow restrictions. The order in which a sequence of restrictions unfolds is based on such factors as the type of event (e.g., weather, traffic, equipment), the location and time of the event, and the amount of traffic expected during the event. For example, a slow developing weather-related event may begin with MIT and reroute restrictions, while the sequence of restrictions for an equipment-related event, such as a radar outage at an approach center, will most likely start with a Ground Stop of all traffic destined for that airport.

1.3.5 Life-cycle of events

Although events trigger constraint changes that initially reduce the capacity of the NAS, air traffic volume does not necessarily decrease throughout the entire duration of an event. As restrictions expire and fewer new restrictions are issued, the capacity begins to increase. Eventually, by the time all restrictions expire, the capacity will reach the pre-event level. Figure 5 represents the hypothetical change in air traffic flow throughout the 'life-cycle' of a single event. The symmetric U-shaped curve is strictly illustrative. It shows the general trend in traffic volume during an event. The increased-flow stage portion of the curve may be flatter (represented by the dotted line), indicating the pre-event capacity level is not reached until after the event has terminated.

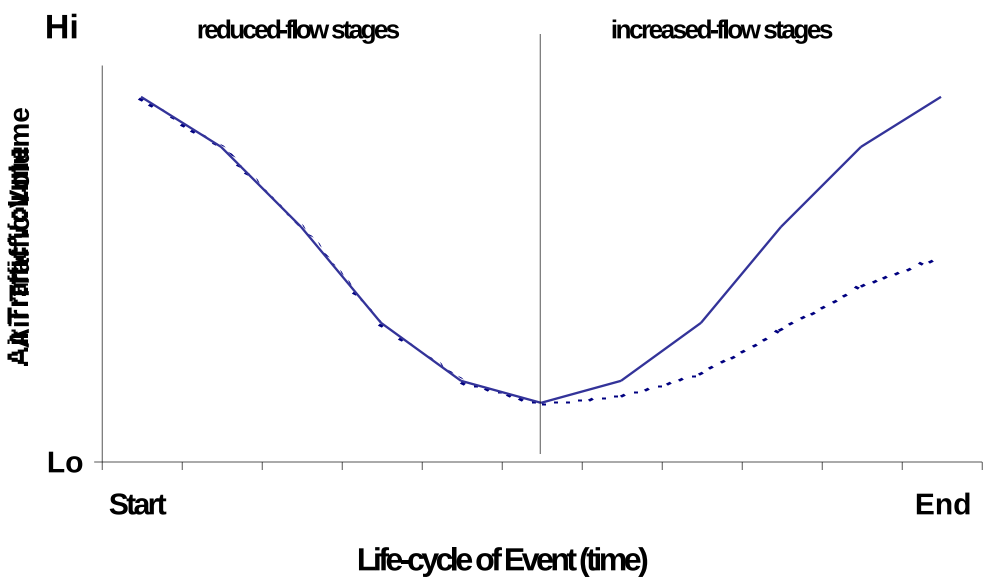


Figure 5. <u>The change in traffic volume throughout the life-cycle of an event</u>

Current information technology makes it difficult to determine the current stage of an event. It would be highly advantageous for ATC coordinator and dispatchers to be able to distinguish between the stages, between those that reduce air traffic flow and those that increase flow. Early recognition of reduced-flow stages and quick response may lessen the impact the event has on the airline's operations. Likewise, timely detection of increased-flow stages and response may help the airline recover and resume normal operations more quickly.

Section II: The ATC Coordinator Position

2.1 ATC Coordinator Duties

The following account is a composite description of the ATC coordinator position at three major U.S. airlines. It summarizes the essential duties and experiences, but does not attempt to portray the position at any one airline. The duties of the ATC coordinator described below are limited to those that require some level of interaction with ATC. It should be noted that the ATC coordinator is usually responsible for other 'in house' duties which are not within the scope of this discussion.

The ATC coordinator position is usually filled by a certified airline dispatcher and consists of numerous duties that either directly or indirectly involve ATC. These duties, which are explained in detail below, range from a routine task, such as maintaining a daily log of communications, to a multifaceted task, such as planning pre-event strategy with ATC.

2.1.1 Compiling daily log

The ATC coordinator position is responsible for keeping a daily log of information relevant to the dispatching of aircraft. The log contains information from a collection of sources. Some of the information sources include:

- ATCSCC Advisories (see section 2.2.5)
- system outlook teleconferences (which supply arrival rates and runway configurations for all major airports)
- severe weather teleconferences (including the Northeast hotline)
- 'in-house' memos, PIREPs, and ACARS
- flight schedules
- weather updates from meteorologists and station personnel.

In most cases, messages are copied and pasted into the log screen, although it is not uncommon for the ATC coordinator to have to retype information into the log. This clerical task can become quite burdensome when severe weather teleconferences are frequent and ATCSCC Advisories are numerous.

2.1.2 Monitoring ATC-issued restrictions

A critical duty for an ATC coordinator is to monitor ATC-issued restrictions on the NAS, which are disseminated in the form of ATCSCC Advisories. The task involves keeping track of which restrictions are in effect at any one time (the temporal component of constraints) and the nature of those restrictions (the geographical, rate, and directional components). Although dispatchers receive all published ATCSCC Advisories, their focus is generally limited to a portion of the NAS (i.e., the geographical area connecting their origin and destination airports). It is largely the responsibility of the ATC coordinator to keep track of current ATC-issued restrictions and to communicate this information to dispatchers when requested.

The manner in which ATC coordinators monitor restrictions varies across airlines, as well as between individuals at the same airline. There are three general methods of monitoring ATC-issued restrictions. First, and most common, is to print each advisory and then either stack them sequentially or group them depending on their type or location. Second is to monitor the ATCSCC web site. This site lists all advisories both sequentially and by type, with both lists linked to the full text version of the advisory. Third is to reference ATCSCC Advisories by scrolling through the daily log. One variation observed is to log the information into an 'advisory template' that is accessible to dispatchers, station personnel and other ATC coordinators. Each template is designated for a different type of advisory (e.g., Ground Stop, GDP, Route Advisory templates) and contains only the most pertinent information. For example, the Ground Stop template contains fields for location, starting and ending time, and probability of extension. While the 'advisory template' screen is an easier way to access advisory information than scrolling through the daily log, it is more time consuming to enter the information into templates than it is to copy and paste advisories into a log.

2.1.3 Monitoring teleconferences

The ATC coordinator is responsible for monitoring various teleconferences throughout the day. The system outlook teleconference provides the airline with a system-wide view of air traffic flow and an indication of developing problems. It is scheduled twice daily and allows for users to ask questions. Commonly, there are severe weather teleconferences during the connective weather season. These teleconferences take place periodically throughout the day when weather-related problems demand it. The ATC coordinator usually participates in severe weather teleconferences, asking for clarification of restrictions or suggesting possible strategies. A third type of teleconference is the northeast hotline. It is specifically conducted to deal with weather problems impacting the northeast en route centers (ZNY, ZBW, ZOB, and ZDC). The hotline is more like an open line than a teleconference. The ATC coordinator can monitor the communications between the northeast facilities, but cannot participate.

The teleconferences supply the ATC coordinator with insight to potential ATC actions. The conversations on these collaborative teleconferences, specifically the severe weather and hotline, take the form of problem-solving verbal protocol. The dialog between participating TMUs and the command center shifts between delineating the existing problems, suggesting possible solutions, and implementing airspace restrictions. The decision process during a single teleconference generally incorporates a number of problem-solving iterations. The NTMSs furnish, either directly or indirectly, information about restrictions that are presently being implemented as well as information that allows the airlines to anticipate future airspace restrictions. The severe weather teleconference also provides the opportunity for collaboration between the airlines and ATC, especially with issues involving reroutes.

2.1.4 Planning weather-related strategy

One of the most productive duties performed by the ATC coordinator is planning strategy with ATC when weather is imminent. Although not a formal teleconference, these conference calls usually take place between the ATC coordinator and TMU responsible for that airline's hub airport, and may include meteorologists from both facilities. The ATC coordinator supplies the airline's perspective of the weather situation and how best to deal with it. In many cases the dialog involves jointly planning reroutes, but may involve discussions about more severe ATC-issued restrictions (e.g., Ground Stops or Ground Delay Programs).

One information source used for planning weather-related strategy is the Collaborative Convective (Weather) Forecast Product (CCFP). CCFP is a collaborative weather forecast produced by National Oceanic and Aeronautic Administration (NOAA) with input from ATC and the airlines. It is designed to provide a system-wide forecast and be available to all users. The goal is to provide a means for anticipating ATC actions by supplying all parties with the same information (i.e., a common weather forecast). Some airline meteorologists have suggested that the CCFP planning teleconferences are more informative than the final product.

The weather-related conference calls are generally more collaborative than other interactions between the airlines and ATC. However, their effectiveness is in part dependent on the working relationship between the airline and the TMU. A common opinion of ATC coordinators is that this type of collaboration does not happen often enough.

2.1.5 Assisting with route planning

One goal of the dispatcher is to plan a safe, efficient route for each flight. For this, dispatchers (especially the less experienced) rely on information from and the expertise of the ATC coordinator. ATC coordinators, with up-to-the-minute details about ATC-issued restrictions, information gathered from teleconferences, and their own dispatch experience, are better able to construct routes in the face of changing constraints on the NAS. This is particularly true when concurrent events are triggering a myriad of constraint changes.

At some airlines, dispatchers maintain a more autonomous relationship with ATC coordinators. Route planning at these airlines is solely the responsibility of the dispatchers. The ATC coordinator is consulted only occasionally, usually to clarify ATC actions (see section 2.1.6), but seldom for route planning advice.

2.1.6 Clarifying ATC actions

ATC coordinators function as the dispatcher's voice by directly communicating with ATC facilities by telephone. Dispatchers commonly approached the ATC coordinator looking for explanations as to why their flights are being affected. As a result, the ATC coordinator spends a disproportionate amount of time clarifying ATC actions concerning individual flights. The types of ATC actions that generally need clarification are reroutes, departure delays, airborne holdings, and, if needed, the content of the ATCSCC Advisory itself.

A major focus of clarification centers on the airlines' need to understand ***why*** a particular restriction has been implemented. Specifically, clarification of actions involves the ATC coordinator identifying the event responsible for the restriction. Dispatchers need to know that a current flight is being rerouted because of weather (either en route or at the destination airport), sector capacity, or equipment problems at an ARTCC. Knowledge of the source of the event enables dispatchers to effectively plan routes for future flights that will minimize delays.

When the ATC action concerning an individual flight cannot be explained by published advisories, the ATC coordinator usually telephones the appropriate ATC facility. This can either be a simple procedure or a fruitless attempt to gain information. When ATC is not inundated with weather-related problems, ATC personnel are usually forthcoming with an explanation to their actions. Not surprisingly, when weather is a significant problem, these telephone conversations are less productive and in some extreme situations can turn confrontational. In the worst case, communications completely break down when facilities do not have enough personnel to even answer the telephone.

2.1.7 Coordinating off-loads

Fix balancing is a procedure used by TMCs for the purpose of reducing or preventing airborne holding over arrival fixes. When traffic over one arrival fix becomes too heavy, the TMC will reroute some flights to a less congested arrival fix. Usually the TMU notifies the ATC coordinator before off-loading flights. The ATC coordinator often has the opportunity to decide which flights will be off-loaded and which will remain on their filed route. The decision is primarily based on scheduling and fuel considerations.

Although, it is not always the case that the ATC coordinator is notified before the off-load is implemented. In these situations, the ATC coordinator often learns of the off-load through the dispatcher who has been informed by the pilot. The break down of communication (described in section 1.2.3 and Figure 4) frequently forces the ATC coordinator to telephone the TMU to determine whether the route change is in fact an off-load and not some other en route area restriction.

2.1.8 Monitoring departure delays

When traffic-flow restrictions impact an airline's hub airport, either directly (Ground Stop or GDP) or indirectly (Enroute Spacing Delays or SWAP routes), the ATC coordinator will monitor the departure delays. Of specific concern is the time a flight spends on the ground after it has pulled off the gate. Excessive delays warrant the ATC coordinator to contact the appropriate Tower or TRACON for an explanation and estimated departure time.

2.1.9 Slot-Swapping

In a severe weather situation when it is necessary to reduce the arrival rate at an impacted airport, ATC will implement a Ground Delay Program. Regardless if compression is run at the onset of the advisory and/or later in the program, the airlines must decide which flights should be cancelled and which flights should be swapped into the newly opened slots. While cancellations are usually decided by other airline personnel, the ATC coordinator is usually responsible for running a slot-swapping program and submitting the swap-list for ATC compression.

The slot-swapping task must be performed under a time constraint in order to meet ATC's compression deadline. If the newly created swap-list is not submitted in time, the slots opened up by the airline's cancellations will be lost. This means that any competitor's flight has the possibility to be moved into the vacated slot. Slot-swapping is a stressful task in severe weather situations when other important duties must be performed concurrently.

2.1.10 Compiling diversion list

The ATC coordinator is responsible for compiling a list of flights that have diverted due to weather at an airport. The list is submitted to the appropriate TMU. This ensures that these flights will have priority departure clearance when operations resume at the impacted airport.

2.2 Information Communication Devices

This section discusses five tools or Information Communication Devices (ICD) ATC coordinators rely on to obtain information about NAS constraints. While the flow of information may travel two ways, the primary direction of information flow is from ATC to the airlines. The ICDs described below are the tools used by ATC to convey information to the airlines. The five ICDs presently in use by ATC coordinators are:

- the Aircraft Situation Display (ASD) presents a graphical display of relatively current information (1-3 minute updates) about aircraft positions and vectors
- the telephone is used for one-on-one conversations between the ATC coordinator and a specific ATC facility
- teleconferences are used to facilitate communications and collaboration among numerous ATC facilities and the airlines
- the Flight Schedule Monitor (FSM) enables the airlines and ATC to monitor arrivals and departures at major airports
- ATCSCC Advisories are text-based messages about traffic-flow restrictions that are disseminated to all ATC facilities and airlines

2.2.1 Aircraft Situation Display (ASD)

The ASD graphically displays current aircraft positions superimposed on maps of geopolitical and ATC center boundaries. It is useful in "creating a shared mental model of traffic flow” between airlines and ATC (FAA, 1997). Its two most important uses are 1) to determine the current location of specific flights and 2) to determine traffic flow into and out of airports and around weather. The ASD is capable of displaying four information classes; *location*, *route*, *weather*, and *flight*.

Location information includes ARTCC boundaries, state borders, airports, navaids, and arrival and departure fixes. *Route* information consists of jet routes and route bins containing pre-constructed routes. *Weather* information includes nexrad returns, echo tops, jet stream, and lightning. The ASD is capable of either displaying or hiding any one of these items. *Flight* information consists of individual aircraft icons with data blocks that include information such as carrier and flight number, aircraft type, origin and destination, altitude and ground speed, estimated time of arrival (ETA), and current route. Flights can be filtered for any or all of these items. Flight information, not displayed within the data block, includes the filed routes of individual flights.

2.2.2 Telephone

The ATC coordinator relies heavily on telephone communications with ATC. Most telephone communications is done through the ATCSCC. However, when a problem is specifically related to an individual facility, the appropriate facility is contacted. In other words, the ATC coordinator generally contacts the ATCSCC when dealing with system-wide issues and contacts individual facilities when dealing with problems concerning specific flights.

As an ICD, telephone conversations vary in effectiveness. These conversations appear to be more productive when the ATC coordinator is dealing with their ‘home’ ATC Center (e.g. ZMP for NWA, ZFW for AAL) than with an ‘outside’ center. In isolated instances, telephone communications with ‘outside’ centers can turn hostile.

2.2.3 Teleconference

As mentioned previously, the ATCSCC holds system-wide teleconferences throughout the day. The system outlook teleconference takes place twice daily, once in the morning and once in the afternoon. All TMUs at the ARTCCs are required to participate in these teleconferences. Most ATC coordinators monitor the teleconferences and often participate by asking ATC for clarification of their actions. Severe weather teleconferences are only scheduled when weather requires collaboration between various ATC facilities and the airlines. The airlines are notified of the teleconference in advance through a Teleconference Advisory issued by the Command Center. ATC coordinators are also able to participate in this type of teleconference. A third type of teleconference is the Northeast hotline. The hotline focuses specifically on traffic problems created by weather in the northeast region (e.g., ZNY, ZDC, ZOB, ZBW). ATC coordinators can monitor but may not participate in these teleconferences.

2.2.4 Flight Schedule Monitor (FSM)

FSM allows the ATC coordinator to monitor arrival and departure flows at major airports as well as track individual flights arriving at and departing from those airports. The FSM is capable of displaying individual flight information, airport arrival rates, and open arrival slots. Airport demand information is displayed either as a bar chart with specified time intervals or as a time-line that sequentially lists and identifies arrivals.

Another component of the FSM is the Ground Delay utilities. These allow the ATC coordinator, for example, to model a Ground Delay Program for various scenarios and view the consequences before taking any action on specific flights (i.e. delaying or canceling a flight). This utility has become an integral tool for airlines, particularly during the convective weather season.

2.2.5 ATCSCC Advisories

The ATCSCC Advisory system supplies the airlines with a list of NAS restrictions. These advisories are transmitted system-wide in the form of text messages that appear in a text window on the airline's proprietary flight management system. The advisories can be copied, printed, forwarded, and deleted. At most airlines, advisories are copied into the daily log and printed.

A second format for disseminating ATCSCC Advisories is a web page on the ATCSCC Internet site (http://www.atcscc.faa.gov/advisories/ADB_sys.html). This format allows advisories to be viewed either sequentially by time or categorically by type (Ground Stop, Ground Delay Program, Weather-related, Airport, Volcanic, and All Others). Regardless of how the advisories are arranged, the web page displays an advisory number and descriptive header that is linked to the complete text message. The text layout of the web-based advisory is identical to the text-message format.

Neither the text-message nor the web page format allows the user to filter out irrelevant advisories. The rate at which advisories are issued can create an intractable task for personnel monitoring them. On days when weather impacts large areas of the country, as many as 150 advisories might be issued in a 24-hour period. The task of monitoring ATCSCC Advisories is generally not a problem for TMCs since they are usually aware of all restrictions relevant to their center, through telephone communications with ATCSCC, before advisories are published. In contrast, ATC coordinators and dispatchers must at least initially attend to all advisories, and then decide whether the advisory is worth monitoring (i.e., "Will the restriction affect my flights?") or should be "filtered-out" (i.e., thrown in the recycle bin).

2.3 Issues and Problems of Air Traffic Flow

2.3.1 Departure delays

Departure delays are probably the most disruptive problem facing commercial air travel today, comprising of approximately 80% of all delays (FAA, 1999). It is not uncommon for a flight to pull from the gate and wait for a departure clearance time, eventually receiving a clearance time that is well past their scheduled off-time. When weather is involved, which it usually is during the summer convective weather season, these departure delays can extend for 1-2 hours or more.

In situations such as this, airlines are left with two less-than-desirable choices. They can either let the aircraft sit on the runway and wait it out, or they cancel the flight and have it head back to the gate. Canceling the flight also requires that there be an open gate to which to return. Continuing to wait on the runway is uninviting since it is not usually clear when a departure clearance will be issued. Departure delays are especially problematic for airlines, not only for the inconvenience and discomfort experienced by their customers, but for the disruption it causes trying to connect passengers, flight crews, and aircraft to their next leg.

The first issue involving departure delays is how to determine when an actual delay is occurring. Currently, ATC has no system in place that notifies the airlines of departure delays for individual flights. ATCSCC issues Departure/Airport Delay Advisories that indicate the reason for and expected length of a delay at an affected airport. Unfortunately, these advisories do not address individual flights and often are published after airline personnel are already aware of the delay.

The airlines have their own means for acquiring this information. First, they have an 'on-ground report' that identifies flights that have exceeded their taxi time by a specified amount. Generally, an ATC coordinator is concerned only with flights that have exceeded their taxi time by more than 15 minutes. This requires the ATC coordinator to check periodically airports that are suspected of having departure delay problems. The second way of acquiring this information is by direct communications with the pilot. Although, this occurs only when the pilot has become frustrated enough with ATC to contact the dispatcher for an explanation.

A second issue concerns the airline's inability to estimate the length of the delay. ATC has no procedure for estimating a flight's expected off-time once it has exceeded its scheduled off-time. Furthermore, the Enhanced Traffic Management System (ETMS) does not update a flight's filed flight plan while the flight is incurring a departure delay. While delayed on the ground, the ETMS periodically adjusts a flight's departure time by automatically adding five minutes to the previous off-time. The flight's flight plan is only updated once the flight actually departs, often many minutes to hours after its scheduled off-time.

2.3.2 Arrival holding

Arrival holding is another serious airline concern. ATC procedures mandate that a landing aircraft put into a holding pattern is issued an EFC (Expected Further Clearance). An EFC is an indication of when ATC will issue further instructions, but not necessarily the time holding will be terminated. This is done in the case radio communication with the aircraft is interrupted or lost. The pilot, as well as the sector Controller, will know when the aircraft should leave the stack and begin the approach. The EFC is dependent on a number of factors such as the airport's arrival rate, the volume of airborne traffic, the number of aircraft in the stack, and an aircraft's position in the stack.

The typical procedure is to give each consecutive aircraft in the stack an additional holding delay of 5 minutes (e.g., the first aircraft receives an EFC of 15 minutes, the second receives an EFC of 20 minutes, the next aircraft receives an EFC of 25 minutes, and so on). Using this procedure means that approaches will be separated by about 25 MIT, greater than the typical approach rate. An EFC is typically the worst case scenario and often is an imprecise indicator of actual holding time. A pilot told to hold and expect an update in 30-40 minutes may immediately decide to divert to an alternate airport when the actual holding time is closer to 15-20 minutes.

2.3.3 Route changes

ATC often change filed routes, both when flights are on the ground and airborne, without input from airlines. Furthermore, ATC is not required to notify airlines of the reroutes. Often dispatchers are notified of the route change by the pilot (section 1.2.3). Other times dispatchers learn of reroutes by noticing the route change displayed on their ASD. Reroutes issued before departure are sometimes done with insufficient time for airlines to adjust for fuel and still remain on schedule. Reroutes issued en route do not take into consideration an individual flight's fuel situation. If the fuel situation is serious enough, it will force the flight to divert for refueling. In both cases, the airlines' goal of safe, efficient, and economical service is compromised.

Reroutes pose a second problem for airlines. ATC coordinators and dispatchers often do not know the extent of the route change. For planning purposes, it is important to know if the reroute is for an individual flight or whether it pertains to all flights filed on that route. It is necessary for dispatchers to adjust future flight plans if the situation is the latter. ATC-issued Route Advisories and SWAP Route Advisories, when published before reroutes are issued, provide the airlines with knowledge that the route change is part of a large-scale strategy and not an isolated instance. Otherwise, the ATC coordinator must attain this information through telephone calls to the appropriate ATC facilities.

Section III: Analytical Account of the Information Requirements

3.1 General Tasks of an ATC Coordinator

Although the ATC coordinator's duties described in section 2.1 vary considerably (e.g., compiling the daily log compared to planning weather-related strategy with ATC), most are performed with the goal of providing dispatchers with information about the NAS. This is accomplished by furnishing dispatchers with information about ATC actions and intent. The first subsection describes a framework that characterizes the duties of the ATC coordinator (described in section 2.1) as a cycle comprised of four general tasks: *gathering information*, *organizing information*, *formulating a system outlook*, and *disseminating the system outlook*.

The sources of information needed to perform these tasks range from in-house (weather, scheduling, and equipment) personnel to airline personnel at airports to ATC personnel at various facilities. Since ATC is the airlines' primary information source about the NAS, it is paramount for the ATC coordinator to pay particular attention to ATC actions. The following three subsections decompose the general tasks into subtasks that specifically focus on ATC actions and intent. Subtasks of the first three general tasks are *monitoring ATC actions* (gathering information), *identifying the scope of ATC actions* (organizing information), and *inferring ATC intent* (formulating a system outlook). The task of disseminating the system outlook is not decomposed here since it is strictly an 'airline-only' activity and its sub-tasks do not involve ATC.

3.1.1 General tasks

Figure 6 depicts the cycle of four general tasks performed by an ATC coordinator. To begin with, the ATC coordinator *gathers information* about the NAS. This is achieved by monitoring teleconferences, ATCSCC Advisories, and departure delays. ATC coordinators also monitor airport arrivals and departures with the FSM, and en route traffic flow with the ASD. In addition, other information sources such as meteorology, scheduling, and equipment personnel at the airline are routinely consulted. The second task is *organizing the information* gathered in the previous task. This is achieved by linking associated, event-related information together. For example, ATC-issued route restrictions to an airport, departure delays at that airport, airborne holding at or en route to the airport, and weather in the vicinity of the airport most likely constitute associated or event-related information. The task of organizing information is essentially grouping or sorting information, including ATC actions, according to the events with which they are associated. Next, the ATC coordinator *formulates a system outlook*, a system-wide view of air traffic flow. Based on information gathered and organized about what is happening throughout the NAS, the ATC coordinator develops a system-wide view of the airspace. This 'view' or insight into air traffic flow is based on an understanding of what and where the events are and how to effectively dispatch around them. The fourth task is *disseminating the system outlook*. The system outlook is primarily communicated to dispatchers in the form of route planning assistance and clarification of traffic-flow problems.

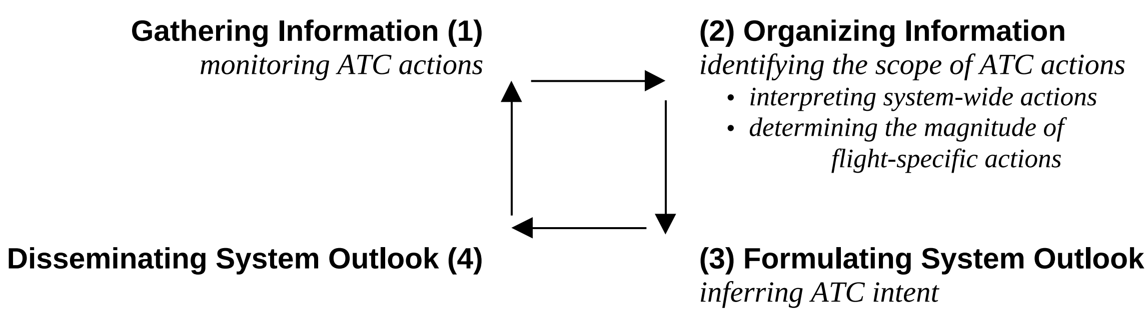


Figure 6. General tasks and subtasks performed by ATC coordinators

3.1.2 Monitoring ATC actions

The ATC coordinator's eventual goal is to provide dispatchers with updated information about the NAS (the system outlook) that will enable dispatchers to plan upcoming flights more effectively. The first step in achieving this goal is gathering information about such things as weather, route availability, and delays, and communicating this to dispatchers. As depicted in Figure 6, an essential subtask of gathering information is *monitoring ATC actions* that trigger changes in NAS constraints and ultimately affect the decisions made by dispatchers.

Monitoring ATC actions requires that an ATC coordinator pay attention to the main source of information about NAS constraints - communications from ATC itself. In-house information sources such as meteorology, scheduling, and the dispatchers themselves (who supply ATC coordinators with valuable information about actions targeted at individual flights) also need to be monitored. Nonetheless, it is ATC that provides most of the information about NAS constraints and most often this information is in the form of ATCSCC Advisories.

3.1.3 Identifying the scope of ATC actions

Before a system outlook can be formulated, the information gathered by the ATC coordinator must be organized in a meaningful way. *Identifying the scope of ATC actions* is paramount to understanding what is happening in the NAS. It helps provide an answer to the airline’s question, “Why is this happening to my flight?” By being able to recognize the scope of an ATC action, the ATC coordinator is able to link associated information (i.e., link actions to their underlying causes). As indicated in Figure 6, a critical subtask of organizing information is to identify the scope of ATC actions. Identifying the scope of ATC actions can still be further decomposed into two subtasks or task elements that focus on different levels of the NAS.

At the macro level, the task element is to *interpret system-wide actions*. System-wide actions are actions taken by ATC that have the potential to affect all users of the airspace, but are not directly associated with specific flights. These types of actions are typically traffic-flow restrictions on the NAS and conveyed in the form of ATCSCC Advisories. Interpreting system-wide actions requires airline personnel to determine which event has triggered the traffic-flow restriction of concern.

At the micro level, the task element is to *determine the magnitude of flight-specific actions*. Flight-specific actions are actions taken by ATC that are specific to individual flights and result in deviations from a flight's filed flight plan. These deviations are often in the form of route changes, departure delays, and airborne holding. A flight-specific action may or may not be the result of a system-wide action. Determining the magnitude of an action involves assessing whether or not the flight-specific action is the result of an existing ATC-issued Advisory and, if so, which advisory is responsible.

The two task elements, interpreting system-wide actions and determining the magnitude of flight-specific actions, together comprise the subtask of identifying the scope of ATC actions. Figure 7 depicts the unfolding of an event and its associated actions. The two solid arrows represent the evolution of a sequence of event and actions. First, an event occurs in the NAS that forces ATC to take a system-wide action (i.e., issue an advisory). The resulting restrictions on the airspace compel ATC to take a flight-specific action (i.e., implementing a route change or departure delay).

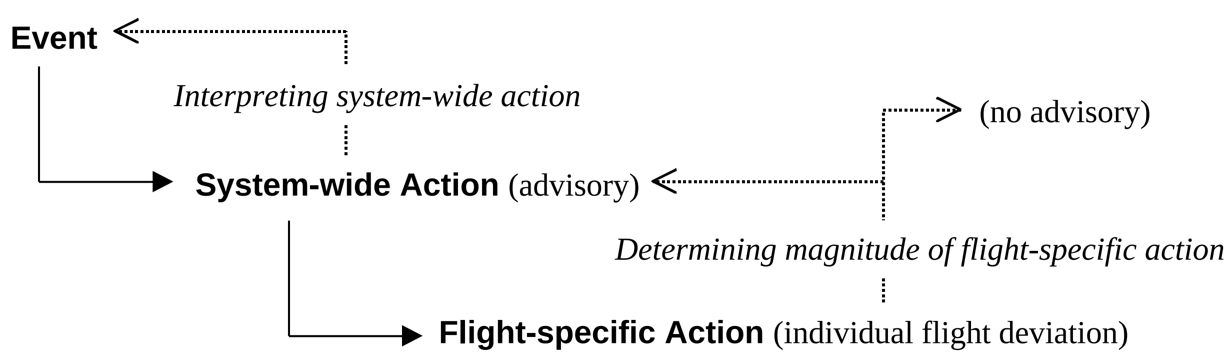
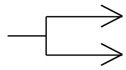


Figure 7. <u>Identifying the scope of ATC actions</u>

The task for ATC coordinators and dispatchers is to recognize the underlying reason for a particular action, whether it is system-wide or flight-specific. Essentially, the task is to follow the sequence of actions backward from the point of concern. For example, if a change in a flight's filed route is in question, it must be determined whether the route change was the consequence of an ATCSCC Advisory or whether the action was an isolated incident. This task element is referred to as 'determining the magnitude of a flight-specific action' and is indicated by the branching dotted arrow in Figure 7. The figure suggests that 1) if an advisory is found, the flight-specific action is interpreted one way and 2) if not found, it is interpreted another way. Similarly, if the concern is over why a particular advisory was issued, the advisory must be traced back or linked to the event that triggered it. This is referred to 'interpreting a system-wide action' and is indicated by the single dotted arrow in Figure 7.

Figure 8 represents the same evolutionary process of events and actions as Figure 7. However, in Figure 8 the complexity of the scenario is increased by the inclusion of time. As noted earlier (section 1.3.4), in most situations an event will trigger a sequence of system-wide actions. Furthermore, to add to the complexity of the situation, it is not unlikely that multiple events will occur concurrently. Figure 8 depicts the occurrence over time of two events with their associated actions, both system-wide and flight-specific. Each advisory is linked to its triggering event by the appropriate arrow. Similarly, flight-specific actions are connected by arrows to their associated advisory. Time, represent by the downward arrow on the right, begins at the top of the diagram and proceeds downward.

Since an event is defined here as an incident, situation or condition within the NAS that leads to changes in the constraints on the NAS, events do not come into existence until the first associated advisory is issued. The straight arrows (⟶) connecting Event 01 with Advisory 01 and Event 02 with Advisory 02 indicate that the event and advisory occurred at the same time. Events and subsequent advisories (Event 01 and Advisories 04, 05, 07, and Event 02 and Advisories 03, 06) are connected by offset arrows in the downward direction. A downward arrow (⎯↳) indicates that the advisory was issued after the initial advisory that instantiated the event. The flight-specific actions on the right side of Figure 8 are connected to advisories in the same fashion with the addition of arrows in the upward direction (⎯↱). These arrows indicate the flight-specific actions that actually took place before the associated advisory was published. The double arrows indicate that more than one type of flight-specific action was associated with a single advisory (). Finally, the 'unconnected' route deviation in Figure 8 represents an isolated action taken by ATC. Actions not associated with advisories or events denote minor traffic-flow adjustments, possibly to balance traffic along a route or at an arrival fix.

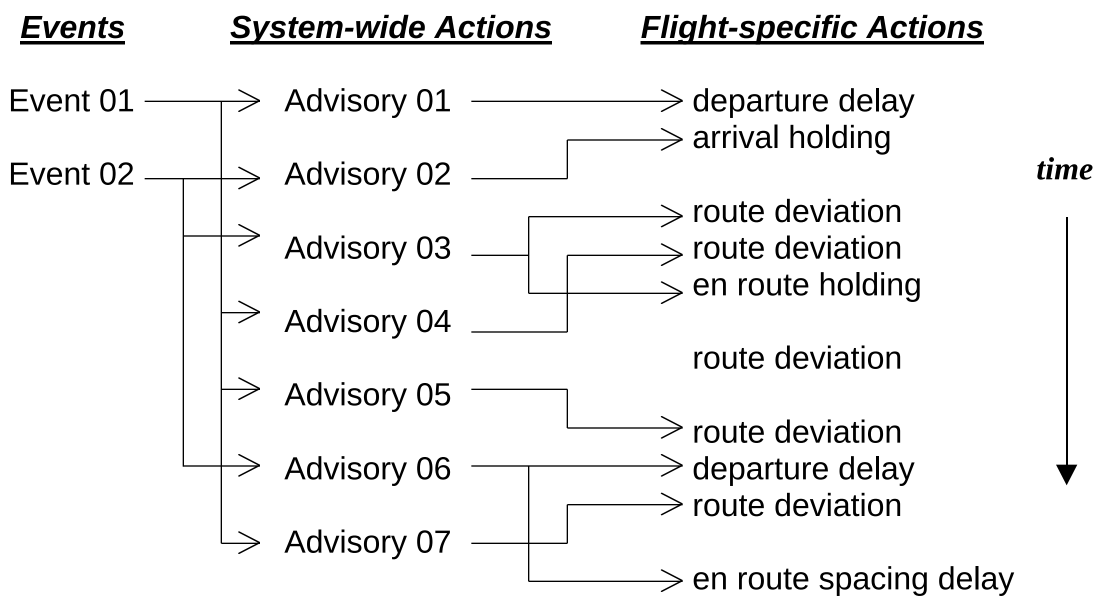


Figure 8. **<u>The evolution of events and actions over time</u>**

The task elements of interpreting system-wide actions and determining the magnitude of flight-specific actions become less routine as the number of events and actions increase. This is especially true when severe weather triggers multiple events with multitudes of actions. Furthermore, the task element of determining whether or not a flight-specific action is the result of an existing advisory is more difficult when the flight-specific action takes place before the associated advisory is published. Initially, it is not possible to connect the action to an advisory that has not yet been issued. Only after the advisory is published can the two be linked, and often by that time the ATC coordinator has already figured out why the deviation occurred. To compound the problem, a flight-specific action that precedes its published advisory and a flight-specific action that takes place independent of any advisory are nearly distinguishable. Situations such as these complicate the task of determining the magnitude of a flight-specific action. Often the solution is either to wait and see if an advisory is forthcoming or call ATC for a clarification.

3.1.4 Inferring ATC intent

The third subtask, under the task of formulating a system outlook in Figure 6, is *inferring ATC intent*. It is not only important for the ATC coordinator to supply dispatchers with information about what ATC is doing, it is crucial for the ATC coordinator to be able to explain what ATC is planning to do. Intent information enables dispatchers to anticipate ATC actions and proactively modify their flight plans accordingly.

Inferring intent is a more difficult task than monitoring ATC actions or identifying the scope of ATC actions. Until recently, the primary means of obtaining information that might be useful in inferring ATC intent was by monitoring scheduled teleconferences (section 2.1.3). Otherwise, ATC coordinators had to rely on ATC's past history to infer future actions. Although there are no tools in place that provide the airlines with historical data for the purpose of inferring action, the development of the National Playbook may provide an important first step in the direction of making explicit ATC intent. The aim of placing all ATC plans into one publication source and making them available to all users hours in advance of implementing the actions should make the task of inferring intent more manageable.

3.2 Basic Information Needs

This section describes three basic information needs of an ATC coordinator, especially for performing the tasks of organizing information and formulating a system outlook. In order for the airlines to operate more efficiently, the information conveyed by ATC must address at least one of three basic needs. These are the need to interpret system-wide actions and determine the magnitude of flight-specific actions (for organizing information) and the need to predict future actions (for formulating a system outlook). The following three subsections describe the information that is essential for addressing these information needs.

3.2.1 Need for causal information

The ATC coordinator must be able to understand why changes in NAS constraints have occurred. Often it is a challenge for the airlines to interpret an action taken by ATC. When asked how he dealt with MIT restrictions, a dispatcher replied, "When I see a miles-in-trail restriction, it's like a red flag … the first step is to figure out what is causing it." ATC coordinators and dispatchers need to know the context in which ATC has undertaken a particular system-wide action. In other words, restrictions implemented by ATC must be clearly associated with an event. The explicit linking of traffic-flow restrictions with their associated event provides causal information (i.e., the underlying reason) about the restriction.

The presence of causal information, created by clearly identifying and defining events, provides critical route planning information. Different types of events usually require airlines to apply different strategies for minimizing their impact. For example, weather-related events are dealt with differently than events that involve high traffic volume. Knowledge of the nature of the event allows the airlines to react more effectively to the changing constraints and make the appropriate adjustments for future flights.

3.2.2 Need for information about all constraints

It is imperative for airline personnel to determine the magnitude of an action directed at a particular flight. Does the action taken pertain to an isolated flight or two, or does the action encompass more flights and other airlines? Too often flights are rerouted by ATC without indication of whether the action is an isolated 'traffic adjustment' or whether it signifies a trend. In order to understand the magnitude of an action, airlines need information about all current traffic-flow constraints. This includes information about both restrictions designated for system-wide distribution (mostly in the form of ATCSCC Advisories) and restrictions designated for select distribution (restrictions typically disseminated between ATC facilities in the form of MIT, (see section 1.2.1)).

The system for disseminating ATCSCC Advisories does not provide an exhaustive account of all traffic-flow restrictions. Miles-in-trail restrictions are generally not included in the current system. MIT restrictions are imposed by one en route center to restrict the flow of traffic coming from a neighboring center. By providing information about all restrictions, including MITs, airlines will be better able to determine the magnitude of flight-specific actions taken by ATC. If an action, such as a route change or airborne holding, is not reflected in an ATCSCC Advisory, then the action can be correctly judged as an isolated 'traffic adjustment' that is not significantly important to factor into future flight planning. When the action does coincide with a published advisory, ATC coordinators and dispatchers will understand why a flight is being affected and take this information into account when constructing routes for future flights.

3.2.3 Need for historical information

In order for ATC coordinators to infer ATC actions, there needs to be information available that will allow for the anticipation of constraint changes on the NAS. Access to a database of previous ATC actions would make it easier for ATC coordinators to anticipate constraint changes on the NAS. If this information were available, the ATC coordinator would be able to formulate a more comprehensive system outlook; the outlook may also include impending constraint changes on the NAS. This will enable airlines to take the appropriate steps to minimize disruptions to service in advance of actual constraint changes. Thus, if ATC were to provide information about their intentions, airlines might actually lessen ATC workload by filing flights around a problem area, precluding ATC from implementing traffic flow restrictions and/or issuing reroutes.

One way of increasing predictive power is to provide ATC coordinators and dispatchers with historical information about system-wide actions. By making available information about past events and their associated restrictions (i.e., the Events and System-wide Actions columns and links in Figure 8), it would be possible to search for and match a historical account of a past event similar to the current flow-constraining event. Airline personnel would then be in a favorable position to anticipate how ATC will manage the current event (i.e., what is the likely sequence of restrictions to be implemented) by knowing how ATC managed a similar event in the past.

3.3 Classes of Information

The information available to airline personnel can be classified into three general information classes: *continuous*, *static*, and *episodic*. These classes are differentiated by the rate at which their information changes. Continuous information changes at a relatively high rate while static information remains unchanged. The rate at which episodic information changes depends on whether or not an event is occurring.

3.3.1 Continuous

Continuous refers to information that can and usually does change from moment to moment. What is unique to continuous information is that it is always changing regardless if an event is occurring or not. Some examples include aircraft position / vector / altitude / speed, weather, traffic flows and patterns, and sector volume. The variability of this information requires that an ATC coordinator monitor it regularly and frequently. It also requires that the system used to display the information be able to update the information at an adequate rate. Tools such as the Traffic Situation Display (TSD) at the TMUs, ASD, and FSM generally meet this requirement.

3.3.2 Static

Static refers to information that remains unchanged regardless of events. Some examples of static information include ARTCC and sector boundaries, sector capacities, jet routes, pref-routes, flight numbers, arrival fixes, and airports of origin. This information is available to the ATC coordinator, either through the computer or in manuals, but does not need to be referenced on a regular basis.

In some instances, static information is necessary for determining the significance of continuous information. For example, a sector may currently be holding 19 aircraft (continuous information). In itself, this information is not particularly meaningful unless one knows that the sector capacity is only 16 (static information).

3.3.3 Episodic

Episodic information refers to information that changes due to the occurrence of an event. For example, types of continuous information such as thunderstorms, changes in wind direction at airports, and high traffic volume in a particular sector or over an arrival fix often produce events that trigger episodic changes in constraints on the NAS. Weather-related events often cause airborne flights to be rerouted or cause departing flights to be given adjusted departure times, referred to as Estimated Departure Control Times (EDCTs). Changes in runway configuration, another example of episodic information, typically affect an airport's arrival and departure rates. Other examples of episodically changing information include filed route plans, available routes, and airports' arrival and departure rates.

Since this information changes episodically rather than continually, an ATC coordinator should need to monitor it only periodically, with an update rate that reflects how often events are occurring. However, this rate needs to be revised whenever ATC revises or augments their original constraint changes in order to deal with an increase in airborne traffic or a changing event. For example, ATC may first start by issuing a MIT restriction and then proceed by issuing Airborne Holding, Routes Advisories, Ground Delays, and finally a Ground Stop. In each instance episodic information, such as the traffic-flow restrictions on the NAS and a flight's ETA, is revised.

The preceding example represents one of the most demanding situations for ATC coordinators and dispatchers - to monitor episodic information when a single event is producing repeated and rapid changes. What is of particular importance about episodic information is that the rate of information change for an event is dependent on the severity of the event. The more severe an event the more likely ATC is to modify their original constraint changes. The difficulty is that these modifications do not occur periodically at a set interval or rate. This requires the ATC coordinator to continually sample information in order to detect periodic changes in episodic information.

Ultimately, it is continuous information that determines the rate at which episodic information changes. Two types of continuous information, weather and traffic volume, are the two most frequent event sources. The rate at which episodic information changes varies depending on the nature of the underlying event(s). Episodic information by definition remains unchanged when no events are present, but its rate of change increases monotonically with the occurrence of events. As more and more events develop or increase in severity, the rate at which episodic information changes increases. Thus, the rate of episodic information change can and will at times approximate the rate of change characteristic of continuous information.

3.4 The Information Gap

The ability to effectively develop flight plans can be facilitated by increasing shared real-time information about traffic-flow restrictions between ATC and airlines (RTCA, 1998). Through observations and interviews with ATC coordinators and dispatchers, it was confirmed that up-to-the-minute information about NAS constraints is critical for the efficient management of air travel. ATCSCC Advisories are the primary means for communicating these restrictions. There are three fundamental problems with this system. The first problem is the rate at which information is updated, second is the form in which the information is disseminated, and third is the absence of causal links between information. This section addresses these problems and recommends a solution: a next-generation advisory system.

3.4.1 Episodic information as continuous

As indicated in section 3.3.3, traffic-flow restrictions on the NAS fall within the episodic class of information (i.e., information about restrictions changes only when events are occurring). When events are few, the rate at which this information is updated is relatively slow, maybe as few as 2-3 advisories per hour. The text-based ATCSCC Advisories work adequately in this type of environment. Yet, when events are occurring often, especially weather-related events, restrictions on the NAS change nearly continuously and the text-based message system does not suffice.

It is the nature of the information that dictates how it should be communicated. Continually changing information cannot be effectively communicated through text-based messages or memos. Rapidly changing traffic-flow restrictions on the NAS need to be continually updated as events develop, change, and dissipate. Thus, a fundamental requirement for the dissemination of traffic-flow restrictions is the ability to display and update these restrictions at the same refresh rate as continuous data.

3.4.2 Components of constraints

All traffic-flow restrictions possess geographical, rate, directional, and temporal components (section 1.3.3). Figure 9 depicts an actual ATCSCC Route Advisory that contains geographical (DRK.J6.LIT.J14.ATL), rate (30 MIT), directional (DESTINED JFK/EWR/LGA), and temporal (15:00-21:00) information. Nonetheless, the current text-message format does not ***explicitly*** convey this fundamental information about restrictions.

First, the geographical relationship between this advisory (Figure 9) and previous advisories for that day supplies information about their associative nature. Not surprisingly, restrictions within the same geographical area tend to be more closely related to one another than to less proximal restrictions. Thus, the geographical relationship between restrictions needs to be made explicit. Such a change would especially help facilitate route planning which relies heavily on the geographical relationship between airport of origin, destination, and restricted airspace.

Second, the rate information associated with many types of advisories is the airlines only means of quantifying the severity of a restriction. MIT and AAR information is often included in the "Associated Restrictions" or "Remarks" area of the text body. Yet, additional rate information disseminated among ATC facilities, such as MIT and the number of streams of traffic between en route centers, is seldom published as part of an advisory. This information needs to be available to all ATM personnel.

QU HDQOWNW
.ATYZZYA 131501
ATCSCC ADVZY 034 DCC 06/13/99 - ROUTE ADVISORY
IMPACTED AREA: ZOB/ZAU
REASON: TSTMS
ASSIGNED REROUTE: DEPARTING ZLA/ZAU DESTINED JFK/EWR/LGA
VIA: DRK.J6.LIT.J14.ATL TO JOIN PREFS
FACILITIES INCLUDED: ZLA/ZAB/ZFW/ZME/ZTL/ZDC
VALID UNTIL: 2100Z
PROBABILITY OF EXTENSION: MODERATE
ASSOCIATED RESTRICTIONS: 30 MIT PER ARPT
131500 - 132100
99/06/13 15:00 FSB.//WKSTN05A 703-708-5105

Figure 9. ATCSCC Route Advisory

Third, similar to the need for the graphical display of traffic-flow constraint locations, the direction in which traffic flow is restricted should also be explicitly indicated. In nearly all situations traffic flow is restricted in only one direction. Commonly the flow restriction is in the direction of an airport (e.g., Ground Stop and Ground Delay Program). In contrast, the direction of constraint for an en route area restriction (i.e., Route Advisory and SWAP Route Advisory) is not made explicit by its advisory type. Since not all advisory types effectively convey directional information, it would be advantageous to represent directional information in graphical form rather than as text.

Fourth, since traffic-flow restrictions are in effect for only a specific time period, the onset and expiration of a restriction needs to be clearly apparent and accessible throughout its valid time period. While the advisory in Figure 9 indicates both the starting and ending time of the restriction, this information is not always easily accessible, especially when it is buried in a pile of advisories on the ATC coordinator's desk.

3.4.3 Causal-linked information

Like a medical doctor trying to treat a patient with knowledge of only the symptoms and not the disease, ATC coordinators and dispatchers are at a marked disadvantage without knowledge of what is triggering a restriction. All ATCSCC Advisories contain a reason (i.e., the event) for the restriction, but often the event description is so terse it is difficult to fully understand it or distinguish it from other similar events. The advisory in Figure 9 exemplifies this problem. The reason for the route change is due to thunderstorms somewhere in the Chicago (ZAU) and/or Cleveland (ZOB) centers. On some days linking this and other restrictions to a specific group of weather cells is not difficult. Nevertheless, on days in which numerous events are occurring in close proximity, determining which event has triggered a newly published restriction can be an intractable task.

The current advisory system does not provide a detailed enough event description nor is it capable of linking a restriction to other associated restrictions. As described in section 1.3.4, a single event nearly always triggers a sequence of restrictions on the NAS. It is often difficult to determine which event has triggered a specific restriction. Linking traffic-flow restrictions with their associated event will provide the user with causal information (i.e., the underlying reason) about the restriction. The presence of causal information, created by clearly identifying and defining events, provides critical route planning information. Specifically, the route planning process needs to take into account not only current traffic-flow restrictions but also the nature of the triggering event - the type of the event, its life-cycle, and any associated restrictions.

3.4.4 Recommendation

This research, as well as the findings of others (e.g., Olvey, et al., 1998), has identified a need for a system-wide, airspace constraint monitoring tool capable of providing personnel at ATC and the airlines with answers to the following questions:

- What are the restrictions on the flow of air traffic?
- When are these constraint changes occurring?
- What is triggering these constraint changes?

The *Event Advisory Monitor System* is proposed as a next-generation ATCSCC Advisory system. The next report in this series will present initial specifications for the design of such a tool. It will graphically display information about restrictions on the NAS in real time and provide continuous updates when changes occur. Since nearly all events within the NAS produce a sequence of constraint changes, the *Event Advisory Monitor System* will be capable of linking restrictions to their associated event.

In addition, the *Event Advisory Monitor System* will function as a planning tool for the airlines. With the ability to archive data, a historical database can be created containing each past event with its associated constraint changes. The ability to access historical information about constraint changes triggered by a past event will provide airlines a way of anticipating ATC actions as a similar event unfolds.

Acronyms

AAL	American Airlines
AAR	Airport Acceptance Rate
ACARS	ARINC Communications And Reporting System
ARTCC	Air Route Traffic Control Center
ASD	Aircraft Situation Display
ATC	Air Traffic Control
ATCSCC	Air Traffic Control System Command Center
ATL	Atlanta International Airport
ATM	Air Traffic Management
CCFP	Collaborative Convective (Weather) Forecast Product
CDM	Collaborative Decision Making
CSR	Customer Service Representative
EDCT	Estimated Departure Control Time
EFC	Expect Further Clearance
ETA	Estimated Time of Arrival
ETMS	Enhanced Traffic Management System
EWR	Newark International Airport
FAA	Federal Aviation Administration
FSM	Flight Schedule Monitor
GDP	Ground Delay Program
HFRL	Human Factors Research Laboratory
ICD	Information Communication Device
IFR	Instrument Flight Rules
KSU	Kansas State University
MIT	Miles-In-Trail
NAS	National Airspace System
NTMS	National Traffic Management Specialist
NWA	Northwest Airlines
OCC	Operations Control Center

PIREP	PIlot REPort
SWAP	Severe Weather Avoidance Procedures
TMC	Traffic Management Coordinator
TMU	Traffic Management Unit
TRACON	Terminal Radar Approach CONtrol
TSD	Traffic Situation Dispaly
VFR	Visual Flight Rules
ZAU	Chicago Air Route Traffic Control Center
ZBW	Boston Air Route Traffic Control Center
ZDC	Washington Air Route Traffic Control Center
ZFW	Ft. Worth Air Route Traffic Control Center
ZMP	Minneapolis Air Route Traffic Control Center
ZNY	New York Air Route Traffic Control Center
ZOB	Cleveland Air Route Traffic Control Center

References

Federal Aviation Administration. (1997). Airline operational control overview: FMS-ATM next generation (FANG) team (DOT Publication No. AND-97/8). Springfield, VA: National Technical Information Service.

Federal Aviation Administration. (1998). Air traffic control overview: Kansas City ARTCC. Lexington, MA: Lincoln Laboratory, Group 41.

Federal Aviation Administration. (1999). NAS performance report, November 18, 1999. Available: http://atcscc.faa.gov/Operations/Opsnet_Reports/data/NASRpt.htm [1999, Nov 19].

Murphy, L., & Smith, K. (2000). TMU structure, positions, and uses of the TSD. Kansas State University Human Factors Research Laboratory Report 99-G-020-2.

Olvey, D., Rhodes, L., Carlson, L., & Reeves, J. (1998). Mid-term FAA-airspace user collaborative routing operational concept. McLean, VA: Mitre, Center for Advanced Aviation System Development.

RTCA, Inc. (1998). Government/industry operational concept for the evolution of free flight, addendum 1: free flight phase 1. Washington D.C.: The RTCA Select Committee on Free Flight Implementation.

Smith, K. (1999). Information requirements for traffic flow management. Kansas State University Human Factors Research Laboratory Report 98-G-013.

Yee, M., Dion, F., Simmons, R., & Walker, G. (1995). Roles and responsibilities of traffic management specialists and traffic management coordinators. McLean, VA: Mitre, Center for Advanced Aviation System Development.