AN AIRCRAFT OPERATIONS SIMULATION MODEL FOR THE
UNITED PARCEL SERVICE LOUISVILLE AIR PARK

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ABSTRACT

This paper presents the development of a flexible data-driven model of the aircraft operations at the United Parcel Service Louisville Air Park. The model describes the unloading, refueling, and loading of aircraft by dedicated crews and equipment during the daily sortation operations. Inputs to the model include aircraft schedules, crew schedules and equipment allocation. Customized outputs include aircraft departure information, crew utilization, and equipment requirements. The model allows planners to develop crew schedules and allocation strategies to employ resources efficiently while maintaining rapid aircraft turnaround time. Preliminary analysis has identified aircraft arrival patterns and the specific crew availability as parameters to which the system is extremely sensitive.

1 INTRODUCTION

Each day over 100 aircraft arrive at the UPS Louisville Air Park carrying over 700,000 packages for Next Day Air and Second Day Air delivery. Ensuring that all of the packages are unloaded, sorted, and loaded within tight time constraints is a formidable task. With customers demanding earlier deliveries, competition increasing and the market expanding rapidly, the effects of poor planning or decision making can be disastrous. Just a single aircraft departing late can result in thousands of dissatisfied customers and a potential loss of millions of dollars. A natural reaction in this type of environment might be to add more and more personnel and equipment with less regard for cost and efficiency.

At the Louisville Air Park, the equipment and personnel used to service the aircraft have become difficult to manage using conventional methods. Studies of aircraft operations and package handling tasks involve analysis of interdependent resources that cannot be accurately studied with static models. Since 1987, the IE Department has used simulation to study and manage the modern resources required to provide on-time delivery to the customer. Earlier simulations focused on single aspects of the aircraft operation, like refueling or maintenance, without considering the interaction between the resources. The Total Air Park Simulation (TAPS) was designed to represent the overall operation accurately by including all aircraft-related tasks in order to capture the interaction of the crews and equipment involved. Experiments to examine crew allocation, equipment utilization and system capacity may be performed without disturbing the actual operation.

2 PROBLEM DEFINITION

2.1 Objectives

United Parcel Service initially envisioned the TAPS project as a tool to allow planners to experiment with resource requirements for the aircraft servicing operations. The effects of factors such as aircraft arrival patterns, aircraft departure patterns, incoming package volume, and crew allocation strategies on aircraft turnaround time may be investigated. Additional goals for the simulation included developing new aircraft servicing strategies, justifying new equipment purchases, and investigating the effects of increased aircraft and package volume on the facility. The model enables analysts to schedule personnel and equipment more efficiently, resulting in cost savings without adversely affecting customer service.

A longer-range goal of the project is to evolve the use of the simulation from a planning tool to an operational tool. Ultimately, the model will be run on a daily basis with near real time data for inputs. Execution of the

model immediately prior to the start of the actual operation will highlight potential trouble areas, which will allow adjustments to be made.

2.2 Model Scope

The TAPS model simulates the aircraft servicing operations at the UPS Louisville Air Park. The TAPS model is designed to evaluate the effect of aircraft arrival and departure schedules, inbound volume, and crew allocation strategies on the aircraft servicing operations. The model scope is limited to operations directly related to aircraft servicing.

The daily operations at Louisville include both a Next Day Air and a Second Day Air sort. The two sort operations are separate and are not linked in the simulation model. Rather, the model is designed to run either a Next Day scenario or a Second Day scenario.

The model begins with aircraft arrivals generated from an input schedule. The aircraft taxis down the ramp to a parking position where a marshaling crew directs the plane into location. After the aircraft powers down, unload, maintenance, and fuel crews are requested. Inbound packages arrive either packed into containers on the main decks of the aircraft or loose in one of the belly sections. Upon unloading, the inbound cargo is transferred to one of several locations based on its cargo type. Most of the inbound containers are transferred to the hub where they are emptied and the individual packages are sorted. Sorted packages are loaded into outbound containers based on destination. When a container is filled, it is weighed and then transported to its outbound aircraft. As soon as an aircraft is ready for the loading operation, a load crew is requested. After all the containers have been loaded, the aircraft leaves its parking position with the aid of a marshaling crew, taxis down the ramp, and exits the system.

3 MODEL DEVELOPMENT AND PROJECT ORGANIZATION

The TAPS simulation model was developed using Arena® from Systems Modeling Corporation. In order to facilitate model development and validation, the model was divided into three segments:

- Inbound Aircraft Operations
- Hub Sortation
- Outbound Aircraft Operations

Each segment of the project was designed to capture the overall sensitivity of the system without burdening the model with needless detail. Because the primary focus was the aircraft operations, both the inbound and the outbound segments were modeled in detail. While the hub sortation segment was not an integral part of the

overall project objective, it was critical that it accurately tie together the inbound and outbound operations. However, because of the incredible volume of packages moving through the hub, creation of a detailed model of the sortation would have greatly increased the model size and run length. To balance these two considerations, the hub was modeled with a series of historical distributions that break the inbound volume into outbound destinations. The sortation model includes a depletion rate for containers and packages arriving at the hub and a travel time to the outbound destination. The actual conveyor sortation process was not modeled explicitly.

In addition, each segment of the model includes two possible scenarios, Next Day Air and Second Day Air operations. While the general processes are the same for each, the two scenarios are different in scope. Because of the small window for on-time delivery in the Next Day Air operation, the primary goal is to get aircraft in and out of Louisville on time. The resources needed in terms of equipment and crews are secondary. Second Day has more options for delivery, and as such, is more concerned with balancing cost with service. Taking these and other fundamental differences into account, operational rules and strategies also differ for the two services. These differences are incorporated in the model by separate Next Day and Second Day logic in each segment.

Due to the size and complexity of the operation, many different departments within UPS participated in the definition of the model. Extensive interviews were held with the operations personnel responsible for the tasks to be modeled. Many of the algorithms used in the model for crew and equipment allocation come directly from actual operation guidelines. However, in a few situations, an algorithm was developed in order to approximate the human decision making in the operation.

4 MODEL DESCRIPTION

4.1 Model Inputs

The model is designed to be as flexible as possible so the user can change system parameters in external data files without having to alter the actual model. The TAPS model is driven by 15 external data files:

- Arrival file: Contains each inbound aircraft, as well as its arrival time, origin, cargo, fuel requirements, and outbound destination.
- Volume file: Defines inbound cargo mix and additional outbound cargo for each aircraft.
- Schedule file: Defines schedule for 17 crew types. Each crew type is dedicated to a specific task and may contain up to 50 individual crews. Each crew can have from one to eight crew

members. Crew schedules are based on half-hour increments.

- Process Time file: Defines each aircraft operation time as a function of crew size and aircraft type.
- Equipment file: Defines the number and initial staging location for all equipment required for the load and unload operations.
- Parameter file: Defines overall system parameters like start time, hub pull time, and model scenario.
- Parking file: Defines ramp parking positions for each aircraft type.
- Sortation files: These files define up to five inbound-to-outbound mixes, belt assignments, sortation times, outbound flight options, and "hot" flights.

4.2 Model Features

The TAPS model that was developed details the allocation, movement, and operation of crews and equipment from aircraft to aircraft as well as to and from the hub. Accurate descriptions of crew and equipment movements between all ramp locations required a detailed distance map that included every possible point-to-point combination. These large matrices were also necessary to display the crew movements for animation.

An arriving aircraft requires a series of tasks to be completed before it can depart. Some of these tasks may be performed in parallel while others may only occur after a preliminary task is completed (see Figure 1). Each task requires a specific type of crew. When a crew is allocated, it first procures the correct equipment for the aircraft type that it was assigned and then moves to the aircraft. Each crew operation consists of a setup time, an operation time, and a wrap-up time. After completion of its task, the crew is then available for assignment to another aircraft.

Incoming packages are either packed into containers located on the main decks of the aircraft or stored loosely in the belly sections. Packages in the belly sections are initially unloaded into empty containers. Upon unloading, most containers are moved to the hub where the individual packages are removed and sorted to outbound destinations.

Outbound containers generated from the hub are transported to an appropriate outbound aircraft where they are either loaded onto the main decks or broken into loose packages and loaded into the belly sections. Because loading individual packages into a belly section is extremely time consuming, load crews first will attempt to fill the main deck of the aircraft. However, if the expected volume for an outbound flight is large, the analyst has the option of pre-loading the belly sections to reduce the chance of a late departure. Both the belly
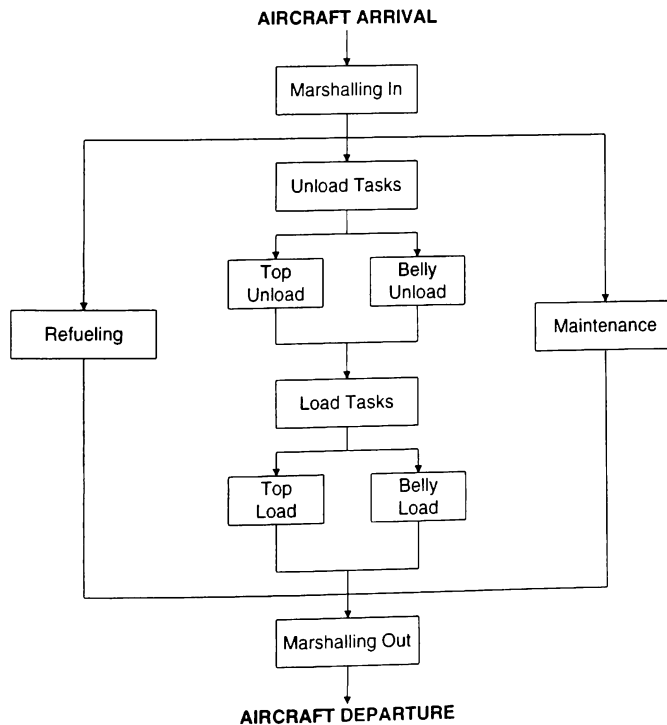

Figure 1: Aircraft Operational Flow Chart

unloading and belly loading tasks may be accomplished by the regular load and unload crew assigned to the aircraft or by special belly-only crews that work in parallel with the regular crews.

Crews are allocated to an aircraft based on allocation algorithms developed to approximate the human decision involved in the dispatching process. The simplest allocation algorithm involves taking the closest available crew for a given task. More advanced algorithms can be used to allocate unload and load crews to specific aircraft.

In order to describe the decision process to assign multiple unload crews to an aircraft, an allocation algorithm was developed utilizing a "Look Ahead" window. The decision to assign additional unload crews is then based on current crew availability and expected arrivals within the window. If enough crews are available to service all of the aircraft expected in the "Look Ahead" window, any additional crews may be assigned to the current aircraft.

4.3 Model Outputs

Extensive performance parameters are collected and reported in multiple output reports. General overall statistics are directed to a customized output file designed for less advanced users. Statistics reported in the generic output file include:

- Equipment Utilization (by ramp area)
- Overall Aircraft Arrivals and Departures (by ramp area)
- Average Aircraft Task Duration (by ramp area)
- Container and Dolly Statistics
- Overall Crew Utilization (by crew type)

More detailed statistics are included in the Arena output report. In addition to those previously mentioned, these statistics are also included:

- Extensive counters for tracking container and package movement through each segment of the system.
- Individual crew statistics. These statistics can track up to 30 different tasks performed by over 500 crews.

Collection of these statistics were facilitated through the use of the Arena Frequencies and Stateset features.

Additional output files are also generated for specific operations:

- Belly Load and Unload
- Holdovers
- Aircraft Departures

5 MODEL VALIDATION

The validation of TAPS was begun concurrently with the model development and is still ongoing. There are two main methods being used in the validation process: the examination of output reports and model traces, and visual validation through observation of the model's animation (see Figure 2). Validation has followed the same basic order as the model development:

- Input Data
- Inbound Aircraft Operations
- Hub Sortation
- Outbound Aircraft Operations

Authentication of the input data for the external data files was the first step in the validation process. Because the input data came from a number of different sources, it was thoroughly examined for consistency and accuracy. Initially, some of the information provided was out of date and was subsequently updated.

Validation of the TAPS unload process included examination of the following processes:

- the arrival of an aircraft.
- the requesting of marshaling crews, maintenance crews, and fuel trucks upon arrival.
- gathering and movement of various crews and equipment.
- removal of containers from the decks of an aircraft as well as loose belly volume.

Validation of the unload operation began with the confirmation of aircraft arrivals and the inbound package volume. The volume was broken down into two main categories: location of the volume in the aircraft, (topside or bellies); and the type of volume, such as domestic, export, import, cargo and empty containers. Utilization statistics for the various crews and processes were validated by comparing output reports to standard work measurement and documented process times.

The allocation of crews, the gathering and movement of various equipment, and the actual unloading and loading of containers at the aircraft were certified through observation of the animation.

The simple counter statistics for the unload operation were extremely helpful in validating the unload process. The model is very sensitive to changes in the scheduling of crews as well as the process times required for each task. Slight variations in the scheduling of crews resulted in the incorrect number of arrivals and/or departures and the incorrect amount of package volume being unloaded. These deviations also directly affected whether the aircraft would complete the unload process. In turn, this had an effect on the total package volume sent to the hub.

Validation of the hub sortation operation involved examining the total number of containers transferred to the hub and the total number of containers generated from the hub. Simple counter statistics are used to track containers into and out of the hub. Container and package volume to and from sortation was then validated by comparison to the expected volumes based on the

model inputs and archived data. The outbound destination for a package sorted at the hub is determined by one of five statistical distributions. Each distribution represents a different regional mix of inbound packages to the Louisville hub. Additional validation was performed by comparing the mix of the containers generated for each destination to historical data.

Validation of the load operation included the examination of the following processes:

- the shifting and staging of containers to various yards,
- dispatching of load crews and equipment,
- loading of containers and loose belly volume,
- departure of aircraft.

Validation began by confirmation of the shifting and staging of outbound containers to outbound aircraft. The allocation of load crews and equipment, as well as the actual loading of containers and loose packages, were validated through observation of the animation and numerous statistical counters. Aircraft departure information was checked against historical records. Utilization statistics for the load crews and processes were validated by comparing output reports to standard work measurement and documented process times.

The validation of the load process again indicated that slight changes had a noticeable effect on the results. These changes included the scheduling of selected crews, the process times for various tasks, aircraft arrivals and departures, or changes to the constraints within the hub. Changes in the crew schedules and process times affected the time required to load the aircraft, which ultimately had an effect on whether the aircraft was able to depart on time.

Overall, the segments of the model are extremely interdependent. Modifications to the aircraft arrival or departure schedule have a significant effect on the number of outbound containers that can be generated by the hub. One minor change can have a domino effect on the rest of the operation—affecting the unloading and loading of other aircraft, the number of empty containers loaded onto the aircraft, and utilization of various crews. Alterations to the arrival times of aircraft also had an enormous effect on the number of packages that the hub processed by the end of the sort.

Various users, including UPS industrial engineers and planners, as well as operational personnel have been closely involved in validating the model. This collaboration has been critical to the success of the validation
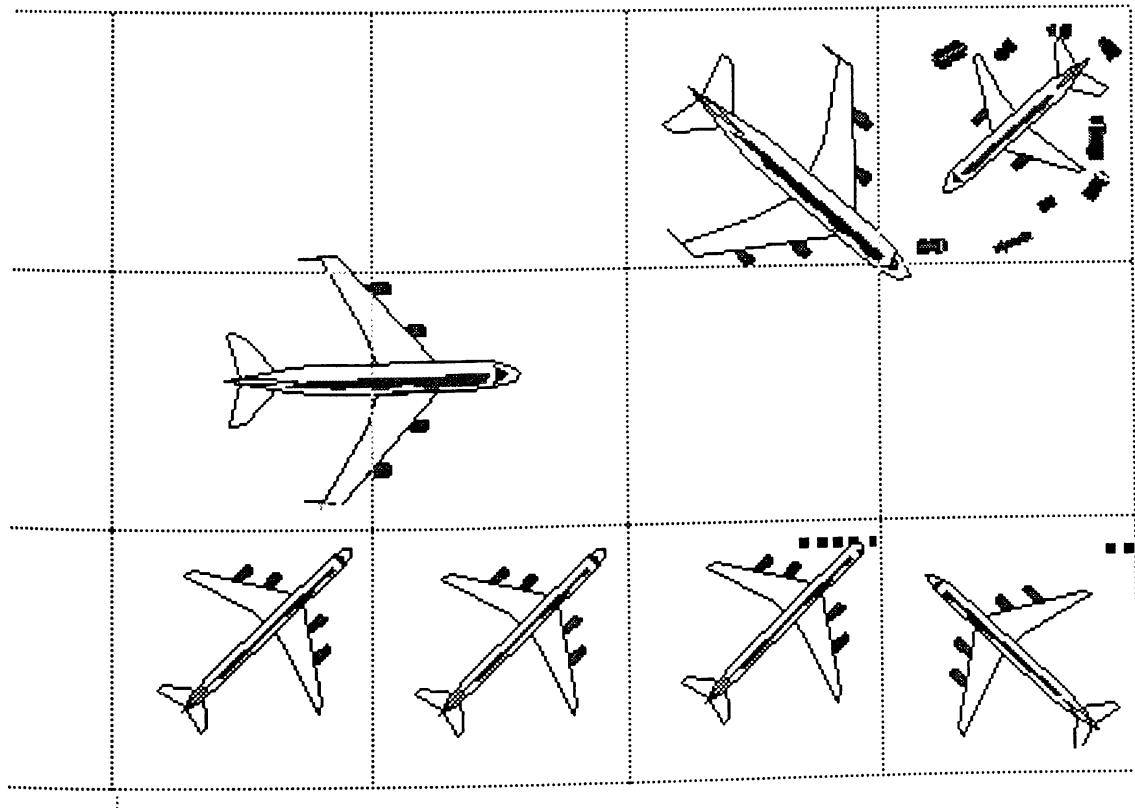

Figure 2: TAPS Model Animation

process. The model animation allows users to visualize aircraft arriving, being unloaded and loaded, and finally departing. Observing the model animation also increases awareness of the various operations (marshaling, maintenance, fueling, unloading, loading, etc.) and raises questions that are extremely helpful during validation. In addition, this involvement creates excitement and instills confidence in the model.

6 SUMMARY

The Total Air Park Simulation was developed as a flexible, data driven model to investigate the aircraft operations at the UPS Louisville Air Park. The model includes all aircraft servicing tasks and was designed to capture the interaction between multiple resources working in parallel on the aircraft. At the time of the writing, preliminary analysis has begun with experimentation on different aircraft schedules and examination of the sensitivity of model inputs. The initial success and acceptance of the TAPS model for scheduling and allocating crews and equipment has laid the groundwork for its transition into an operational tool. In the future, execution of the model with near real-time data prior to the start of the actual operation will highlight potential problem areas and facilitate adjustments to the crew schedules and allocation strategies.

KEYWORDS

General applications, transportation systems, logistics, resource allocation, resource scheduling

BIOGRAPHIES

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