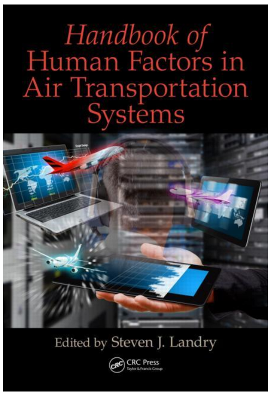

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Steven J. Landry

Distributed Work in the National Airspace System

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5 Distributed Work in the National Airspace System

Traffic Flow Management and Airline Operations Control

Philip J. Smith and Ellen J. Bass

CONTENTS

The National Airspace System (NAS) relies heavily on distributed responsibilities across individuals in multiple roles in order to help ensure safety and efficiency (Smith et al., 2001, 2010). By distributing responsibilities, the workload and cognitive complexity for any individual are reduced to make tasks tractable. By carefully defining these responsibilities, partial redundancies are also introduced to provide safety nets (Smith et al., 2012a).

The other chapters in this book have discussed the roles of pilots and controllers. Those roles represent one important aspect of the NAS as a distributed work system (Hutchins and Klausen, 1996; Hinds and Kiesler, 2002; Salas et al., 2008; Harwood, 2010) and merit careful study from that perspective. However, for this chapter, we look at two other groups within the NAS, Federal Aviation Administration (FAA) traffic flow managers and airline aircraft dispatchers, who have a number of responsibilities that complement those assigned to pilots and controllers. Some of these responsibilities are tactical in nature. If, for example, a flight needs to divert to an alternate airport the airline dispatcher—who has shared responsibility for the operation of the flight with the pilot (14 CFR §121.395 [FAA, 2017a], 14 CFR §121.533 [FAA, 2017b])—is very much involved in determining the nearest *suitable* airport. Similarly, FAA traffic flow managers frequently make tactical flight amendments, changing the planned route that a dispatcher originally filed for a flight as it is taxiing out (FAA, 2016a, 2016b).

Many of the responsibilities of traffic managers and dispatchers, however, are more strategic in nature. From an FAA perspective, they involve identifying constraints in the NAS and implementing plans to safely maximize throughput given these constraints. For example, a traffic manager at the FAA's Air Traffic Control Systems Command Center (ATCSCC) may implement a ground delay program (FAA, 2016b) for flights scheduled to arrive at Philadelphia International Airport (PHL) over a six-hour period, reducing the number of arrivals per hour. From an airline operations control perspective, such strategic decisions involve managing the airline's schedule and the development of plans for implementing that schedule (such as planning the route for a specific flight).

HUMAN-CENTERED DESIGN OF A DISTRIBUTED WORK SYSTEM

Abstractly, the design of the NAS provides a classic example of a distributed work system. The architecture for distributing work can be categorized along several interacting dimensions:

- Allocation of strategic versus tactical decisions (Smith et al., 2003)
- Design for coordination versus collaboration (Lee and Bass, 2014)
- Incorporation of overlapping responsibilities to provide safety nets (Smith and Billings, 2009).

These different dimensions have important human factors implications, which are discussed briefly in the following.

ALLOCATION OF STRATEGIC VERSUS TACTICAL DECISIONS

One of the challenges in managing a stochastic process such as the NAS is the time-varying nature of uncertainty (Smith et al., 2003). As the time for an event approaches, there is often less uncertainty about what will actually happen. However, some of the alternate options for dealing with the event may no longer be available as time progresses (Bolton, Göknur, & Bass, 2013).

In the case of traffic flow management, an illustration would be the uncertainty about whether forecast convective weather in the terminal airspace around JFK will actually materialize from 2100 to 0200Z. If a decision is made at 1500Z to use a ground delay program to reduce arrivals into JFK from 2100 to 0200Z, the decision about what rate(s) to assign will be based on a forecast that is much less precise, potentially resulting in underdelivery or overdelivery of inventory (arrivals) relative to capacity, with an associated impact on delays. However, if this decision is delayed until 1800Z, it will be too late to delay the departures of flights from the West Coast, which means the short hauls into JFK could experience longer delays. Moreover, if the decision is delayed until individual flights have pushed back from the gate (using a call-for-release strategy), then the set of flights affected will again be quite different.

Thus, from a human performance perspective, the system designers need to consider how to design operational concepts, procedures, training, and supporting technologies to support making four decisions given the time-varying nature of the uncertainty:

- When should I make a decision?
- What alternative decisions should I consider?
- What alternative should I implement?
- Should I adapt my plan over time based on how the scenario is evolving?

Note that the fourth decision highlights the fact that strategic and tactical decisions are not independent. If the system is designed to support continuous adaptive planning, strategic decisions can explicitly include contingency plans or enable ad hoc replanning as necessary.

Note also that such a division of labor in terms of strategic versus tactical decisions is often consistent with the goal of decomposing the system into a set of nearly independent subtasks that can be assigned to different people (or in some systems, across some combination of people and automation) (Bass, et al., 2011). For instance, airline dispatchers have a primary role in developing the flight plan (route, cruise altitude, alternative airport, fueling, etc.) for a flight (a strategic decision), whereas the flight crews have a primary role in making small tactical adjustments while the aircraft is enroute in response to encounters with weather or requests from air traffic control (ATC) made in order to maintain separation (tactical decisions).

Although the strategic decisions made by the dispatcher have to anticipate potentially necessary tactical responses, to make these strategic decisions some of the data, expertise and cognitive processes used by the dispatcher are quite different from the requirements for pilots when making tactical adjustments to their trajectories while in flight. In addition, the focus of attention is quite different. The dispatch staff is looking at a bigger picture of the system (in terms of traffic flow management, weather, and airline scheduling) when developing flight plans, whereas the pilot is focused on more immediate impacts to his/her flight. Thus, a decomposition based on access to the necessary data, expertise, cognitive processing, and attentional requirements necessary to support these strategic versus tactical decisions can be very effective.

DESIGN FOR COORDINATION VERSUS COLLABORATION

The word *nearly* used earlier in discussion about system decomposition is critical in terms of designing a distributed system. As Figure 5.1 indicates, although coordinated activity is preferred, collaboration is necessary when scenarios arise that require the interaction of individuals fulfilling different roles.

By coordination, we mean a system in which each individual performs his/her task independently, simply providing the outputs of that task to the other individuals without any need to interact in a richer, unstructured manner (talking with one another, texting, emailing, etc.). An example of such coordination is provided by Ground Delay Programs as they operate today. When a traffic manager at the Systems Command Center sets an arrival rate at JFK 25% below the normal capacity for an airport, software translates this into a set of arrival time slots that are then assigned to different airlines based on a ration-by-schedule prioritization. The responsible airline ATC coordinator (a specialized role for a dispatcher) does not have to talk with or otherwise interact with that traffic manager in any rich sense, he/she just has to know which arrival time slots have been allocated to his/her airline. He/she can then use airline software to help in swapping flights among his/her airline's slots to adjust the airline's schedule, for example, giving priority to a flight that has a large number of passengers with international connections at JFK. In short, the traffic manager and dispatcher coordinate rather than collaborate.

In addition to supporting such coordination, however, enabling procedures, training and software also must be incorporated to ensure that the responsible individuals will detect the need to shift from coordinated work to collaborative work when necessary, and to ensure that they can effectively collaborate. Today, for example, if a flight that is included in a Ground Delay Program has an issue that requires special handling from an airline perspective, the dispatcher can submit a request to a website hosted by the Systems Command Center (the *TCA page*) asking for an exception, which is then evaluated by a traffic manager at the Systems Command Center in consultation with the relevant enroute facility or airport.

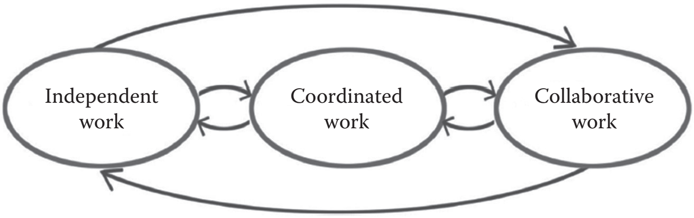

FIGURE 5.1 Forms of interaction: independence versus coordination versus collaboration.

INCORPORATION OF OVERLAPPING RESPONSIBILITIES TO PROVIDE SAFETY NETS

The design of the NAS is very sensitive to the fact that people and technologies are fallible (Reason, 1990; Pidgeon and O'Leary, 2000; Dekker, 2003; Bolton and Bass, 2012). There are numerous safety nets in place so that if one *component* fails, another one will detect this and respond appropriately to ensure a safe operation. The manner in which responsibilities have been distributed plays an important role in providing these safety nets.

At a very high level, the safety net provided through the design of the NAS as a distributed work system is illustrated by the fact that, at some level of abstraction at a given point in time, two pilots, a controller, a dispatcher, multiple traffic managers, and various software functions are *looking* at a flight. As a result, any one of them may detect a problem with that flight and trigger a response to ensure its safety.

For instance, the pilots, a controller and a collision avoidance system are all *looking* at the flight relative to other aircraft in a very direct sense with a responsibility for ensuring separation from other aircraft. Moreover at a more abstract level, the dispatcher and several traffic managers are implicitly considering that flight when they ask the question: Has the weather developed in an unexpected way that requires some change in the routing for flights in the vicinity of that weather? In addition, the dispatcher has an alerting function that is watching a specific flight and indicates if it has deviated significantly from its planned route.

Thus, by assigning overlapping responsibilities to operational staff and designers (through their technologies) who have different primary tasks with different expertise and experiences, and who are looking at different (partially overlapping) data, slips, mistakes and hardware failures, are much more likely to be detected and dealt with.

THE FUTURE OF AIRPORT SURFACE MANAGEMENT: A CASE STUDY

The management of departures from an airport is a highly distributed subsystem within the NAS. Consider the task relative to the airport layout illustrated in Figure 5.2 for a future concept involving departure surface metering.

In this figure, the dark gray lines are runways, and the light ones are taxi-ways. For this discussion, the vertical runway in the center (18C) and the vertical runway to the right (18L) are being used exclusively for departures.

Figure 5.3 provides an oversimplified indication of the individuals who affect airport surface management directly or indirectly. An Air Route Traffic Control Center (ARTCC) is a regional air traffic center; a Terminal Radar Approach Control Facility (TRACON) is responsible for metroplex airspace within an ARTCC; an ATCT is an airport ATC tower.

Figure 5.4 shows the departure routes mapped to Runways 18C and 18L for this airport. The center five routes to the north, east, south, and west are the standard departure routes. The adjacent routes (located in what is normally arrival airspace) are available for the flexible use of arrival airspace for departures if conditions warrant.

To provide a sense of how they all interact and impact airport departure management, consider the following example based on the FAA's operational concept for the use of virtual queues to better manage surface traffic (Atkins et al., 2004; Doble et al., 2009; Smith et al., 2011, 2012b; Simaiakis et al., 2014).

- Convective weather is approaching the airport from the west, impacting some of the departure fixes.
- Two of the departure fixes to the west/northwest, WILEY and WICKR, are forecast to be impacted from 1700 to 1800Z, reducing departure throughput.
- At 1645Z, the TRACON traffic manager, in consultation with the surrounding ARTCC traffic manager (collaboration by voice with shared displays), decides to place a throughput (Miles-in-Trail or MIT) restriction on WILEY and WICKR (20 MIT as one).

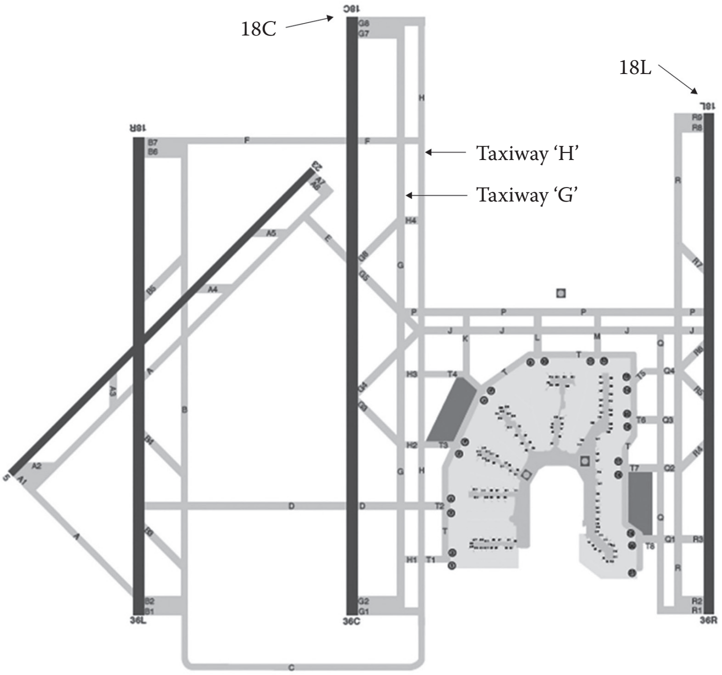

FIGURE 5.2 Sample airport layout.

- This is communicated to the Departure Reservoir Coordinator (DRC)—a new role for a traffic manager at the ATCT (coordination electronically).
- The DRC looks at the lineup for departures using 18C and finds that 30% of the flights scheduled to depart from 1,700 to 1,800Z are filed to depart via WICKR and WILEY and that, with the MIT restriction, throughput is predicted to be reduced from 52 to 34 flights from 1,700 to 1,800Z. The good news is that there are only four flights filed to WICKR and WILEY that are actively taxiing at this time, so there is an opportunity to hold a number of the WICKR and WILEY departures at their gates to change the lineup so that splitters (flights filed to depart via unimpacted departure fixes) can be placed between the WICKR and WILEY departures in order to maximize throughput.
- The DRC checks with the Tower Supervisor and learns that the ground controller plans to queue all departures filed to depart WILEY and WICKR on the taxiway H, and all other departures using 18C on taxiway G (coordination by voice).
- The DRC sets a target runway queue length for taxiway G of eight flights and a target queue length of eight for taxiway H in order to reduce taxi out times and queue lengths but still have enough inventory filed to the different fixes in case the weather develops differently than expected. The predicted departure throughput for 18C with this resultant change in the departure lineup increases to 47 flights from 1,700 to 1,800Z.
- The Departure Metering Program (with *virtual departure queues*) is put into effect and is communicated to the flight operators (coordination electronically), and the FAA sends target spot times (which are translated by the flight operators into target pushback times) to the flight operators.
- Airline ATC Coordinators (dispatchers with supervisory responsibilities) look at the departure delays assigned to particular flights and (with software support) swap some of their high priority flights with low priority flights to move up their pushback times.

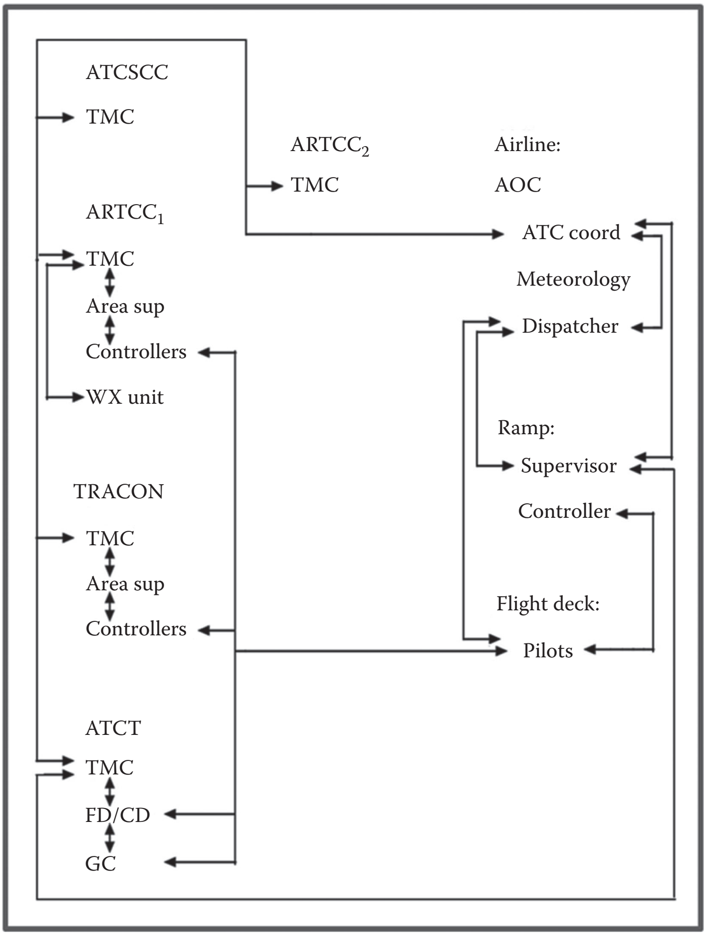

FIGURE 5.3 Distributed roles in the NAS.

- These changes in pushback times are communicated to the FAA for use by traffic managers at the ARTCC and TRACON and to the DRC and controllers in the ATCT (coordination electronically).
- The assigned pushback times are also communicated to airline ramp controllers, the gate, and pilots (coordination electronically).

As the aforementioned steps indicate, this future design for airport departure management focuses on a highly distributed work architecture, enabled by a number of technologies. The example itself somewhat oversimplifies the full richness of this system but serves to illustrate the interweaving of coordination and collaboration among individuals assigned to a number of different roles. (Issues such as interactions of Departure Metering Programs with Ground Delay Programs and the use of alternative strategies such as reroutes instead of the use of splitters add further interesting twists to the actual functioning of this operational concept.)

CONCLUSION

The goal of this discussion has been to identify conceptual issues that need to be addressed in designing the architecture for a distributed work system as well as to use the NAS as an example to illustrate these issues. Several important dimensions were highlighted, including the need to

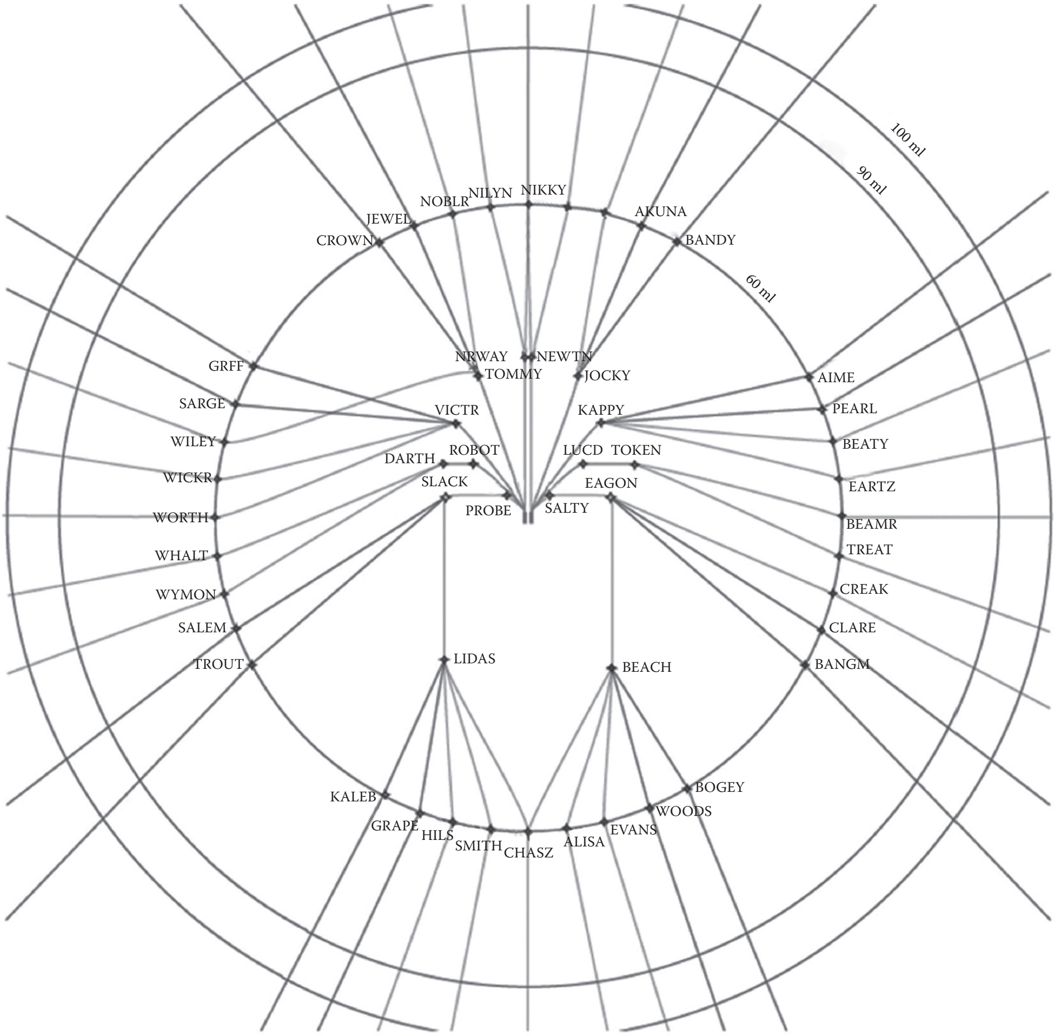

FIGURE 5.4 Airport departure routes.

- Integrate strategic and tactical decision making.
- Support both coordination and collaboration when the system can only be decomposed into a set of *nearly* independent subtasks and ensure effective transitions between these two forms of interaction.
- Decompose the system into subtasks in which the necessary data, expertise, and processing capabilities are available for the individuals assigned particular roles and responsibilities.
- Incorporate overlapping responsibilities in order to provide safety nets.

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