Display Overload: An Artifact-Based Work Analysis of Air Traffic Management

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Air traffic management personnel manage traffic flows into, out of, and through the area for which air traffic controllers in their facilities are responsible. We report on a cross-domain, artifact-based, work analysis of air traffic management that employed a hierarchical modeling methodology centered on the artifacts used in the operational setting and the information and decision-making support they provided. Many tools support traffic managers in planning for, managing, and monitoring traffic flows, but information and decision support functions are rarely integrated across tools. Thus, traffic managers spend much of their time acquiring and assimilating information from multiple displays and manually entering information into multiple systems. NextGen initiatives such as System-Wide Information Management, En Route Automation Modernization, and the Terminal Flight Data Manager represent opportunities to implement a data exchange standard that facilitates display and decision support tool integration.

Air traffic management personnel in Traffic Management Units (TMUs) manage traffic flows into, out of, and through the geographic area for which their facilities are responsible with the goal of using the National Airspace System (NAS) as efficiently as possible (Federal Aviation Administration, 2010). An artifact-based approach was used to analyze the environment of TMU personnel in three different domains: Air Route Traffic Control Centers (ARTCCs), Terminal Radar Approach Controls (TRACONs), and Air Traffic Control Towers (ATCTs).[1]

The analysis focused on the tools used by TMU personnel and the key tasks accomplished using those artifacts. Those of most interest are coordination tasks, many of which involve acquiring, assimilating, and sharing information across domains via the TMU. These tasks require traffic management personnel to acquire information from several tools and share it across domains using several different tools. This information sharing often must be done manually, creating opportunities to introduce errors into communication and reporting.

Some manual data entry tasks could be automated by improved integration of TMU tools. However, many tools are developed by different organizations for different purposes. Emerging technologies can be leveraged to create data exchange standards to support integration of TMU tools and functions and decrease the data entry burden on traffic management personnel.

This paper provides a brief background of air traffic management and task analysis methods. It also describes the analysis performed in this effort and key results, and proposes a method for supporting TMU integration.

[1] Few ATCTs have formal TMUs. Some have Traffic Management Coordinators, while all have personnel that coordinate with other facilities and perform surface management functions.

Air Traffic Management

To carry out their responsibility to maximize NAS efficiency, traffic management personnel perform functions such as (Federal Aviation Administration, 2008):

- Monitor the status of NAS resources, often including constraints some distance away.
- Anticipate constraints that will impact the ability of aircraft to operate efficiently in airspace under the control of their facility.
- Develop programs such as Traffic Management Initiatives (TMIs) to modify traffic flows and maintain efficiency despite the constraints.
- Coordinate with traffic management personnel in other facilities to implement TMIs, including neighboring facilities and facilities in other air traffic control domains.
- Coordinate with flight operator personnel as necessary to maintain traffic flows.
- Report events of interest to other air traffic control facilities

Traffic management personnel use a variety of tools to accomplish these goals. Some tools facilitate traffic management planning, providing information such as weather and traffic demand forecasts. Others allow personnel to record traffic management activities and share NAS information within the facility and with other facilities to facilitate cross-domain coordination. However, few of these tools are integrated with each other, requiring mental information fusion and manual entry of data into multiple systems.

The lack of integration of TMU tools is a well-known but rarely documented issue. Borgman and Smith (2010) reported that several TMU personnel interviewed noted the lack of integration and duplicative data entry requirements as issues they would like to see resolved in new traffic management systems. Similarly, Nadler (2005) discussed ways in which the National Traffic Management Log (NTML) could be used to decrease manual data entry requirements for TMU personnel. However, in both cases the need for improved integration of TMU tools was only a tangential theme, and the issues cited have not been addressed.

Artifact-Based Work Analysis

A variety of work analysis methods have been documented and used to understand work as performed and the environment(s) in which it is performed. See Annett (2004) for a brief history of task analysis methods. Some methods make use of the artifacts of the domain to identify how they support cognitive work and to guide the design of new technologies to support joint cognitive systems (Hutchins, 1995; Nemeth, Cook, O'Connor, & Klock, 2004; Woods & Hollnagel, 2006). Artifacts often represent boundaries between system components and can provide insights into ways in which systems can be improved.

This work used artifacts of the air traffic management domain to identify cross-domain coordination processes and ways in which practitioners achieve this coordination using the tools provided to them. The analysis is discussed in the next section.

Artifact-Based TMU Analysis

The artifact-based analysis identified the tools at each TMU position in an ARTCC, TRACON, and ATCT, the users of each tool, the work process(es) that used each tool, and the frequency with which the tool was used. Due to space limitations, discussion is limited to the identification of tools and the work processes they support.

Identify Tools at Each TMU Position

The first step in the artifact-based analysis was to visit ARTCC, TRACON, and ATCT facilities and document the tools and displays at each TMU workstation. An ARTCC TMU, for example, includes several positions such as Supervisory Traffic Management Coordinator (STMC), Coordinator, En Route Spacing, Departures, and Severe Weather. When a TMU is fully staffed, there is at least one person working at each station. However, a TMU is rarely fully staffed (because of both lack of need and lack of staffing availability) and therefore each person working in the TMU often must work multiple positions.

Figure 1 shows the Supervisory Traffic Management Coordinator (STMC) position at one ARTCC. The STMC has several responsibilities (FAA, 2010; FAA, 2008) related to managing the air traffic operation, coordinating with other facilities and other fields of expertise such as Technical Operations, keeping data accurate in a number of air traffic management systems, and responding to “special situations that may arise” (FAA, 2008, p. 17-4-1).

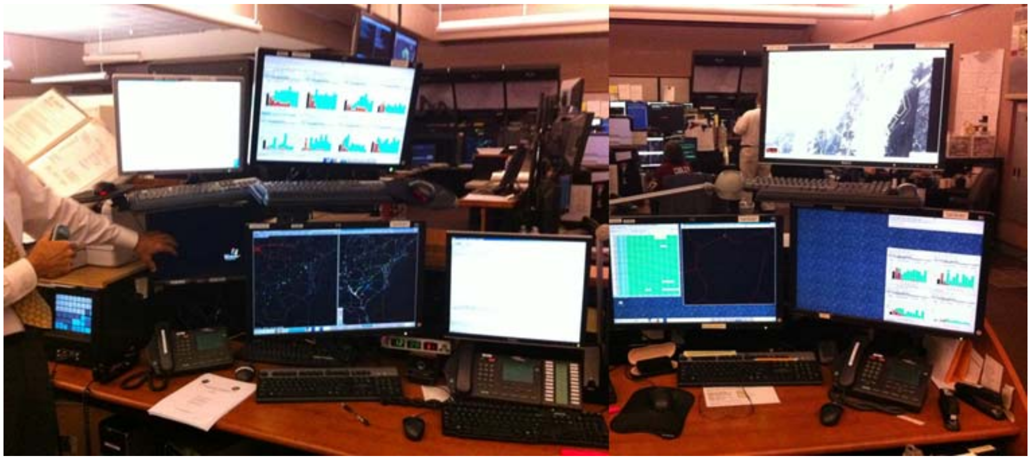

Figure 1. Supervisory Traffic Management Coordinator (STMC) position at one ARTCC TMU.

The STMC workstation shown in the photograph includes 8 displays, 7 keyboards, and 3 telephones, as well as paper and other office supplies. In addition, the workstation is located such that the STMC can see other TMU displays from the workstation. In all, 23 ARTCC STMC tools were identified, 13 of which are constantly in use. Similarly, 23 TRACON STMC tools and 19 ATCT traffic management tools were identified, including many tools that are used in multiple air traffic management domains.

While all of these tools are not deployed at every ARTCC, Borgman and Smith (2010) reported as many as 10 and as few as 3 displays at STMC workstations in other ARTCCs and discussed numerous other tools in use as well. Some of the variation in tools at a given STMC workstation is due to the tools available at a given ARTCC as well as the ability for the STMC to see displays at other workstations.

Identify Work Process(es) Using Each TMU Tool

Once the tools in the TMU were identified, the work processes they supported were identified based on observations and interviews in situ and interviews with additional subject matter experts. These work processes were characterized according to the kind of task performed. Table 1 shows the types of STMC work processes identified and the number of tools used to support the STMC in carrying out each type of work process. Two tools were counted twice. The National Traffic Management Log (NTML) supports both communication and tracking and analyzing traffic data. The Route Management Tool (RMT) acts as a database of alternate routes and also supports tracking and analyzing traffic data. Note that many of the tools used by the STMC also are used at other positions.

Table 1.
Types of ARTCC STMC work processes supported by TMU tools and the number of tools supporting each type of work process.

Purpose	Number of Tools
Communication	5
View Traffic	2
Manage Traffic	3
Weather	3
Database	3
Track and Analyze Traffic Data	9

Many work processes are supported by multiple tools. However, each has a different purpose, such as the tools for viewing traffic: the Display System Replacement (DSR) See-All Display allows TMU personnel to view the data shown on the scope of any facility controller and the Traffic Situation Display (TSD) provides a view of aircraft locations in larger areas.

Although each tool provides TMU personnel different information, they are not well integrated with each other. As a result, users must manually transfer information from one system to another. Some systems allow electronic transmission of data but do not allow automatic transmission and reporting. However, emerging technologies provide opportunities to develop data exchange standards and capabilities to support integration of the various TMU tools.

Leveraging Emerging Technologies to Improve Data Exchange

The number of tools and displays that TMU personnel must consult to gather information, make a decision, and implement an action is excessive. There is an obvious need to address the diversity of un-integrated TMU tools and displays and ensure that future capabilities relieve, rather than exacerbate, the display overload problem.

The FAA is deploying new technology such as System Wide Information Management (SWIM) as part of its air traffic control modernization program (FAA, 2012). SWIM is a data exchange interface that can be used to provide a standard that must be achieved by all TMU tools. A SWIM interface layer can facilitate data exchange among existing tools before major upgrades associated with the NextGen modernization program are available. The interface layer also can facilitate integration of additional capabilities such as traffic management course of action analysis and planning (Brinton, 2011).

The Air Traffic Course of Action Planner (ATCOAP) concept utilizes a hierarchical task network based on an operational analysis of traffic management tasks to identify and track traffic flow management issues in real-time, facilitate cross-domain coordination, and support decision-making based on integration of data from the variety of systems present in the TMU. It supports TMU personnel in identifying issues, prioritizing tasks, executing traffic management actions, and monitoring their results, as well as coordinating with other facilities in achieving these goals.

Some cross-domain coordination can be better facilitated by automating workflow and task assignment, tracking and feedback. Tasks required to achieve courses of action developed collaboratively are identified and included in a task list that is coordinated among all relevant NAS operators. The ATCOAP allows users to accept, initiate, decline or assign tasks to another operational position. Task ownership is communicated to all actors that have a ‘need to know’ about a given task. Figure 2 provides a graphical example of how this task tracking capability can be implemented in the ATCOAP system.

Position: ZOB TMU		
Task	**Status**	**Owner**
Re-Route Flights from ZOB37	In Progress	ZOB TMU
Implement GDP for ORD	Recommended	ATCSCC
Reduce Miles-in-Trail from ZID	In Progress	ZOB TMU
Implement Playbook LUTHE3	Completed	ATCSCC
Re-Route Airborne J32 Flights Over LUTHE	Assigned (by ATCSCC)	ZOB TMU
De-Combine ZOB22 and ZOB19	Declined	ZOB Area 1
Handle Lost Comm Aircraft in ZOB48	In Progress	ZOB Area 4
ZOB Area 2 End of Shift Log	Required	ZOB Area 2
Start Training on ZOB57	Recommended	ZOB Area 3

Figure 2. An Example of task tracking in the ATCOAP system.

In addition to developing a data exchange layer to integrate existing tools, care must be taken to ensure that emerging tools expected to support cross-domain integration also are integrated with other traffic management tools targeting the same users. Data exchange standards and plug-and-play capabilities are more appropriate for this purpose than assuming that any one tool will satisfy all TMU needs.

Conclusion

Traffic management personnel have a large number of tools to support their work. However, these tools are not well integrated with each other and therefore much TMU effort is spent in mentally integrating data from a variety of displays and manually transferring data from one system to another. A lightweight SWIM-based data exchange layer can help reduce the data entry workload of TMU personnel. It also can reduce the number of TMU displays by allowing related information to be displayed together. Such a data exchange layer also can support integrating additional capabilities to support traffic management coordination and decision making.

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